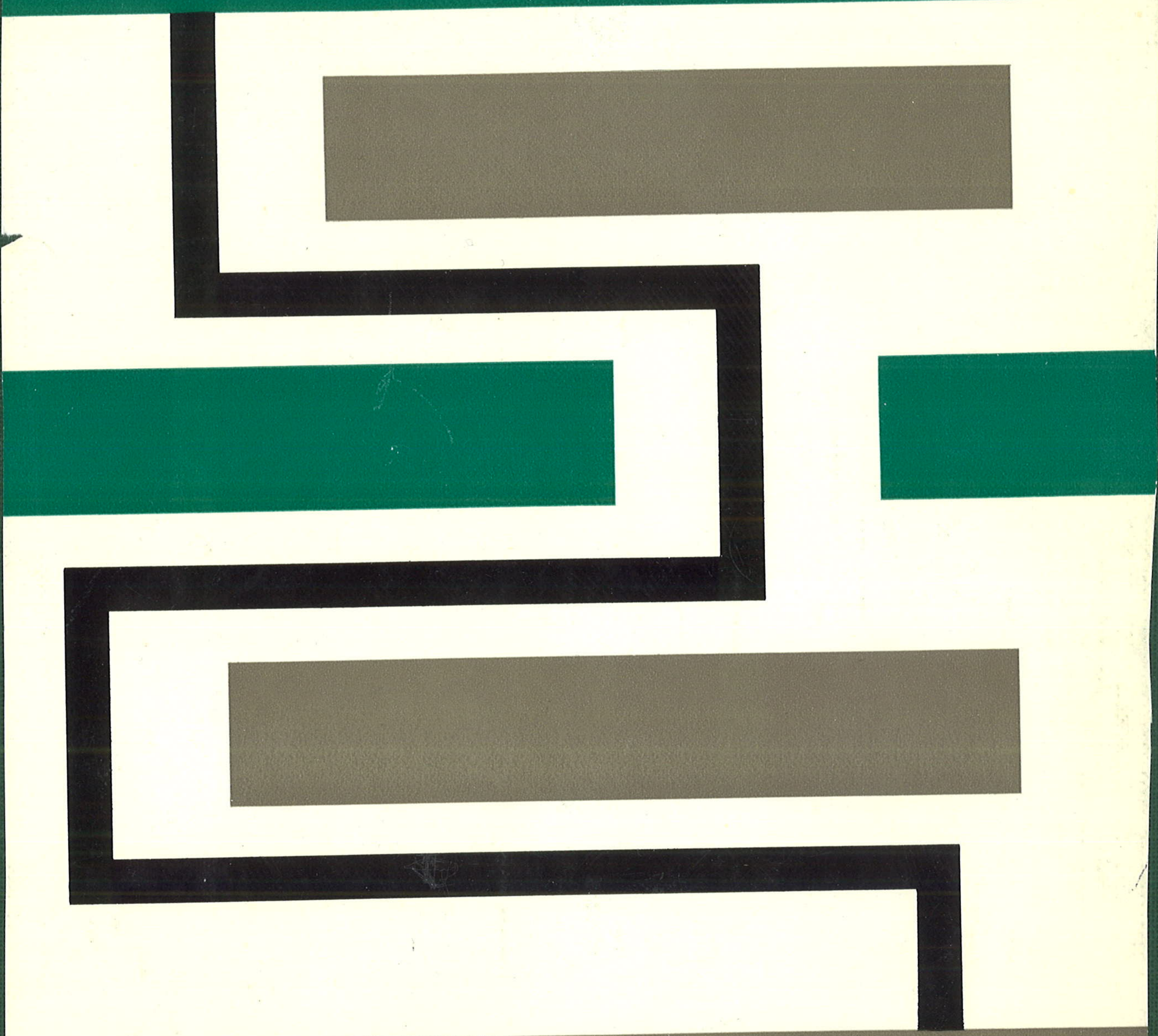
TOWARDS
INDUSTRIALISED BUILDING



CONTRIBUTIONS AT THE THIRD CIB CONGRESS, COPENHAGEN, 1965,

TOWARDS INDUSTRIALISED BUILDING

ELSEVIER

TOWARDS INDUSTRIALISED BUILDING

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Preface

This volume is the final record of the 3rd C.I.B. Congress, held in Denmark in August 1965, the theme of which has been the worldwide trend Towards Industrialised Building.

To some the term industrialisation means especially prefabrication and the predominant role of factory production, to others it means an attempt essentially to rationalise traditional site production processes; yet again others regard it as an attempt to adapt structural patterns of procedure to arrive at a type of industrial efficiency that has proved beneficial in industries other than building. Many different connotations are put on the term industrialisation by different specialists connected with the building industry, and the aim of the 3rd C.I.B. Congress has been to review the present position as a whole with respect to these numerous different ideas in the hope that, in this way, it would become more clear how an increasingly industrial approach could best make the building industry meet the great challenges facing it.

In order to arrive at a sufficiently comprehensive review the subject of the congress was broken down into ten main aspects, interrelated in several ways; and for each of these aspects a considerable number of papers was invited, short papers because of the desire to bring to the fore new trends and developments, rather than purely descriptive information of systems at present in use. Following introduction by group rapporteurs, the ten sets of papers included in this volume were discussed within ten groups, and the evaluation and summary of these discussions, compiled by the rapporteurs, may be found preceding the papers of each group. To set the scene for these discussions a general introduction to the whole subject within the general field of the world economic situation by Professor Gunnar Myrdal, and a congress opening address by Mr. Ph. Arctander, congress President and President of C.I.B. 1962–1965 were delivered at the opening session of the Congress, and both these are included here.

As a result of the invitation to a large number of experts to submit papers, the reader will find here on the one hand a multiple variety of what one might term recent information about the continual increase throughout the world of an industrial approach to building, and, on the other hand, particularly in the final statements of the group rapporteurs, indications of how industrialisation tends to, or should develop. The reader should not hope to find here solely agreement with regard to comprehensive answers to problems of building throughout the world. On the contrary he will often find reflected in the papers printed here considerable disagreement between the experts themselves. Such disparity in the ideas expressed, however, was in fact expected when it was decided to invite so many reports, so that those connected with building, in their often praiseworthy and urgent efforts to find solutions to what sometimes appears to be an insoluble problem, should be in no danger of confusing means with ends, of seeing in industrialisation the answer to short term, but immense, needs while ignoring the possibility that in the long term industrialisation may itself raise problems no less difficult. For this reason contributions were invited from representatives of numerous separate disciplines which all have relation to the complex structure of the industry, architects, engineers, pure scientists, economists, sociologists, town planners, lawyers and administrators. No attempt has been made to avoid, during the discussions and in the preparation of the papers, such controversial issues as the aesthetic appearance of an industrially produced environment, the need for interrelated professional education, or different methods of investment. Overshadowing all the discussions has been the responsible attempt of those with specialised knowledge to put this knowledge at the service of all countries, whether wealthy or underdeveloped, in the conviction that only in this way can a satisfactory habitation be provided.

Numerous suggestions with regard to future action, both of limited scope applicable in given circumstances, as well as of wider scope and of interest far beyond national boundaries have been included in the papers presented here.

Serious questions such as the integration of present day scientific knowledge in different fields of the natural and human sciences with regard to the qualitative aspects of our buildings, through the formulation of building codes and regulations based on human and functional requirements rather than on legal concepts, the incorporation of new ways of thinking with regard to the present day educational system, the need to relate increased industrialisation in developing countries to raw materials and labour possibilities in those countries, and many others, are stressed in a way which may bear fruit in the future thinking and consequent work of all those interested, as well as of C.I.B. itself.

Therefore C.I.B. owes thanks to the many authors of the papers in this volume, to the group rapporteurs and to the group chairmen, for making available to an international audience the results of their research and study. It may also be mentioned that the vast editorial task involved in the preparation of the entire contents of this book, accomplished by the General Secretariat of C.I.B., has been considerably facilitated by the substantial assistance of staff members of the Danish National Institute for Building Research, the Centre Scientifique et Technique du Bâtiment in Paris, and the Institut National du Logement in Brussels. Thanks should also be expressed to the publisher of this volume whose collaboration has made it possible to present it in this form.

Finally a word about language. The papers themselves were presented at the Congress in English and French, and are printed here in English, but in their original form were written often in languages other than these. The reader may find here some infelicities of expression, and sometimes some unusual constructions, but in many cases, when preparing the papers for publication, such imperfections have been consciously retained, as a reflection of the truly international flavour of the contents.

A satisfactory existence for all people throughout the world demands immense construction activity, which in turn demands the best possible use of world wide intellectual advancement. At the same time all must foster a comprehensive understanding of the fundamental decisions of all those responsible for building in all its different stages. We earnestly hope that this book will contribute at least to one important aspect of such understanding.

Rotterdam,
24 November 1965

J. de Geus
Secretary General

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Needs Versus Capacity

Opening Address
Professor Gunnar Myrdal, Institute for International Economic Studies.

It is just about twelve years since I had the privilege of opening the CIB's very first General Assembly held in the Palais des Nations in Geneva, Switzerland, when your organization was formally constituted. At the time I was the Executive Secretary of the United Nations Economic Commission for Europe which for the preceding five years had given shelter for the preparatory work leading first to the creation of the International Council for Building Documentation (CIDB) and a few years later to the transformation of that organization into the International Council for Building Research, Studies and Documentation (CIB). Thus, being a sort of godfather, or even at times midwife, it is with a great sense of pleasure, but also with some responsibility, that I have accepted the invitation to address you at this Opening Session of the CIB 3rd Congress.

The History of CIB

Let me briefly first of all recall the main steps -- the hard uphill work -- which resulted in establishment of the CIB. I sketch this historical review both for my own pleasure and of the many friends whom I meet here again after so many years of absence, but also perhaps to satisfy the curiosity of the many new friends attracted to the CIB 3rd Congress from all over the world.

The CIB beginnings can be traced back to the immediate postwar period. International technical contacts had been broken by the war; in any case they had never been as close in the building field as in most other economic sectors. There was in pre-war times very little international trade in building materials and components which would have made this industry more internationally competitive and therefore more productive and cost-conscious. Yet governments, municipalities, private corporations, and persons were spending vast sums of money for all kinds of buildings in the reconstruction period and have continued to do so on a growing scale ever since. I have often made the reflection that, had the housing and building people been equally alert in the immediate post-war period when there was such a willingness and eagerness on the part of the governments to create international organizations, they would easily have got their own international organization as, for instance, the forestry and timber people did within the framework of the Food and Agricultural Organization.

As it was, my colleagues and I in the Secretariat of the ECE found it imperative to establish a panel for discussion of housing problems which rapidly consolidated itself as the ECE Housing Committee and, indeed, started to function more and more as the missing international organization in the housing field. Very soon we turned our attention to the wider field of the building and building materials industries and found support among the representatives and experts of these industries and member governments in the ECE for promoting international cooperation, first in the field of building documentation and later extending this to building studies and research.

About two years of careful preparatory work was required, which culminated in the setting up in 1950 of a new international non-governmental organization, the International Council for Building Documentation (CIDB). The purpose of that organization, as some of the veterans among you will recall, was to provide a link between national centers or committees for building documentation and to promote the establishment of common principles with regard to terminology, classification, and methods of arranging and presenting building documentation.

The ECE next turned its efforts to promoting systematic arrangements for international cooperation in building research. An ECE Conference on Building Research, held in Geneva in 1950, established a *prima facie* case for new international arrangements. With this in view, a recommendation was made to governments to establish, where this did not already exist, national organizations for building research in their countries. A small ECE organizing group established thereafter the scope and nature of international collaboration in building research, showed the close links between research and documentation, and concluded by recommending the setting up of a new international non-governmental body. Subsequently, after further preparatory work both by the ECE and the CIDB, the CIDB was formally transformed into the CIB in 1953.

The CIB was conceived as a decentralized organization, with the burden of the work resting primarily on the national institute members. I think you will agree with me that this decentralization has proved to be at the same time both its strength and weakness. It is clear that international cooperation in building research must rest on a solid base of strong national research institutes. On the other hand, the corollary of having to operate with only a very small central secretariat in an organization which was undergoing growing pains and had yet to prove itself has always been an obstacle to bolder leaps forward. Nevertheless, in a field in which historically there had never been any radical and sudden new departure, the setting up of the CIB was undoubtedly a great event, the implications of which we may not yet be able fully to evaluate. We in the ECE, I should confess, were most pleased at the CIB's creation. This freed us to concentrate our limited resources on key government policy issues of an economic and social character relating to housing, building, and physical planning.

In preparing for my statement today, I have been in touch with my old friends in the ECE secretariat, particularly Mr. Benjamin Reiner, Chief of the Housing, Building and Planning Section. I find that the Housing Committee and its various suborgans have done fine work and increasingly filled its role as the substitute for the international organization in the housing field, we did not get in the propitious time when the war ended. As a recognition of its wider field of activity, it is now the ECE Committee on Housing, Building and Planning. In working out my statement today, I have also had the assistance of a young compatriot of mine on the ECE housing staff, Mr. Yngve Palm, who is also participating in the Congress and has contributed an important paper following up some earlier documents on the topic of the Congress from his own pen and from the ECE secretariat.

After these personal introductory and historical remarks, may I now turn to the subject of my statement.

The Theme of the Congress

"Towards industrialised building" is the theme of this Congress. How could it be that in the year 1965 – in the era of automatic computers and rockets to the moon – the subject of a big Congress like this of technicians in a crucial sector of every national economy could be how to proceed towards industrialisation? How can this major sector of economic activity, representing such a very large part of all investment in every country, be so retarded that not until recent years has industrialisation been taken up as a subject for serious discussion?

How can it be that the problem of building industrialisation has still not been adequately solved even in the most developed countries? Other branches of the industry have been industrialised long ago and are by now approaching, to a larger or lesser extent, the late stage which we refer to as automation. What is then so particular about building? And why have all countries, suddenly and just now, realized the necessity of industrialising building construction?

The answers to these questions are several and complex. The main reasons for the present situation could be traced, however, to the evolution of demand for buildings and to economic, technical, and many other factors involved in the problem of raising the capacity of the building industry.

Rapidly Rising Demands

Let us first have a look at the demand for buildings.

The search for shelter is as old as man himself. From caves, huts, and nomads' way of life, man has settled down to till the land, build villages, and, in the end, build ever-growing cities. Man is no longer content with a shelter over his head to protect him from weather hazards, but he demands a properly equipped dwelling in which family and individual lives can develop. He also requires schools for educating his children at various age levels, hospitals and clinics when he is ill, museums, theaters and other buildings for cultural activities, shopping areas, etc. Factories and office buildings have to be constructed for his work and administrative buildings to regulate all these activities. Finally, a network of roads and many types of public utilities have to be constructed to provide the infrastructure.

All this now adds up to an enormous demand for construction, a demand that is constantly rising and tends to overwhelm any rise in building capacity. Many countries have already faced the situation where governments have from time to time felt compelled to intervene by restricting in some way or other the growing building demand. But why is the situation more out of gear now than ever before?

Some reasons are obvious. Everyone is today aware of the population explosion, and in the first hand we are forced to think of its effect on food requirements. Fewer have begun to appreciate its implications in terms of housing, health, and education. In particular, in underdeveloped countries – where the population is expected to double within the next thirty years or so – while economic resources are scanty, everything they are attempting to do in the field of not only food production but also housing, health, and education has to run a desperate race with population increase; many countries are losing out and few have a rapid pace of development measured in terms of *per capita* consumption in these main fields, including housing. For eight years I have been working harder than I ever have on the development problems in South Asia, where a quarter of mankind lives; in my address today, however, I shall, after this reminder, leave aside the problems of the underdeveloped countries.

In the more developed countries there is less of a population rise as the population cycle is ended, resulting in a near-balance between births and deaths; but instead there is a continuing and mostly rising tide of internal migration from rural areas to towns. One has even sometimes spoken about an urbanization explosion. Countries like the Netherlands, the United States, and Britain, even Sweden, are rapidly becoming almost completely urbanized societies. At the same time, in the earlier industrialised countries the building stock is becoming old and functionally out of date, calling for large-scale replacement and slum clearance. In some countries, as for instance the United States, a more or less complete renewal of the centers of old cities is required to prevent complete paralysis and enable society to function and advance. In other words, our urban fabric has to be enlarged tremendously and at the same time improved radically to keep pace with the rapidly changing technology and changing ways of life.

In the dwelling sector, each one of the rapidly increasing number of persons and families who are now flocking to the urban areas demands higher quality standards and more space. With steadily increasing incomes and prosperity, people are no longer satisfied with a mere shelter over their heads and a minimum space of a room or two for the family. More individuals demand to have an apartment of their own and families demand ever more space and better equipment in their dwellings. This is a natural evolution. Why should not people wish to spend an appreciable share of the 3-5 % annual increase in their real incomes on housing? At the national level, why should not a greater share of the gross national product be spent on providing more sophisticated and better housing services to the population?

Lagging Supply

All this calls for building construction. But it is not easy to meet such a rapid increase in demand. There are probably few periods in history which have shown such a steady and appreciable rise in income as the post-war decades. If we assume that in advanced countries real incomes have risen by at least 3 % per year for already a long period of time and compare this with the rise in the rate of annual building production, we will immediately see the dilemma. Even in countries with the most intensive building activity, the annual output of new building amounts to at the most 3-4 percent of the building stock already existing; in most countries the figure is only 2 percent. Furthermore, from this total production should be deducted the decrease in the building stock due to slum clearance, urban renewal, and other destruction work, as well as a substantial number of residential buildings, which are left unoccupied in rural areas as a consequence of urbanization.

The widening gap between the acceleratingly rising total demand for housing and the current net production rate represents a major element in the problem facing the building industry today. The high cost and long lifetime of the product put buildings in a position not comparable to any other product which has now become the output of mass production for mass consumption. If we want to double our consumption of entertainment, shoes, or clothes, this can be achieved rather quickly by doubling the annual production. In the case of more durable consumer goods, such as television sets, cars, refrigerators, etc., the doubling of consumption will call for either substantially more than a doubling of annual production or the stretching out of the increased production over a somewhat longer period of time. Buildings present the extreme case. Even with a doubled or trebled production, actual consumption will not be able to rise appreciably in the short run, and neither in the long run unless the high production rate is maintained over a very considerable period of time. But in the meantime, the demand for more buildings and better buildings can be expected to continue to grow. As a matter of fact, in the housing field in particular, we can see a very long way ahead of us before a point of saturation of demand is reached. Since, however, as I said before, the post-war period has shown an unprecendented and stable economic growth, we have now come to the situation of a deepening crisis which can be solved only by a radical increase in building production.

In Terms of Needs

I have so far been speaking mainly in terms of demand for buildings. If we analyze the real needs for buildings, the situation seems even more serious. One reason for analyzing the housing problem in terms of needs for buildings is the fact that in many countries, including my own country Sweden, we have not yet come away from the war-time rent regulations. These regulations, now prolonged for decades, have severely distorted the market for housing and made some demands ineffective, while at the same time decreasing supply by encouraging some families to continue to occupy more space than they would if the rent were not held down. At the same time the prolongation of these regulations has resulted in an accelerated rate of deterioration of the housing stock by discouraging the owners of buildings from going into expenditures for upkeep and modernization. In some countries the result has also been a spotty replacement even of such old houses which—according to rational calculations—should only have been modernized. Everywhere the rent regulations have led to black-market operations and, generally, seriously lowered moral standards in society, so even in stable countries like Sweden with otherwise high public morals. The housing regulations and their consequences for housing policy generally have in some West-European countries made housing probably the worst example of bad planning, due to lack of foresight and courage on the part of the governments. The Secretariat of ECE early in the post-war era criticized the prolongation of the rent regulations from these points of view. In the present context my points are, first, that the rent regulations tend to worsen the gap between demand and supply of homes, and, second, that by leaving some demand ineffective they make an analysis in terms of demand and supply less possible and less pertinent to the analysis of the prevailing and future housing situation.

If, therefore, we move over to speak in terms of needs, it is clear from many studies undertaken in several countries that any calculation of needs for dwelling construction, even if based on quite modest standards, results in requirements which would take decades, or indeed centuries, to meet—at the *present* rate of construction. A deeper analysis, taking into account changes in the size and structure of the population, urbanization trends, replacement needs, and other relevant factors, shows that in some countries *no improvement at all* of the existing situation is presently on the way. This is a serious situation, since I believe that we all agree on the importance of adequate housing and public services as primary means of satisfying basic human needs and preventing social problems of many kinds from arising. Investment in new and better residential construction should not be regarded as is sometimes the case—merely as a consumption item in national accounting but as productive investment which substantially contributes to overall productivity and which indirectly leads to savings of government expenditure in many other fields. And even if we *were* to regard housing construction as merely aimed at consumption, what consumption item – besides food – could be put higher on a priority list? The dwelling is the framework of the entire life in the family, which remains the basic social unit, however much our institutions and attitudes are changing.

I am not suggesting that all our resources in terms of construction capacity should be spent on housing. Obviously that would be an impossible policy. But we should neither forget the responsibility – in particular of governments – to ensure a continuous and considerable output of residential construction. It is in *this* sector of building production that there are found the most urgent, though pent-up, needs – and also demands, and much larger demands if they were released in the market. At the same time this sector provides the best possibilities for applying much more of industrialised methods of construction. Mass consumption should be met by mass production.

Insufficient Capacity of the Building Industry

This leads me to the other side of our problem, namely the insufficient capacity of the building industry. Why has it been – and why is it still – so difficult to apply principles of industrial production in building? Well, mass production – to be economic and thus able to match the resources available to the majority of the consumers – calls for the adoption of certain principles which have so far been rather neglected in many countries.

First of all, continuity of operation is required if the building industry shall be able to amortize any great increase in capital investment. The industry cannot be expected to take the risk of employing highly capital-intensive methods of production as long as governments keep using housing construction as a regulator of the national economy. This point has been made before but is worth repeating. There are few sectors of the economy which are less suited for economic balancing than housing production – *nota bene* if it is lifted to industrialised building. If construction activity has to be used for economic balancing purposes – which may occasionally be necessary, though less so with wiser economic policies applied by the governments – the projects for periodic retrenchment should be searched for in other sectors than housing: in urban renewal projects, public works, and other demands of a once-for-all type. The most important incentive towards industrialised building would be a guarantee on the part of the government that mass construction of residential buildings will not be interfered with but everything done in order to make possible a steady, rising level of housing construction.

But continuity of demand is not enough to ensure the adoption of industrialised methods of production. Variations in the *composition* of demand must also be decreased as far as possible in order to make standardisation possible. Buildings are complex products, that is true. They have to satisfy different needs; they must be adapted to differences in outside conditions (climate, ground conditions, earthquake hazards, etc.); and tastes are different. But this does not justify *unlimited* variations of the product, and in particular not of its components. Indeed more discipline is necessary on this point; no other mass industry has developed without standardisation of the products.

Investigations into the composition of actual output of the building industry have revealed tremendous variations of the building product. And most of these variations could not at all be motivated by differences in functional requirements or preferences of the consumers. On the contrary, the requirements – in particular in residential construction – have been found to vary rather little and the tastes to be conventional and traditional. The samples made of produced houses show a number of *almost* identical types of product: millions of almost identical living rooms, bedrooms, kitchens, bathrooms, etc. are produced. But the small variations in measurements and arrangement prevent effectively the adoption of industrial methods of mass production. And all these differences are not – in the majority of cases – specifically asked for by the actual consumers, but are prescribed by the impulses of designers, investors, or client organizations. The market research, which forms an important and integral part of any industrial production, has so far been more or less neglected in building production. Too little effort has so far been devoted to the task of finding out, in a scientific way, which are the preferences of the consumers and which variations in design could be justified from the functional point of view.

As in other branches of industry, a distinction should be made between the products suitable for mass production under industrialised conditions and intended for the great majority of consumers, on the one hand, and the comparatively very limited amount of tailormade handicraft work for those who can afford to pay for it, on the other. This distinction is not very clear in building today. In fact, it seems to me as if the building industry today is often trying to mass produce tailormade products – but without first taking measurements for size and form. It is clear that such a confusing situation cannot be very advantageous either for the industry or the consumer.

Some of you may find this reasoning exaggerated or, at least, inapplicable to the building industry. You may say: "He doesn't understand our problems; building is *not comparable* to manufacturing of consumer goods." I agree with you – to an extent. There are, no doubt, some very specific characteristics of building production which are not common to any other industry. The first fact that strikes an outsider is the division of the production process into two fairly distinct stages, namely, the manufacturing of building materials and components, on the one hand, and their assembly on the building site, on the other. In fact two industries – or even many more, if one separates all the different branches of industry delivering all kinds of materials and equipment necessary to make up a building – are involved in the production process leading to the end products: homes. As a matter of fact, today the greater part of actual production in the more developed countries takes place outside the building industry proper. The work on the building site no longer contributes so much to the production of the building but rather constitutes a service of assembling parts and components which thus become a finished building. This is clearly illustrated by the fact that today normally 50–60 percent of the production value of a building—in some cases up to 70 percent or more—represents outlays for building materials, components, and equipment delivered to the building site by other industries.

There are natural reasons for this division of the building production process. As a rule, the building is too heavy and bulky to be completed in a factory; moreover, the low value/weight ratio of the finished building economically prevents transporting it over too long distances. Apart from exceptional cases, the constituent parts of buildings are therefore manufactured and transported to the site separately.

There is, of course, great danger involved in breaking up the production process into too many independent units. Bearing in mind that the building industry is internationally not very competitive, such a proliferation of the production process could lead to a "laissez-faire" policy, implying that nobody cares about the quality and price of the end-product while everyone concentrates on making his own little part of the production process most effective and profitable. The natural consequence is that the different manufacturers of building materials and components, the suppliers of equipment, and the building contractors all tend to accept prevailing preconditions for their activity, diverting most of their interest to maximizing their own profit within this given framework. The gap between demand and supply in an internationally noncompetitive industry means also that the contractors regularly operate in a sellers market, which implies that he has less incentive to rationalize his production in order to cut his costs.

The split pattern of the production process is further aggravated by the division of responsibilities for the final building betwcen the client, the designer, the quantity surveyor, and other specialized experts taking part in the projecting of various aspects of the buildings. Each participant in this collective work may do his best—seen from his own narrow angle—but without caring much about what lies outside his own profession. There is apparently a risk that not enough efforts and thought are given to planning the end-product, taken as a whole, and to the maximum efficiency of the over-all production process.

Despite these disadvantages, however, I believe we should be very hesitant to abandon the organization and division of work, traditionally applied in building production. Naturally, it is much easier to solve problems of coordination, management, and control if we integrate within one single enterprise all the different stages of the production process. And this solution has indeed been tried, if I am correctly informed. But isn't that, so to say, to "throw out the baby with the bath water"? Doesn't the original division of work provide the *best* possibilities of specialization and hence standardisation and mass production, a standardisation and mass production not of identical buildings, but of identical components, which can be combined into a great variety of buildings and thus satisfy a whole range of functional and aesthetic requirements?

But specialization calls for coordination. Indeed, to obtain real economic gain, a specialized production process, divided into a large number of independent sub-processes, calls for *more* special efforts for coordination than a process integrated within the framework of one single organization or company. There is otherwise an obvious risk for "sub-optimization." In industrial production, "*best*" partial solutions must give way to the best *total* solution which can be economically realized and thus come within the reach of the majority of the consumers. I mean that the decisions on quality, appearance, price, and other basic characteristics of the building should not be decided upon separately and independently by all the different participants taking part in the production process, but by a strong directing enterprise, directly responsible to the consumers for the end result. I may illustrate this by a comparison with the automobile industry, which is really highly industrialised. Which car manufacturer would stand the competition for a long time if he let the motor specialist decide upon the design of the motor, the structural engineer on the chassis, the designer on the appearance, and the equipment specialists on the layout and fittings. The result might be a wonderful car, but it would be impossible to sell at a price the customer would pay.

Another important function which must not be forgotten in a highly specialized production process is research and development. I am not in the first hand thinking of specialized research into new building materials, better technologies, mechanisation, and other important but restricted aspects of building production. This kind of research and development will undoubtedly be taken care of by the different specialists and building materials manufacturers taking part in the building production process. I am thinking of *interdisciplinary* research with the aim of finding the best compromise solutions of the final building in terms of functional, technical, economic, aesthetic, sociological, and other requirements. And not interdisciplinary research into the building itself only, but into the environment of the building as well.

In other branches of the economy, we confidently leave most of the problems of organization, coordination, research, and development to private enterprise as guided by the market. The competition between different production enterprises, each integrating within one single body all the different stages of production—from market research through research and development and finally to production and sale—ensures that good products at reasonable prices are offered to the consumer. In building production, however, the specific nature of the product, which in turn calls for a split pattern of production, combined with the lack of international competition and, to a certain extent, inelastic demand and a permanent sellers market, limit our possibilities of just leaving the whole problem of building production to the forces of the market. Comparisons with other industries in this respect are misleading. Nevertheless, those responsible for building production have certainly much to learn from other branches of the economy in terms of planning, organization, cost and quality control, and management. The fact that the building production process is divided into a number of sub-processes should not make us forget, however, the main function of the producer of the final product: the leadership.

Who provides the leadership may be of less importance. In the case of detached single-family houses, where production is designed to satisfy the demand of individual consumers, the main coordinating responsibility may stay with the building contractor. This system has proved efficient, in particular in countries with highly competitive economies and where building firms may operate rather freely and independently of restrictions, as in the United States.

As to building for collective demand, the natural coordinator is the group of clients or the investor. In this case there is no direct contact between the individual consumer and the producer of the building. This is a danger, of course, but should at the same time provide unusually good opportunities for a rational industrialised production. But have these opportunities been utilized so far? Have the investors and the client organizations fully appreciated their responsibilities as representatives of the ultimate consumers? Have the technical possibilities for mass production been exploited?

The answer is both yes and no. In the socialist countries of Eastern Europe, standardisation of measurements and qualities of building components, functional units, and whole buildings has in individual cases gone very far and methods of mass production have been adopted with substantial savings as a result. Some experts argue - and this is in fact beginning to be recognized in these countries as well - that standardisation has in some cases even been driven too far, so that functional requirements and the characteristics of the products do not harmonize. It has also led to monotony in architecture. A more flexible approach is now searched for in these countries. On the other hand, as I have already noted, in the market economies of Western Europe comparatively little has so far been done to restrict the number of product types and thus make way for industrialisation. In all countries it is now becoming realized that radical measures must be taken to speed up production. This, and the different experiences having been made up till now, would seem to suggest that there is considerable scope for international collaboration between all countries in this field.

International collaboration

Fortunately, I know that international collaboration is now well on the way. The Economic Commission for Europe is – as I said in the beginning of this address – steadily developing its activities in the fields of housing, building and physical planning. And just recently the Housing, Building, and Planning Branch of the secretariat at the United Nations headquarters in New York has been converted into a Center for Housing, Building, and Planning and is expected to expand substantially its work. Furthermore, a number of non-governmental, international, professional, and technical organizations are also very active. CIB is the most important of them, particularly potentially, and this Congress marks an important step in international collaboration on building research, studies, and documentation.

There is clearly tremendous scope for further work in this field – nationally as well as internationally. I have already touched upon some important problems which will have to be subject to further research. Indeed I can see from the excellent program prepared for this Congress that most of these problems will be subject to specific discussion in the next few days. Dimensional coordination, standardisation of building laws, and regulations, research into functional requirements as a basis for design, integration of design and production, development of the building materials industry, better planning and production methods, are all important prerequisites for advancing towards industrialised building. As I have already emphasized, however, the overall aspect and interdisciplinary research must not be left out of the picture. The governments have an important function in this respect. Let us hope that the governments of whom many have failed miserably in their general housing policies after the war, will exhibit more foresight and courage in the future and thus naturally become prepared to take large-scale initiatives for providing research in the building field and for creating such conditions for the building industry that it can rapidly proceed towards industrialisation.

Conclusion

I have spoken very little about specific technical means and industrial methods of building production as such. This is not only because I feel incompetent to talk about these matters among this large group of prominent experts in this field. It is also because I believe – indeed I am convinced – that some of the major obstacles on the road towards industrialised building are not of a technical but rather economic, organizational, and political character. Perhaps I am exaggerating or even altogether wrong. In any case, I am sure that the technical problems will be adequately dealt with by others. May I end therefore by wishing all success to the Congress, which has such an important mission to fulfil.

Industrialisation and Building Research

The President's Address

Philip Arctander, Director, Danish National Institute of Building Research; President of CIB, 1963-1965.

Professor Myrdal has opened this congress by formulating a challenge to building research and the industry, to builders and governments—the challenge of humanity to building technology. We need more and better shelter.

In trying to establish now the first links between this challenge and some of the many developments reported in the congress papers, I shall address you in two languages concurrently.

You will hear the language of technology—duly interpreted—while you will see the language of humanity—open for your own interpretation. Let it at the same time be a demonstration of the good industrial principle of economy in man-hours—your man-hours.

Whether the loud or the silent culture appeals most to you is your choice. Should the counterpoint leave you just a little uneasy, should it make you slightly less certain about the brilliance of our present efforts, that might induce a searching mood in which we would like to meet for the next 6 days and onwards by the way.

With the competence of a godfather guiding the 12 years old child Gunnar Myrdal did indeed "read us a lecture" on behalf of 3.000 million people trying to inhabit this world now, and of the 6. or 7.000 millions who will have to try by the turn of the century, using the houses we build to-day.

Now, can our building technology meet this challenge of humanity? The answer is that we shall have to twist and shape it until it does. Because what on earth would be the raison d'etre of a technology if not to comply with human requirements.

How we shall develop building technology, that is the subject of this congress, and you will deliver a more detailed answer in the coming 6 days.

During these coming 6 days you will meet in 10 working groups, where you will dive into the jungle of distinct details and separate aspects exposed in the 170 papers.

The movement to-day towards industrialised building shows an overwhelming fertility of uncoordinated initiatives. The sum total is however of relatively small value—or even in some respects negative—as long as the many efforts are not woven together in one coherent pattern.

Industrialisation of building is looked upon by some as the golden door to wonderland, where all problems dissolve, by others as a monster threatening our culture—or their own occupation and income.

It is not in itself any of these things. Far from being a monster, behind the surface it is very human, made by human minds, and meant for human needs.

And industrialisation is not going automatically to solve our problems. The danger is, as in other industries, that it will rather solve its own.

To apply it purposefully we shall need not only new knowledge in dozens of fields, as exemplified throughout the congress papers, but also a new level of understanding of the interactions of all the separate developments.

We must mobilize a constantly alert analysis of where we are going and make industrialisation as such a subject for research as was done e.g. at the ECE Prague seminar on "Changing Relationships in the Building Industry" proposed to be followed by one or more similar meetings.

Most of what we have seen so far under the name of industrialisation is only a small step off the traditional crafts. An industry is not created just by replacing one kind of burnt clay by another. We must review and rethink and reshape the end product itself.

To-day we have reached approximately the stage of producing petrol-driven horsecarts. The industrialised house remains to be seen in its industrialised shape, with function, construction and production melted together in forms of an obvious clarity equal to what the crafts have produced in earlier balanced periods.

So far the industry and research have been concerned mostly with minor amendments to the existing situation: finding structural failures, saving some man-hours, devising less wasteful uses of known materials. Surely, there is still much to do in this line, but it won't produce the answer to the needs we are facing if the analysis by professor Myrdal is anywhere near correct.

It is true that efficiency of traditional building crafts has increased nicely over the last 10 years, under pressure of competition from new methods, and it can go on doing so for still some years.

But in building a nice steady increase in productivity will not do in the present situation. We shall have to perform a big leap to reach a quite different level of total annual output where we can then go on with nice steady increases in productivity.

The root of our problem is that we are dealing with the commodity with the longest lifetime of all and in a period of growing wealth.

The desired annual increase in consumption of our long term product can only be realised by a doubling or trebling of the output that was adequate in a stagnating economy.

We have known housing shortage as a poverty problem. To-day it is already in many countries a wealth problem. The main difference is that we then only need the *decision* to solve it.

The big leap is necessary now just exactly because we are getting richer.

Our growing wealth permits us finally to admit needs we have suppressed only because of poverty until now. It is important to understand this basic character of housing needs. Due to human endurance and adaptability to conditions we have survived in housing of a standard way below what was not only scientifically established, but also generally felt.

It has never been a positive value for a family of 5 to eat, sleep and live in one room. As soon as society can afford two rooms this need comes to the surface, and when we can afford five rooms, that soon becomes the acceptable standard. It has never been a positive value to force women to cook kneeling in smoke in a corner of the room.

Human housing needs are fluid within certain limits—but the present world supply is way below the standards we recognise as reasonable to-day.

Not only do we need more houses—many more—we also need more living space per family member to ensure that he/she shall not, for this reason at least, be deprived of the chance to live a good life.

We need more working space too. With increasing mechanisation and automation in all branches of production there is several times more space between operatives.

We need more room for more and recurring education of more people - more room for better care for the youngest, the oldest, and the disabled—and more room for more leisure.

True development in the sense of movement towards more happiness, does not consist in one or another impressive advance, but in a balanced change in all fields of human interest.

Our underdeveloped industry could draw a lesson from so called underdeveloped countries or rather from the futility of technical assistance as it is offered from the temperate zone of the world to the tropical. Its immediate effect, where it has any, is mostly to disturb patchwise an existing balance, a complete cultural pattern that has functioned earlier.

While it is hardly possible to measure whether any new balance on a higher technological level will produce more happiness than any earlier balance, it seems evident that periods of unbalance itself costs unnecessary sufferings. Yet, change may be inevitable.

There is little doubt that the building industry by lagging behind other industries contributes to unnecessary sufferings. The industry is not to blame alone, though. Society tolerates, or directly inspires, a concentration of efforts, public and private, on chasing other values.

And if I may offer a personal yardstick, for lack of a scientific one, there is less happiness to expect at present from higher car speeds, and car densities, more noisy jets, better Mars snapshots and increased destructive power, than from better housing.

The new technology that we are now trying to switch on to building problems holds wonderful prospects—but it has a frightening tendency to live its own life.

We know only too well from other sectors of production how, particularly when technological capacity expands, technology somehow takes command. We end up by producing what technology can, and not what humanity needs.

This danger is imminent in building when new materials, designs and techniques are applied enthusiastically without sufficient knowledge of needs and understanding of coherence.

We have here a variation on C.P. Snow's theme "The two Cultures" that fail to communicate. Even Lord Snow admits, however, in his "Second Look" that there is hope that the gap is beginning to be bridged by a third culture emerging amongst others in such fields as architecture, economy and sociology—i.e., in the building world.

Let me stretch his statement slightly: There is an obvious meeting place for the two cultures in architecture, in building, and in building research. And then for our purpose, let me reverse Lord Snow's second look: there is hope for architecture, for the building industry, and for building research if we manage to bridge the gap, if we manage to unite form and function, material and method in products of that natural obviousness which make the user and the producer equally happy.

But if architecture circles around form alone, vaguely excused by superficial arguments about function—and if industry is too thrilled by what technology can now produce, supported by some odd sales-oriented motivation studies - and if research buries its head in technological details of great academic interest—then we shall not be moving towards the new building culture we have within reach.

Building research was originally conceived as little more than materials' testing—breaking beams and crushing cubes. Its field of activity has since expanded into many and very different subjects: operations, management, planning and design, etc. It is no secret that many particularly among the pioneers maybe - consider this diversity a weakness - or even anti-scientific.

It is not—on condition that we manage to establish order and consistency among the different research branches, the multitude is a strength. An example may show something of what I mean: Building research has gone into the study of living habits and working conditions and has produced a wealth of new and important knowledge though the technique is only in its infancy yet. There are promises of much more to come.

But what are the directives for action we can obtain from these studies? We can study to-day's life in yesterday's buildings, but will that teach to-day's designers of tomorrow's buildings enough? The mean date of use of any house being designed today is somewhere around the turn of the century—or of the millenium, if that sounds more impressive.

The user requirements we should aim at satisfying are, therefore, those of around the year 2000, and not those of yesterday. Isn't this asking for the impossible?

Of course we could get a much better approximation of future needs by applying well-known experimental techniques in actual scale to study the relationships between the arrangement of space, actual use, and satisfaction. This has rarely been done, it should be, and it would help. But certainly it would still tell us very little about life 40 years from now and human desires early next century.

Yet the problem remains—no it grows with the acceleration of change. The origin of this problem is that the world has for the last few generations become a changing world, a world of growing technical capacity and of growing wealth.

One solution frequently offered is to produce buildings from short-lived materials. This may become possible with unknown materials—or with unknown wealth. To-day it is not.

Another suggestion has been to design fully demountable buildings which would seem conceivable in one storey, hardly in several.

But we are doing nothing of this. We are still building "fixed property", tailor-made to obsolete requirements.

How can we produce the best probability of offering in the future reasonably useful space to house unknown activities in the buildings we must produce to-day? By doing exactly the opposite of tailoring buildings to momentary requirements.

If we combined the understanding of changing requirements with functional aspects of modular theory a solution might emerge.

It would consist in producing, apart from the still tailor-made projects, quantities of unspecified "general purpose shelter". Just protected, engineered space, built up from large modules, with the simplest possible dimensional interrelations. Arithmetically organised volume, capable of being adapted and subdivided to-day for to-day's requirements, to morrow for to-morrow's. Built-in functional possibilities.

This would, in a sense, stretch planning some way into building, and draw a line rather between the structure and equipment in its wider sense. And it would constitute an absolute model task for industrial production of both shell and equipment, of unspecified, general purpose structure, and a wide variety of specific equipment.

The structure could be envisaged for a fairly long lifetime without impeding flexible use, while the adaptation would be designed for a shorter life.

From functional studies, we have reached an industrial conclusion.

We have been taught to build for eternity or at least for generations. We shall have to learn what it means to build for change.

The movement towards industrialised building is composed to-day of many separate trends still largely uncoordinated. Are all of these trends truly industrial?

One of the most striking trends in recent years is the growing size of elements. From bricks via blocks over room-high to room-sized elements, and finally to completely prefabricated rooms. Striking results achieved on the way—but is it industrial enough?

The ultimate perspective of this line is the shipyard stage, and not the more advanced stage of e.g. the chemical industry.

In at least two papers for this congress, one from Hungary and one from Sweden, there is, independently, an indication of what may be a more industrial approach. Both papers deal with the idea of producing wall elements by extrusion of endless profiles, a method much more likely to lead towards automation.

Another characteristic feature to-day is the explosion of the building materials and components market. Countless new products are being offered, the designers' files are exploded and so is the building workers' traditional knowledge of how to build a house from the materials he is given.

In an attempt to master this apparently endless variety we introduce computers. A clear success: electronics can process these numbers of data conveniently. A fine new technique cleverly applied to a building problem, and promising useful service in other building problems.

But is it a paper tiger we have killed? Do we want these large numbers of different products at all? Will not such functional requirement studies as have been started in many institutes reduce the number of desirable products to something quite handy, something we can manage even without electronics?

The latest in production planning is, if I am not wrong, *non*-computer programming. Surely, there remain some quite real tigers which we shall have to hunt with EDP—without having to invent new ones.

Building research is probably the only industrial research started outside its industry and in response to a demand not from the industry, but from society. No wonder that communication between research and industry, both ways, has been unsatisfactory.

Much effort has been spent on devising ingenious schemes to build up contacts. The truth is, I am afraid, that adequate communication can only be achieved with firms either big enough or specialised enough to employ a certain minimum of technical staff. To-day this is not the case for 5 % of building firms. With industrialisation their share will increase and so will communication.

At the same time the pattern of research is due to change. Particularly manufacturing firms are likely to take over increasingly research, mostly on technological refinements of their own products. To-day this is loading the conscience of many national research institutes incapable of coping with more than a symbolic fraction of it.

The more industry takes over, the more can the central institutes dive into the multiple transverse and combination problems so characteristic for the building industry.

Already now many central institutes are active in such fields of research as functional requirements, building performance, relations of design and use, planning procedures, the interactions of the many parties involved from town planning to final use, etc.

These studies are characteristically different from the classical analytical research where the approach was to isolate and limit one problem sufficiently to enable undisturbed study.

But ever so many isolated bits of detailed knowledge will not produce the desired development in building, if they are not fitted into overall concepts.

A typical responsibility for central research is dimensional coordination. It combines problems of user requirement, structural design, jointing and tolerances, etc. and cuts across all the building trades.

There is a widespread popular fear that modular coordination, standardisation and industrialisation will reduce to-day's individual variety and freedom to a dull machine uniformity.

Much of to-day's variety is, however, nothing but lack of clear thinking and purpose-definition. And far from producing uniformity, industrialisation may be used to reduce the present infinite aimless variations to a large finite number of deliberate differences.

A building research institute is to-day believed by many to be "the place that should be able to supply all the right answers". This is both over-optimistic and un-progressive. In many cases the institute will serve progress better by acting as "the place that formulates the right questions". Not only is "well asked half answered", but such an attitude may accellerate the creation of research nuclei in the industry to answer their part of the questions.

Nor is the research institute always "solving problems". At least it is frequently uncovering more new ones in the process. What research does is rather to *accelerate the production of new knowledge.* It is difficult to imagine a research result that would not have come about "by itself" some time later.

But the acceleration alone is worth many times what it costs—and so is the exposure of new problems.

Even this steadily accelerating production of new knowledge will leave us with only a small volume of solid information, surrounded by a universe of unanswered, and unformulated, questions.

This endless though shrinking ignorance we must handle two ways: in the short run we must master all our capacity to understand and grasp what we cannot know—and here science has a lot to learn from art—while in the long run we shall just go on patiently piling brick on brick, fact on fact.

Here is where I ought to bring CIB into the picture. There is no end to the usefulness of meetings between colleagues—like this one, or even more so, smaller ones like CIB Commissions—but we are due to take the next step. The better we can define our problems before attacking them, the more often will we find such similarities from country to country that we can do more than holding interesting discussions about them—we can actually divide them between us and thus cope with so many more at a time. This is a way of increasing research productivity—and why should we escape.

Let me mention one type of problem particularly suitable for possible collaborative action. While housing and building needs are urgent everywhere they are terrifying in the countries of delayed technical development.

Can we imagine any sort of combined project to boost the rate of development, in our field of responsibility, in these 2/3 of the world?

As a small beginning a CIB study has just been made, financed by UNESCO, of building research already done in 3 countries and applicable to tropical areas. But an effort on a quite different level is desirable. Could a group of CIB institutes develop "the roof" for low cost tropical mass housing—or "the sanicore" a unit that could be mass-produced and mass-delivered as material assistance.

It may seem quite some way off the usual work programme of member institutes, but the need is there.

We are leaving centuries of safety spent within the solidly established framework of traditional building and are trying to feel our way ahead. By employing research and industrialisation we can meet more housing and building needs for more people.

This process may become a mere performance of productive power. But we should not aim that low. Our aim should be to develop a new building culture, uniting our new needs and new tools in an overall artistic concept of equally simple obviousness as distinguished previous building cultures.

Group A
The Changing Structure

Final report from the group rapporteur Prof. V. Červenka, Director of the Research Institute for Building and Architecture, Czechoslovakia.

Reports sent in for our Congress illustrate the composite pattern in the building industry, town planning and housing construction in different parts of the world. However all the papers have one basic keynote, illustrating and documenting the impression we have already from the Prague Seminar "On changes in the structure of the building industry" and which was formulated in the discussions held in both Committees for Housing, Building and Planning of the United Nations in New York and Geneva. It is the consciousness of links between the changing structure of society and the necessary changes in the structure of the building industry. Simultaneously the reports underline the consciousness of the urgency of this task and of the effort for its solution.

Recent successes of science and rapid technical progress go hand in hand with the speedy development of the nations of Africa, Asia and South America, creating a new situation in the economic, social and cultural development in the world. The development of production forces of society and consequently increasing living standards are manifested by growing demands for environmental changes claimed by the majority of the inhabitants. Society now needs more homes, homes of better quality, better civic services in towns, superior transport and power facilities and supply of sound water of high quality. A rapid increase of the population multiplies these requirements. All of these factors contribute to a steadily increasing pressure on the capacity of the building industry.

At the same time as the production forces are growing we see as one of the characteristic signs the building industry falling considerably behind the rapid progress of organisation and techniques in general industry. Today in many sectors of industry, production is fully automated while at the same time, in building, handicraft methods are slowly being replaced by industrial methods, and even this development is in many places a question of discussions.

The capacity of the building and construction industries, being a decisive factor in creating an appropriate living environment, is not able to cope with the rapidly growing requirements of the development of civilization.

It is only natural in this situation that improvements in technique and industry are not always manifested in improvements in living conditions but sometimes can lead to a deterioration in the environment of whole towns and regions. In many countries building costs are rising, especially in the construction of new houses. Society finds growing difficulties in securing the conditions for a healthy development of all its members. There is no doubt, that the most important resource in the solution of this serious question, how to increase in a short period the productivity of labour in building and how to enable society to master this task, lies in the industrialisation of building at such a level as in the most advanced industrial sectors.

The problem is, how to attain such fundamental changes in such a short time and to achieve the expected results on the largest possible scale. It is necessary to take into account the present situation in the building industry, its disintegration and the special market conditions. The building industry still works on individual orders, not on stock, and this substantially aggravates the change to industrialised mass production. Building has some special features, which also in the future will make it different from the majority of industrial activities. Construction is more or less influenced by the building site and a certain amount of work must be realised on the site. Furthermore construction creates directly the living environment for society and for the individual, and it must meet not only economic conditions but also hygienic, psychological and cultural requirements. This problem is the more important, as buildings have a substantially longer service life than the majority of industrial products and serve for several generations.

It is evident, that taking over mechanical methods of other progressive industrial branches into the building industry may cause serious difficulties and that therefore particularities of the building industry must be respected and the methods and organisation of mass production used in other industries, must be consequently adapted. In my opinion this is the most serious task, and to this and to related problems will be given the main attention in this report.

Investment - Continuity - Productivity

Capital investment in production equipment is the main prerequisite for the development of industrial mass production with a high productivity of labour. It is the fundamental measure enabling us to raise the capacity of construction and to reduce the costs of the building process. Capital investment creates the fundamental conditions for a change from handicraft methods to industrial methods, which are economically much more favourable. It stands to reason that this economic process can be realized only provided that society develops its economy and that the demand for new buildings and structures of the same kind is sufficiently large and lasting over a long period. Initial motives for capital investment into industrialised building can be different in various countries according to their structure and economic situation.

In countries with a planned economy such decisions are made when state plans of economic development are drafted. Differences, arising during the preparation of the economic plans, between economic needs imposed on the building industry, and the capacity of handicraft construction (under a condition of limited manpower), clearly demonstrate the necessity of industrialisation and provide the reason for capital investment. These favourable conditions may have sometimes less favourable results. The development of industrialisation is sometimes pursued so fast, that it is not possible to secure the necessary basic conditions. This enhances the quality and the economic contribution of industrialisation.

In countries with a free market capital investment for the industrialisation of building is conditioned in a certain way by grants from the state, i.e. by long term orders or similar actions. Capital investment is also realised by entirely private initiative in such cases when conditions for the production of large series arise. As an example may be given factories for the production of prefabricated timber houses in the United States. Variations of demand on the building market substantially and sensitively influence capital investment into production equipment. This changing demand often prevents the building industry from procuring expensive production equipment, which could effect a fundamental change in the rise of productivity, and so the development of industrialisation is set back. It seems that in countries with a free market a certain form of state guarantee or state support for the realisation of such effective production equipment might support the industrialisation of building and raise its productivity. One of the effective ways of support for long-term programming of building production is physical planning. In many countries with a market economy, Governments have taken measures to ensure that that part of the national building programme which is controlled – directly or indirectly – by Government or local authorities, is carried out as large projects or groups of projects of a duration of 4 to 10 years or more. These projects have in many cases created the market necessary for establishing component factories on an economic scale.

Industrial equipment with a high productivity of labour producing large series of corresponding parts enforces – and simultaneously by its economic effect motivates – typification and standardization of building products and of requirements on buildings. This means in substance, that a great part of the project must be decided much earlier, than in the case of traditional building, often already in the stage when decisions are taken on the industrial equipment for the production of building components. It is desirable that, at the same time, the competive tenders should be invited; this is to secure the type of a certain building by its functional properties and costs giving optimal results and fitting in with the needs of society.

Tendering Procedures

The introduction of industrialised building demands that to a certain extent the preparation of the building process, i.e. design studies, typification, call for tenders, fixing of prices etc. should be already in the decision stage on capital investment into industrial equipment for the production of building components, which usually means 2 to 3 years before starting the assembly of the first structures.

Competition by tender, as in the case of individual buildings, is here replaced by a competition between types of structures and competition between industrial equipment for the production of building components. It is obvious, that decisions on the choice of certain types of building components and the machinery for their production is much more committing as it influences a higher number of structures than the decision on the tenders for an individual building. For this reason, as a rule, studies or research and development work on requirements for functional properties of the structures and the technical possibilities of their realization are undertaken beforehand. One of the conditions for the economic efficiency and quality of industrialised building is the necessary lapse of time between research and development work and the realization. This period should also be decisive for the collaboration between client, architect, producer of building components and materials and the contractor, i.e. 3 or 4 years before starting building proper, when conclusions should be drawn prior to research work being done on typification of building elements and the choice of machinery. This is the fundamental distinction from the traditional way of building, which is often forgotten.

Changes in the structure of the production basis influence not only the relation among the participants of the building process but also the structure of the building industry. First they necessitate the concentration of small building firms, which are typical for the handicraft way of building, into economically strong industrial enterprises, which are able to realise capital investments in production equipment and also in development work.

The question is, which changes in the organisation are useful in order to obtain from industrialisation optimal results for society. The traditional way, corresponding with the present situation of the building industry, anticipates that the client procures himself or by intermediary of his experts the collaboration of architect, contractor and other suppliers. Progressive forms of industrial production, as we know them from developed industrial sectors, concentrate all the responsibility for carrying out the work to be done for the client in the hands of the main contractor. Between these two extremes development is going on. It is necessary to add in this analysis that both methods can have, in concrete examples, different schemes of organisation. For instance, in the second method all responsibility and activities can be merged into one enterprise, or the so called general contractor may cooperate on his own responsibility with further independent specialized sub-contractors, eventually with research institutes and design organisations. Just these forms of organisation are decisive from the point of view of the structure of the building industry and of the creation of conditions for the development of industrialised methods. For this reason the difference between them must not be neglected.

Integration at various levels

What are the facts supporting an integration of the different contractors and what are against it? A favourable consequence of the integration of contractors into one organisation is higher responsibility and competency, and following this a higher degree of promptness and flexibility in supplying and also in coordination, in the case of changes etc.

On the other hand the development of advanced industrialised methods of production in larger series calls for superior specialised production equipment and thus for specialisation of an enterprise on a more limited coverage of products. This demands independence of enterprises and, simultaneously, a smooth cooperation with a wider circle of customers. It is necessary to consider the fact that the building industry has to deal with a large assortment of quite different kinds of materials and products and that the concentration of the production of different kinds of materials into the hands of one enterprise for a long period does not guarantee the development of advanced production methods.

The difference between the building industry and other industrial sectors is manifested most clearly in the relations between design and production. In the greater part of industry it is common that the design is part of the enterprise, in the form of a department (motor-cars, refrigerators, shoes etc.). A building which is the final product of the building industry, differs fundamentally from industrial products, in that it cannot be completed in a factory, and in that where it will be situated must be taken into account from the design stage. Its use value is influenced to a large extent by how far its siting in relation to other buildings and to the surrounding nature, with which it will create an entity, i.e. the living environment of society, has been successful. It is therefore reasonable to integrate in industrialised building enterprises only those parts of design, which are concerned with the design of building components and their assemblies, i.e. those parts of a structure which can be produced for stock and used at different places. Designing of individual buildings should be concentrated into independent design organisations, which are responsible to the client for the final social, economic and technical effect of the building and its environment. As I stated before, it is important for a successful development of industrialisation that representatives of both these design organisations should cooperate well ahead of the designing of a certain building, and especially in the case of development work and when deciding on types of building elements produced by industrial methods and on their structural assemblies.

The process of industrialisation, which fuses small production firms into bigger economic entities, creates also favourable conditions for the integration of investors.

Strong investors' organisations are able more efficiently to defend the interests of the users by typifying functional requirements on structures in the process of typification of building elements and technical equipment for their production. They can contribute also to a useful concentration and use of investments, mainly in the building of neighbourhood facilities and technical installations for settlements and industrial districts.

The stress put on research and development work and the endeavour to use its results most effectively for the construction of the production basis of the building industry calls for reliable methods of measuring technical progress and also for reliable methods of analysis of the present standard of the building industry. The change-over to long-term planning, the requirements of market research and the steadily extending application of organisational and managerial methods applied in other developed industrial branches will necessitate the broad application of mathematical methods and automatic computers. These measures are related circumstances to the structural changes of the building industry.

The rapid development of industrialised methods could have unfavourable results in the structure of specialised professions in the building industry. Even in the case of fully introducing progressive methods of mass production, there will remain a considerable number of smaller, scattered building jobs, and the full amount of repair and maintenance work, for which it will be necessary even in the future to train a considerable number of building specialists. In training it is necessary therefore to maintain the right proportion between traditional and progressive building professions.

Conclusions

Coming to the conclusion I should like to sum up several observations, which might contribute to the explanation of the further development of the structure of industrialised building.

A decisive factor in the change in the structure of the building industry ensured by industrialisation is the development of its production basis together with the investments accompanying it. The proper process of industrialisation, being in fact a change-over from handicraft methods to a mechanized or automated production, with the goal to be achieved being a substantial rise of the productivity of work as well as of the quality of the construction, requires relatively large investments in production facilities. It is sometimes necessary to realize these capital investments much before the proper construction is started, the investments serving, as a rule, a larger number of constructions. The new production facilities produce the building components and the construction more quickly and turn out larger quantities, compared with hand-made production. Should those investments become profitable, it is necessary to ensure for their output a continuous, long lasting market in large series. This requires the establishment of a long-term plan embracing a larger coverage of building types.

Due to its final product—the building—, the building industry, has got some qualities that distinguish it from all the other industrial branches. I spoke of them in the first part of this report. To some extent, those qualities have been the reason for the delayed development of industrialisation. The significance of the building work for the cultural and biological development of society and the direct influence exerted by the building site on its technical performance and the functional properties, constitute factors which must be respected if the process of industrialisation is to bring a real benefit upon society.

In the traditional building industry the initiative in establishing a building team lies with the client. Architect firms, consultant engineers, contractors and suppliers of materials work together on the clients' projects, and the coordination of their activities may be rather poor, because collaboration will only exist for the duration of a specific project. This improvised coordination is a characteristic feature of the traditional building industry.

When we look at progressive forms of industrialised building production it appears that two highly different principles of organisation are being applied, and this leads to two partly conflicting structures within the building industry. One organisational form for industrialised building is to concentrate the responsibility for carrying out the building for the client in the hands of one single contractor. This single contractor is responsible for design, for production of components and for the assembly. In typical cases all these activities are integrated into one enterprise.

The other organisational form may be identified under conditions where advanced industrialised methods are used for production in large series. These conditions call for superior specialised production equipment and hence for specialisation of enterprises on a more limited range of products. This demands the independence of specialised enterprises and simultaneously smooth collaboration with other participants. In this case the enterprise, which undertakes assembly of the building, is a general contractor, who buys the components from specialised manufacturers. The design of a building is prepared by an independent design organisation which is responsible to the client.

As the process of industrialisation of building proceeds, we may expect that these different principles of organisation will be applied, according to the conditions and resources available in a region.

Thus industrialisation of building may for a period be characterized by the co-existence of different structural relationships. But it seems most likely, that accelerated technical progress and high economy of labour and quality will be associated with the last mentioned principle of organisation.

The progress towards broader industrialisation in the building sector does not seem to come about by itself, without any promotion from Governments. At least in the commencing period of industrial development within the building sector some encouragement seems necessary.

From the experiences of those countries where industrialisation has progressed most, it seems that the most effective form for Government promotion is long-term planning of large scale building projects. This applies to countries with a planned economy as well as to countries with a market economy.

Physical planning has already been recognized as a necessary tool for establishing a coordinated development of public and private investment in the field, and thus the basis for long-term planning of the actual construction and building work is already provided in most countries.

Other typical Government measures to promote the industrialisation of the building sector are introduction of dimensional coordination, standardisation of components and typification of building design based on research into functional requirements.

There is no doubt that Governments by implementation of an all-round building policy may accelerate the industrialisation of the building industry and thus contribute to narrowing the gap between needs and capacity.

Research on industrialised building will be the forerunner of technical and economic development in the same way as it is already in more advanced industries. For this reason the significance, and also the tasks, of research and development departments will increase. This applies to all branches of building research, whether they are located within government bodies, investors' organisations or building enterprises.

The specific task of the building industry in the creation of the living environment will stress the importance of the coordination of technology and economy of industrialised building, with the results of scientific research in the fields of sociology, hygiene, town planning and regional planning.

One of the conditions of the economic efficiency and quality of industrialised building is the necessary lapse of time between research and development work, and the realization. This period should also be decisive for the collaboration between client, architect, producer of building components and materials and the contractor, i.e. 3 or 4 years before starting building proper.

Organisational measures ensuring industrialisation of building in Czechoslovakia

By V. Červenka (Czechoslovakia)

The purpose of this report is to give a survey of fields in which the countries with a planned economy adopt principal measures ensuring the development of industrialisation of building. The differences between the individual East-European countries are not of a fundamental character and are generally irrelevant for this general survey. However, their explanation would necessarily lead to general descriptions which would not contribute to a clear specification of the problem at hand, making it, on the contrary, more involved. This is also the reason why I have decided to elucidate the problem on the example of one country, viz. Czechoslovakia.

By way of introduction I should like to point out that the whole national economy is controlled by a uniform system of long -and short-term economic plans, the plans of capital investments and of building production forming an integral part of the said system. The development of industrialised methods of construction represents one of the principal means of ensuring the required growth of the capacity of the building production in order that it may correspond to the ever increasing planned needs of society. For this reason the creation of prerequisites for a further development of industrialisation of building forms an integral part of state economic plans, the system of economic planning creating simultaneously prerequisites for the necessary continuity of technical requirements imposed on the building industry.

Measures ensuring the development of Building Corporations

The process of industrialisation exerts a decisive influence on the development of the individual corporations of the building industry. Those corporations which had an industrial character at the time of their nationalization, such as cement works, brick factories etc., underwent only minor changes. On the other hand the building construction corporations, which were relatively small (the majority having had less than 100 employees, insufficient plant and only capable of working in a traditional way) underwent fundamental changes which can be characterized as follows:

- small firms and works were concentrated into big national and communal enterprises. National corporations carry out the construction of new investments, employing, in accordance with their purpose, 2 000–15 000 people. Local communal corporations, on the other hand, are mostly concerned with maintenance and minor constructional jobs, employing some 500–1 500 people;
- national building corporations specialize in accordance with the types of construction (housing, transport structures etc.) or in accordance with the technology of the individual production (earthworks, production of reinforced concrete precast units etc.);
- some of the specialized building corporations were provided also with works equipped for the production of the respective prefabricated components, thus forming combined works (complexes) combining both the production of the respective components and their assembly on the site.

One of the most important measures is the building-up of permanent works for the production of prefabricated building units. In the first phase works for the production of precast reinforced concrete units were built, uniformly distributed on a regional basis over the whole country, to make the transport of materials as well as that of the relatively heavy units as advantageous as possible. Annual production of one such works varies between 30 000 and 60 000 cu.m of precast reinforced concrete units. Further development in the construction of prefabricated houses using unified components will create prerequisites for an increase of the capacity of these works to some 100 000 cu.m a year and for the utilization of highly mechanized plant. The trend of building-up of works for the production of precast reinforced concrete units can be characterized by the following figures giving annual production in thousands of cu.m of precast units:

1955	1960	1963
483	1840	2312

Of even greater importance for the development of industrialisation of building is the origin of works for the production of building units and parts based on the use of plastics and metals, such as factories producing curtain walls or prefabricated plumbing units (sanitary cores) for flats. The production of the latter has attained an output of approximately 40,000 plumbing units a year. Simultaneously it is necessary to develop the production of initial materials, particularly insulating materials on the basis of minerals and plastics. This trend affords so far optimum prerequisites for the development of economic industrial methods characterized by a high productivity of labour. The favourable ratio of their weight and their labour requirements facilitate the concentration of production and use of highly mechanized production plant, thus creating prerequisites for an increase of the capacity of the building industry without imposing further requirements on labour.

In dealing with the problems of the building industry we are often confronted with the problem of whether it is more advantageous to set up combined works (complexes), incorporating both the production of the respective components and their assembly on the site, or build-up independent specialized corporations and ensure their mutual cooperations on a contracting basis. In the past fifteen years the development has taken both courses. Experience gathered hitherto in this field has shown that in the cases when the capacity of production of the respective materials or prefabricated components corresponds to the needs of the building activities both as regards its volume and the locality of its use, it is more advantageous to combine both activities in one organizational unit. In such cases where it is advantageous to concentrate production of some materials or building components into large capacity works to ensure economy of production, labour-saving progressive production methods and the use of highly productive plant, the capacity of such a works consequently exceeding the requirements of one building corporation, it then seems desirable to organize such works as an independent corporation. As a rule it is advisable that such works ensure also the assembly of its products on the sites.

Organisation of design activities

Design of investments important for the individual sectors of the national economy, particularly industrial investments (investments of the chemical, engineering, and other industries) is ensured by specialized design institutes whose activities cover the whole territory of the country. The design institutes dealing chiefly with design of housing estates, towns, residential and civic constructions are organized territorially, being located in every region. Apart from this, some of the building corporations have their own design departments ensuring the preparation of working drawings. Some of the bigger industrial corporations are also provided with their own design department ensuring the preparation of their investments.

The organisation of design activities developed in connection with the development of the national economy and the process of industrialisation of building. For a certain period the individual design institutes were subjected to the Ministry of Building, part of the design activities being carried out by the design departments of the individual building corporations. At present the respective specialized design institutes are controlled by the ministries of the respective specialization (e.g. the institute for the design of chemical works by the Ministry of Chemical Industry, the institute for the design of health service institutions by the Ministry of Health etc.), the regional design institutes being subjected to the individual regional national committees (local government).

Organisation of investors

The preparation of investments is ensured by investment departments of large national corporations, ministries and departments of local government. With regard to the building corporations and design institutes they represent customers ordering the realization of their investments. They prepare the conception of the investment briefs, order and take over designs as well as finished buildings or structures and inspect the work in the course of construction.

Relations among the participants in building activities

During the first phase of existence of the nationalized industry, characterized by large production organisations, the investment, building production and design activities were often combined in the most varied manner. As we have already mentioned, works producing building materials or prefabricated building components were combined with building corporations. Large industrial corporations with large programmes of capital construction incorporated also design institutes and building enterprises. Similarly the individual building corporations had their own design departments, etc.

Several years experience has shown that the economic and organisational amalgamation of the individual participants in the building activities, in spite of certain initial advantages, particularly higher flexibility and readiness, is later on characterized by certain principal deficiencies, such as:

sinking the construction in the investors' corporation leads, sooner or later, to a stagnation of the construction technique and finally to a lower economy of actual construction. The management of the investors' corporation is responsible, in the first place, for the operation and efficiency of its own factory, the construction remaining always only a means which will receive, sooner or later, only its secondary attention and material support.

The combination of a design department with a building corporation is usually connected with the fact that higher attention is afforded to the problems of the actual construction than to the functional, architectural and town-planning qualities of building.

A combination of all participants in construction in one organisational unit is advisable only in the case when it is necessary to ensure difficult tasks, particularly of a development character, when it is necessary to ensure, within a very short period of time, coordination and utilization of the optimum results of several fields of activities for a new project which is expected to bring about new quality. However, as soon as the said task has been fulfilled, the new technique and organisation being introduced and mastered and the whole project becoming part of the regular course or of mass construction, it seems advisable to dissolve the combined organisation and to afford the individual parts specialization and organisational independence, to give them responsibility of their own and the desirable freedom for the development of their own specialization.

Technical progress

In connection with the plans of capital investments and of building production, plans of technical progress are prepared, i.e. plans of research and development work which are to create prerequisites for further increase of the productivity of labour and quality of construction. These activities are concentrated in research institutes and development departments. Research institutes are controlled by the ministries or by associations of production corporations and specialize in the research of building materials, building structures, technology of building construction, technology of civil engineering structures, mechanisation and automation of building production, organisation and economics of the building industry, typification and the theory of building and architecture. The individual development departments form part of building corporations and are specialized accordingly.

Research problems included in the plan of technical progress are solved by teams consisting of several research and development departments, one of which is endowed with the leading function and entrusted with the coordination of the whole work beginning with theoretical research and ending with the producion of the first series of products (for evaluation).

The plan of technical progress includes also problems of the development of typification and modular coordination which are of particular importance for the industrialisation of building. They ensure the prerequisites for the technical continuity of production. Within the framework of these problems types of structures, products and buildings suitable to the development of industrial methods of construction are selected. The preparation of typified design is carried out in cooperation with research institutes and building corporations.

Industrialisation of building—Australian news and experiences

By H. J. Cowan (Australia)

The need for industrialising the building process is felt as strongly in Australia as in most other countries; however, the size of the country, its small population, and its remoteness from other industrialized centres have not been favourable to highly organized production processes. System building, which has played so prominent a part in recent developments in both Western and Eastern Europe, is unlikely to make a significant contribution in the foreseeable future. Few Australians live in blocks of flats or multi-storey buildings; houses stand on blocks of land measuring 7500 sq. ft. (700 sq. m.) or more, and are consequently single-storey. The climate permits the use of gardens all the year round, and this is one of the factors perpetuating the trend towards individual homes in widely-spaced suburbs.

In New South Wales "fibro" (asbestos cement) is the predominant building material, and in Queensland and in Tasmania it is timber. While these materials lend themselves to substantial prefabrication (even to the extent of providing ready-cut houses) without superseding the traditional trade practices, this does not result in mass-production of private houses. Developers generally confine themselves to a sub-division of land, and the owner builds his own house to an individual design, not infrequently assisting with his own labour. In the public sector of housing, which in most States is confined to families below a certain level of income, development is planned on a substantial scale; but in New South Wales, the largest State, the Housing Commission firmly adheres to traditional building methods. Only the Victorian Housing Commission has developed system building (Fig. 1).

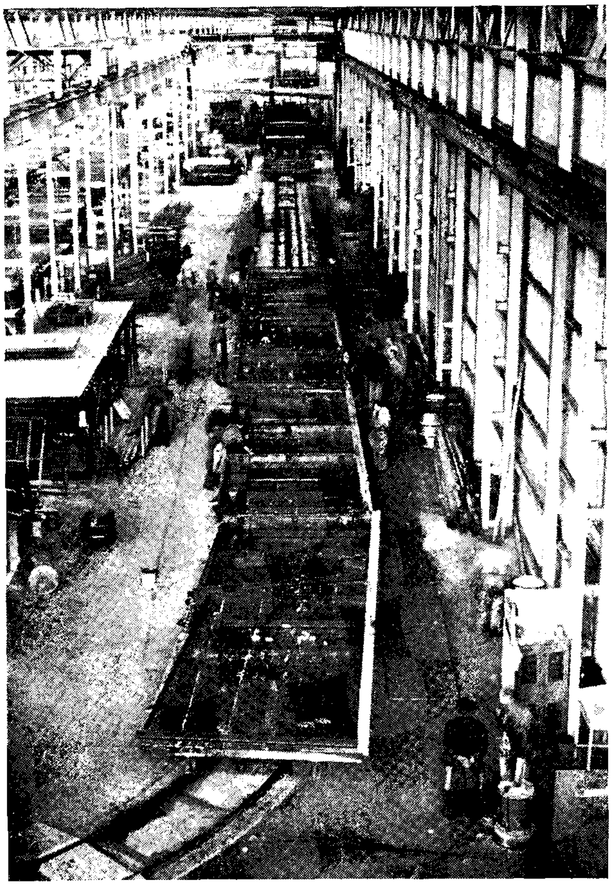

Fig. 1. Concrete House Factory of the Victorian Housing Commission, established in 1946, and producing 1140 living units per annum. The photograph shows the main production line, looking towards the pouring machine. The units have been used for single-storey houses and for blocks of flats up to 20 storeys in height.

Partly because of immigration from the European Continent, and partly because of the high cost of transport and services in cities like Sydney, which has a population of 2,256,000, there is a growing trend towards taller residential buildings; but this *is* unlikely to lead to a large increase of industrialisation in the near future.

The position is different for commercial buildings which, during the last six years, have been erected on an unprecedented scale in all capital cities. Buildings above twenty stories are common, and one building of 600 ft. (183 m.) is projected. Flexible planning of the interior is generally required, and both exterior and interior walls are therefore mainly built from factory-produced units. Large areas of glass were used in the early days. However, these present difficult thermal problems, since Sydney, for example, is nearer to the equator than any European town. Concrete curtain walls are now frequently used, and sun-shading devices are becoming common. Prefabrication of part of the building services is normal practice.

Although many buildings are large enough to provide an economical quantity for factory production to an individual design, the potentialities of assembling buildings from standard components have been recognized since the foundation of the Australian Modular Society in 1959, and both that body and Committee BD/5 on Modular Co-ordination of the Standards Association of Australia have devoted much time to the problem. The draft of an Australian Standard for Modular Co-ordination in Building, in four parts, has been completed, and publication is expected this year. The production of modular components has made little progress so far, but the concept of nonmodular "neutral zones" in an otherwise modular building, recently developed at the University of Sydney, may go some way towards facilitating modular design in the future.

It is generally felt that further progress towards industrialisation is essential if the cost of building is to remain at a reasonable level without lowering the quality of the architecture. In addition, we must allow for a demand for higher environmental standards in the future. A conference on Industrialized Building has therefore been organized in Sydney in May 1965 by the Building Science Forum of Australia, an organization formed in 1962 to provide a forum for the discussion of common problems by architects, engineers, builders, research scientists and building materials manufacturers. This is expected to range over the entire problem of industrialized building as it affects Australia. The conclusions and a summary of the proceedings of this conference will be presented to the Third CIB Congress.

Industrialisation of building in Japan

by K. Hiraga and O. Furukawa (Japan)

Conditions requiring industrialisation of building construction

In recent years building activity has remarkably increased in Japan, especially since 1955. According to governmental statistics, the quantity of buildings constructed in 1963 is 256% or 413% of that in 1955, in the terms of floor area or nominal amount of investment respectively. This is mainly attributable to the increase of investment in industrial facilities and of housing construction. Besides these increases, there occurred changes in the nature of construction works. For instance, the ratio of wooden buildings, which have been traditionally dominant in Japan, has gradually decreased in relation to the whole building activity. The ratio of floor area of nonwooden buildings, which was around 20% annually in the early 1950's, became 30% in the latter half of the 50's, and 40 to 50% in the 60's.

TABLE 1. Change of Construction Works Completed

Year	Area constructed × 1,000 m²		
	Total	Wooden	Not wooden
1955	33,920	27,684	6,236
1956	40,866	31,289	9,577
1957	43,669	32,553	11,116
1958	42,429	30,726	11,703
1959	50,766	33,622	17,144
1960	61,461	37,537	23,914
1961	76,872	41,384	35,488
1962	76,645	39,408	37,237
1963	86,835	43,156	43,679

Source: Ministry of Construction

Construction time has been much reduced, due to the large quantity of construction to be completed in a limited period. Statistics show that the construction time was reduced by 20% on average during the period from 1955 to 1960.

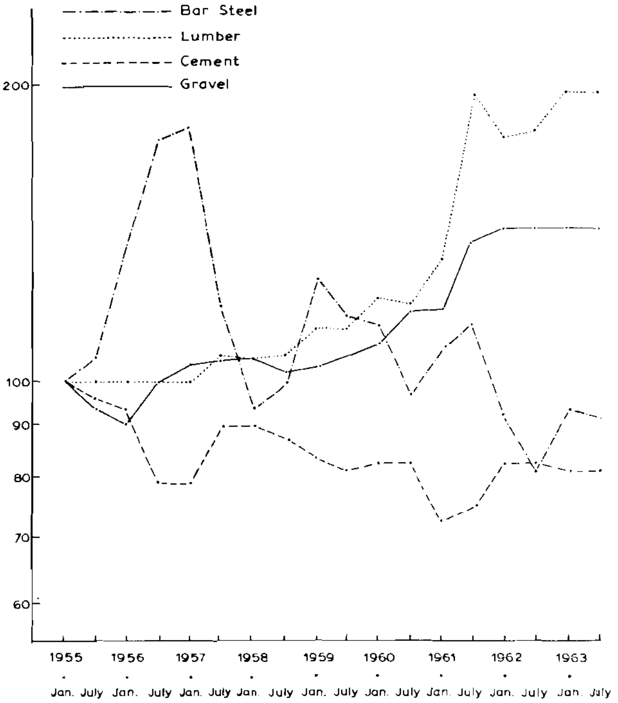

Fig. 1. Change of Price of Construction Materials (in %, Jan. 1955 100).

The increase of construction has brought a strong incentive to the building industry on the one hand, but has caused a gradual shortage of resources on the other hand. One of these resources is labour.

The shortage of labour resources due to the high progress of economic development, does not only exist in the building industry, but is particularly acute there. According to governmental statistics, the shortage of skilled workers in the building industry in 1962 is estimated at about 35%. The supply of natural extracted materials such as timber, gravel and sand has become insufficient. This is quite obvious from the rise of prices of these materials shown in diagram 1 in comparison with that of the manufactured materials such as cement and steel. Due to these factors the building cost has been consistently increasing during recent years. The rise of building cost between 1955 and 1963 comes up to 40–50%.

These trends will not change in the near future, because the high level of building activities is expected to continue for sometime. In the field of public works such as roads, ports and rivers, the yearly volume of construction will become almost twice as much as the present level. In the building industry, the principal increase is expected to be in housing construction.

Housing activity since 1955 is almost at the level of one million dwelling units per year, and the government expects that, for the coming seven years, construction of 1,100,000 dwelling units per year may be required and possible.

These circumstances are the conditions which necessitate the rationalisation of building works or the introduction of industrialised methods to building construction.

Conditions realising industrialisation

Among conditions for bringing about industrialisation of building construction, the development of new materials suitable for industrialisation and the increase of construction machinery will be discussed.

Japan's production has developed amazingly particularly since 1955, in the fields of steel, cement and other heavy chemical industries, and the progress in the fields of construction materials is remarkably high.

In the field of the building materials industry, the characteristics of recent progress are the wider utilisation of manufactured materials, the increase of half-factory-made materials, and production of various new materials.

The utilisation of a large quantity of construction machinery in construction works, where manual labour has long been dominant, is the notable tendency in these years. The investment in mechanisation in the construction industry has especially increased. The speed of increase is so high that the amount of investment for the mechanisation which was 10 billion yen in 1955, comes up already to 150 billion yen in 1963, although the larger part of this investment went to civil works and the building construction received comparatively less.

The mechanisation of building works, however, is progressing through employing cranes, conveyance equipment, machinery for foundation works, and portable machine tools for carpentry. A notable case is that of ready mixed-concrete plants which have been established at the rate of one per day in 1962.

Various types of industrialisation

In Japan, wooden-buildings have traditionally been dominant. Even at present, except for industrial buildings, 85% of existing housing units have timber as their main structural members. Houses composed of the combination of timber and paper, and accompanied by small gardens are tightly woven with the living style of the Japanese.

Destruction of cities by the war, acute concentration of population in large cities, and enormous housing shortage have compelled Japan to promote public housing activities. The gradual increase of reinforced-concrete flats in public housing has strong effects on the style of living in urban communities.

This new living style is getting more popularity among urban citizens. Industrialised buildings belong to this new living style and still require many technical improvements for livability suitable for Japan.

As regards industrialisation of housing construction, three kinds of structural materials have been and are being developed: cement concrete, light steel and wood. The former two are more prevalent. The concrete type is further divided into a) tilt up method which has been developed by the Japan Housing Corporation in cooperation with the Building Research Institute, Ministry of Construction, and construction firms in the private sector, and b) the small size ready made concrete panel method adopted by local governments in their national subsided housing construction programmes since 1961. Both are being developed under the sponsorship of public authorities. About 3,000 units of two storey terrace houses have already been completed by the tilt up method. As regards the small size ready made panel method, about 6,000 units of two storey terrace houses have been completed.

However, due to delay of enactment of the standard regulation for earth quake-proof construction, these four-storey apartment houses are not many in number. The regulation was issued after experiments in earthquake-proof construction had been conducted on a model of a four-storey apartment house and two full-size apartments of four stories. It is expected that this type of construction will rapidly increase in future.

Prefabricated building using light gauge steel has been developed by steel manufacturers, and sold mainly under the form of individual houses since 1960. There are more than ten manufacturers of these prefabricated houses and their production capacity came up to the level of around 15,000 units per year.

Since 1962, the Housing Loan Corporation has taken up these prefabricated houses as the loan object and has given incentives for their improvement. Besides these, there is a curtain wall method using a steel framework, prefabricated window sashes and metalic components with spandrels. This method has been popular in the field of urban commercial buildings and further use is expected in the construction of much higher buildings in the near future. For example, it was reported that at a hotel construction completed recently about 60% of manual labour at the construction site was saved through using the curtain wall method and prefabrication of bath-units.

Through establishment of the committee for standardised components for public housing, the government has promoted standardisation of building components such as kitchen sinks, doors and sanitary ware for public housing. Since 1962 the committee for modernisation of building production established by the government has the role of promoting the modernisation of the building industry.

The building industry in Japan is, however, still at the starting point of its modernisation due to various limitations such as unsatisfactory business conditions, shortage of available land, and underdevelopment of potential demands.

Demands for housing construction

Even when the necessity and technical possibility for industrialisation of building construction are recognised, there must still remain certain conditions for the actual industrialisation. In the field of the building industry which has a special market different from those of other industries, it is very important to examine whether the nature of building demands requires industrialisation or not. Taking housing construction as an example, I would like to explain the origin of housing demands in Japan, especially in relation to its economic and physical aspects. In the building industry in Japan, the order-made production system is dominant and a ready-made one is not so much developed. Attention must be paid to the point that in housing construction the users do not always have direct contact with the producers. The data are given for 1962. (Differences among the numbers of constructed dwelling units have no significance except the limitation of statistical technique.)

The major part of housing demands in Japan is for individual houses, and the demands suitable for industrialisation are mainly attributable to the Japan Housing Corporation or other public authorities. From this reason, it is necessary on the one hand to integrate the same kind of demands in order to promote industrialisation and on the other hand, to develop industrialisation techniques through higher prefabrication and standardisation of materials and components.

Economy of industrialised building

As the industrialisation of building construction is still at its primary stage in Japan there are rather few instances discussed. Even these instances are not stable enough to make an economic analysis. Therefore, we can only deal with the limited information available through experimental constructions, and cannot analyse its economic features throughly.

Industrialised buildings have clearly saved labour at the construction site. An example of such is shown in a small size precast concrete panel method which has been adopted in national subsidized housing.

A survey conducted at a construction site covering 1350 units constructed during 1962–1963, shows that the necessary labour is 1.21 man day/m^2–1.51 man day/m^2 (excluding fittings and equipment). The break down of the above shows that the weight of labour required in structural works is considerably less than that of ordinary construction methods. Although reliable information as to labour in housing construction by ordinary method is not available, we may guess the quantity of labour at 5 man day/m^2 as for buildings in general and 4.70 man day/m^2 including equipment based on the research made by the Building Research Institute in 1955.

In case of public housing such as small two storey houses, the labour at the construction site may be estimated at $\frac{1}{3}$–$\frac{1}{4}$ of the above figures, and quantity of skilled labour at $\frac{1}{5}$.

The analysis of the whole economy of industrialised building construction including fixed investment, maintenance and running costs for machinery in the factories and assembly equipment necessary for this labour saving is not available yet, but the total cost of a dwelling unit built by this method is almost the same as by ordinary methods. The situation is a little improved in the case of the large size precast concrete method, the so-called tilt-up method, developed by the Japan Housing Corporation. In this kind of analysis so many conditions must be assumed as to the amount of investment, maintenance and running costs and operation time of the mechanical facilities, that the analysis can only be theoretical. We have, however, a rough calculation as follows: 38% of labour cost required in structural works excluding foundation may probably be saved by the tilt-up method even including production cost of the panels. On the other hand, if investment for factories and equipment increases by 15%, then the cost of structure will decrease 9% in total. This means a total saving of 3%.

As a comparatively strict calculation was made to the tilt-up method in this analysis, it is expected that this method is more economical in practice. The fixed investment for production, transportation and machine and tools for tilt-up of panels is estimated at around 600 yen per square metre or less than 40,000 yen for a dwelling unit of 59 m^2, and including the cost for maintenance, running and transportation costs of machinery with portable equipment for panel casting, it will rise up to around, 1,800 yen per square metre.

Conclusion. As we see in the previous sections, introduction of industrialisation to building construction is now inevitable in Japan due to the increase of building demands and relative shortage of resources especially of skilled labour. The development in production of various materials is making it possible, although at present we have many problems to solve for real industrialisation of building construction. One of these problems, not mentioned yet, is the popularisation of the industrialised method.

For instance, constructors accustomed to ordinary methods are compelled to adapt their business organisation to this technical progress. Desirable coordination between components production and works at the construction site is not yet fully established. The rationalisation among designing, production of components, and works at site is a vital condition for promoting industrialisation, and there are many problems to be improved in organising these various professions. The possibility of industrialisation exists in the field of housing construction, especially in the public sector, but still further integration, stabilisation and systematisation of demands (or orders) are required.

Serious investigation should be undertaken in order to introduce a long-term contract, competitive negotiation, and coordination of producers and constructors at the stage of designing into the prevailing ways of contracting in the public sector, which, at present, adopts the individual competitive bid system with building specifications made by the building owner. These problems are all concerned with the organisation of the building industry.

A 4

V. E. Jennings

Limits to industrialisation imposed by the nature of the building market

By V. E. Jennings (Australia)

The building industry and industrialisation

The building and civil engineering industry is taken to be that part of secondary industry concerned with providing fixed physical facilities, and it may be regarded as consisting of two principal groups, one concerned with the supply of materials and parts and represented by every type of production system, and the other mainly concerned with assembly and represented by the various professions, builders, trades and government administrators. The essential point about the first group is that primarily they service a number of common building requirements from fixed factory sites, while the second group apply their skills on a job by job basis.

With the assembly group, for a given income and size of organisation and degree of specialisation, an architect may need twice as much work as a builder, a structural engineer or a mechanical engineer may need 5 times as much, while an electrical engineer may need 10 times as much work. This inbalance of work load and variation in trade mix for individual buildings helps to explain the general independence of operation of the various assembly groups in fields other than detached housing and schools.

Generally, industrialisation implies making the best use of readily available resources, achieving the longest possible uninterrupted production runs, seeking repetition of effort and greater efficient adaption of industry to changes in market size. In terms of the building industry industrialisation will take at least four forms.

An increase in the proportion of work done by suppliers, since short production runs and high production friction (the number of non-factory type interruptions per work unit) is usual for site construction other than civil engineering.

The achievement of greater integration and industrialisation in the assembly group, so that it will be easier to identify responsibility and authority, and provide incentives for improving productivity in the building industry.

An increase in the acceptability of standard products and parts.

An increasingly accurate programming of markets in terms of location and time, with the aim of achieving a more efficient industry.

This in turn should lead to greater elasticity in the supply of buildings as the demand fluctuates.

Productivity

In the building industry in social fields such as housing, productivity is the appropriate criterion for judging the worth of industrialisation, since we require a maximum output for a given input of resources. In economic fields such as industrial and commercial building, return on investment is the appropriate criterion.

Because the building industry provides accommodation for functions which are only partly effected by building design, we are led, when comparing productivities, to consider the effect of increments of input (or changes in design) on output. The input C will be taken to be the annual building costs including interest, maintenance, depreciation and/or obsolescence, and depending upon the case, a fair apportionment of community service costs. The output V will be broadly taken as the net annual value added by activities accommodated by a building, and measured in monetary or nonmonetary terms, whichever is appropriate.

Thus, if a change in design increases C by dC, and there is a corresponding increase in V of dV, then the productivity of the facility will have been increased if $dV/dC > V/C$, i.e. if the proportional increase in value exceeds the proportional increase in costs. However, the corresponding investment criterion is $(dV - dC)/dI >$ (rate prevailing in other investments) where I is defined in terms of (capital × time) units. In this case because V and C are annual rates, I is taken as an averaged annual outlay. The investment criterion leads to lower acceptable productivities.

Typical measures of output and corresponding productivities are as follows:

Houses and flats:

Output: Number of persons housed to a satisfactory minimum design standard per annum plus as above, except that the houses are below standard and hence their number is multiplied by a reducing factor.

Productivity: Detached housing about 1.15 persons per £ 100 per annum. Four floor flats about 0.9 persons per £ 100. per annum.

Commercial buildings and factories:

Output: Net Value added per annum at the building.

Productivity: Offices about £ 1,000 per £ 100 per annum 10:1. Factories about £ 2,000 per £ 100 per annum – 20:1.

Therefore, despite an initial productivity of 10:1 a commercial client may justify a 15% increase in annual building charges by a possible 3% increase in output, with a corresponding productivity increment of 2:1. It is clear that rapid increases in the commercial and industrial sector of the building market will occur whenever there is an innovation in building design, such as air conditioning which can result in economically justified increased output.

Effective demand

Industrialisation is limited by effective market size and location. Effective demand E is dependent upon the degree to which building requirements are channeled into; making better use of existing buildings; making repairs and additions to existing buildings; or constructing new buildings. The relative size of these alternative channels will be dependent upon more or less mutually exclusive classes as follows –

$$E = D_v [D (R (F \times L))]$$

Where L = Classification of fixed facilities by location
F = Classification by function, for example, as shown in table 1
R = Requirements for facilities
D = Major demand factors i.e. user-producer—economic relationship
D_v = Variable demand factor.

Thus E will be composed of a group of elements each of which consists of a classification by region and function, and which will have attached to it a date and quantity dependent upon the influence of the various major and variable demand factors. For example, an element of E may be –

New type buildings (D_v.1) with government finance (D.4) which are replacement work (R.1) and are schools (F) in Melbourne (L), and to which we attach a date and quantity. The classification is analogous to the S.f.B. system.

R, D, and D_v are classified in more detail as follows:

R = Source of the general requirement for fixed physical facilities. This source falls into two categories.

R.1. *Replacement work.* This may be maintenance. Alternatively, it may result from the obsolescence of the location or of the design of a building, which are in turn dependent upon changing work patterns, rising standards of accommodation or improvements in design, it being noted that requirements are relative. Since buildings have a long life, the proportion of new buildings added to the building stock in any one year is quite small, being 3% for housing, 6.5% for factories. Hence a relatively small change in the pattern of use of existing buildings can have a large effect on building needs in any one year, and this is a cause of market instability.

R.2. *Additional facilities.* This may be due to population increases or movement, or changes in population characteristics. For example, the proportion of per capita disposable income may alter, or the rate of economic growth and/or productivity may change, or there may be an existing unsatisfied requirement for buildings.

D — *Major demand factors.* These essentially express relationships between the user, the producer, and the economy. The more easily goods may be transferred from the producer to the user, the larger the market for these goods will be. In our case there are at least five main sub-groups.

D.1. *User-developer relationships.* If these relationships are inappropriate, then user needs will be met less accurately, and because of lower occupancy ratios, more building may be required in order to meet them.

D.2. *Direct government intervention.* Where there is a shortage of accommodation, new building may be rationed to users, or with housing, finance may be manipulated to suit government policy.

D.3. *Economic factors* e.g. There may be changes in the proportion of national income devoted to investment and consumption, or in the relative costs of buildings and other articles. Changes in building regulations may alter costs.

D.4. *Financial factors.* Most buildings involve a relatively high capital investment, which may exceed annual income in the case of a commercial client or householder. Building sales are thus usually dependent upon the availability of long term finance, and this availability is thus a key factor in market stability. Demand is therefore effected by the nature and volume of finance available, the relative advantages of purchasing, leasing, renting or making do, and the degree to which there are restrictions on resale.

D.5. *The degree of uniqueness of the building requirement.* May result in difficulty in getting work done.

D_v Factors causing short-term variability of demand. Typical factors are:—

D_v.1. *The time* required to develop designs. This is dependent in turn upon the size of orders and the uniqueness of the requirement.

D_v.2. *The stability* of economic and lending conditions expressed in terms of the ratio of building cost to mortgage size, and the extent to which deferment of building activity is made necessary by changes in economic conditions.

D_v.3. *The existence or otherwise of a long term government policy* encouraging the replacement of old buildings or structures.

D_v.4. *Weather.*

D_v.5. *Resource limitations* such as skilled labour.

D_v.6. *Miscellaneous factors* such as legal and zoning matters and sudden stresses in the economy.

Modifying demand to suit industrialisation

Reducing fluctuations. Better utilization of resources and lower building costs are possible if there are smaller fluctuations in demand. Therefore, because of its influence on credit, which greatly affects demand, reduction in fluctuations should be a major aim of government.

Grouping of needs. Industrialisation of building is limited by the degree to which building requirement may be grouped.

However, in the life of a building, the requirements of a user will change. The alternatives available, therefore, are that the user moves as his requirements change, to be replaced by a user with the requirement; that the building is adapted to the changed requirements; or that the building is demolished when it becomes obsolete.

The first condition is practical if there is a general user requirement relatively constant, but independent of individual users. This is typical of housing where the life cycle of human requirements is fairly stable for a large group of people. Other examples are light storage type factory buildings, or public works and public buildings.

If, in addition, the requirement is standard and very large, then standard products such as houses, windows, doors, become possible. The greater the complexity and size of requirements per site, the more unique the building is likely to be — such as a town hall.

Table 1 gives an indication that the non-housing type building shows quite a wide variation in design requirements.

TABLE 1. Function classification

Main Function	Volume %	Std. Error %	Main Function	Volume %	Std. Error %
Detached Houses	33.3	3	Health	1.2	41
Multiple Unit Housing	5.8	9	Religious	0.7	47
Fixed Services to Houses	7.1	—	Entertainment and Recreation	0.6	—
Shops	2.9	12	Hotels, Motels, etc.	1.0	—
Offices	7.3	27	Alterations and Additions	7.7	—
Education	3.3	30	Non-household type Civ. Eng.	15.9	—
Factories Process Plants	11.3	33	Miscellaneous	1.9	—

The percentage standard error has been calculated by taking the total gross floor area of all building measured in an approximate but fairly representative sample (5% or more of the market). The unit for calculating frequency is the unit area 100 sq. ft., while the variate taken is the unit cost. Location of buildings is ignored. This measure gives an indication of the range of variation of building requirements, assuming that unit floor area costs will vary with requirements, while floor area is proportional to use.

Clearly, the easier it is for users to move as their requirements change, the more standardised may be the design of buildings, since one may design for a narrower range of requirements. Mobility of users is limited, however, by the transportation available, social and economic ties, location of places of education and work etc. Where social and other links are strong, one must design community areas within the limits imposed by these links if mobility is to be encouraged, for example urban communities or large industrial zones. Mobility is greater at certain ages (for example between school and marriage) than at other ages. Greater mobility is necessary with an increasing standard of living, since the needs become more diverse and increasingly psychological rather than physical in nature, otherwise building will become less standardised.

Grouping of uses both spatially and chronologically has firstly the advantage of rendering greater standardisation in design possible since this facilitates the movement of the user as his requirements change, and secondly in reducing transport costs. To some extent this occurs automatically, since urban regions are the best means yet found for distributing goods and resources of skill in relationship to fixed physical facilities. We have, for example, grouping of office building in business districts, factories in large industrial areas. We may consciously group uses, for example, in a city, one parking garage for a number of buildings makes design for each of the buildings more standard than if each of the buildings had its own parking. Similarly, with various special uses in multiple unit housing, or in the consolidation of small land holdings into larger. In the latter case, government support may be necessary.

From table 2, we note that the majority of buildings are small with short production runs, so that grouping is important for greater efficiency in production.

A building may be adapted to suit changing requirements. The requirement may be divided into stable and variable aspects, in which case one may design separately for each. For example, the administration and ablution area and some classrooms of a school may be designed for permanency, and the remainder may consist of portable classrooms, which can be removed when a short term requirement has ceased. Another example is a caravan park. In the case of a factory, one may have sufficient land for horizontal extensions. An advantage of detached housing is that one can easily extend them, allow for later addition of garages and storage so that the initial product can be highly standardised. One may also adapt buildings by re-decorating or altering the furniture layout. Multi-storey construction is least suited to adaption.

The third alternative is demolition, or drastic modification to the building when the user requirement changes. This may apply in process plants such as oil refineries or some roads. Where buildings are designed to accommodate a technological function, then because of the rapid changes taking place in technology we can expect increased obsolescence. In urban location, demolition may be caused by such factors as road relocation, or more generally obsolescence of location.

TABLE 2.

	$\overline{X_1}$	Q_1	Q_2	Q_3	$\overline{X_3}$
Houses – by rooms* (Census data) (Total number existing)	4.1	4.4	4.8	5.6	6.6
Schools by value of work (Company data) (For the year) in £'000s	2.3	3.1	4.8	20.6	51
Factories – by employees (Census data) (All existing factories)	-	3.5	6.4	10	127

* number of rooms excluding bathroom and laundry

Where $\overline{X_1}$ — mean value of sizes in lowest quarter of sample
$\overline{X_3}$ — mean value of sizes in highest quarter of sample
Q_1 — Lower quartile, Q_2 — median, Q_3 – upper quartile

Transport is a critical factor in building costs because of low cost densities (Cost/unit volume) of assembled buildings, and low cost/unit weight of materials particularly traditional materials. For example, a house has one-tenth the cost density of an automobile, and consequently its transport rating (the distance one can transport an article for a given proportion of its price) is less than one-tenth that of the automobile. Traditional materials are cheapest, but their transport ratings, and hence, area of economic haulage, is lowest, so that they are normally manufactured close to urban concentrations or building sites, while very low density building areas are best served by higher cost density materials or components. Civil engineering projects have often such large volumes of materials that it is economic to set up mobile or fixed factories at the construction site.

Adaptability to market variation

The assembly side of the building industry is trade based and because of the period necessary for training of tradesmen it cannot easily adjust to peak demand requirements. However, assuming a reasonably stable industry there are at least three ways of increasing adaptability: -

- by building more skills into machines, since it is much speedier to train process workers than tradesmen for peak demands;
- to subdivide the skills of a tradesman and take the responsibility for retraining when a tradesman changes his job; for example when a carpenter wants to change from fixing-out to concrete formwork; providing tradesman with technician assistants;
- more standardised products.

Conclusion. Better detailed measures of building demand are necessary if building markets are to be anticipated and stabilised. More knowledge is necessary of the nature and stability of user requirements, if we are to rationally determine the degree to which they may be grouped for the purposes of industrialisation. The rationale is either productivity or return on investment. The industry needs to acquire greater ability to adapt to changing market requirements. If the market remains stable, and an orderly programme is devised for rationalizing the control systems over the industry, we can expect greater integration to take place within the assembly group and with the supply group. Because so much of the industry is subject to governmental control, government must take the leadership with respect to research and control simplification.

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Financial planning model as a means to the continuous production of blocks of flats

By M. Kjeldsen (Denmark)

In April 1964 a seminar was held in Prague by the United Nation's Housing Committee to study the alterations in the structure of the building trades resulting from the commencing industralisation of the latter. In connection with a discussion of the technical development of house building M. Blachère, the French discussant, put forth the interesting theory that advances in the industrialisation of house building are practically everywhere the result of an initiative on the part of public authorities. According to this speaker's views the nature of this initiative might vary, but among the conditions particularly necessary he mentioned the creation of market conditions which allowed for the development of new production methods.

A comparison of the technical development in the different European countries will show that the industrialisation of the building trades has indisputably progressed farthest in the countries where the value of long-term planning has been realized and where it has been politically possible to carry through such planning, without which industrialisation is not possible.

Unfortunately the pioneers of industrialisation have not worked under equally good conditions in all countries. It has been necessary, for instance, in many places – either on account of lack of understanding or lack of political possibilities – to plan a beginning industrial production on the basis of building programmes laid down for one year at a time! Such were, for instance, the conditions in Denmark up to 1960. Up to 1958 practically all blocks of flats were built by social building societies on the basis of a system of government loans which was administered by the Minister of Housing.

In 1958 certain alterations were introduced with regard to the financing of house building, which i.a. resulted in an increase in the share of the building activity on the part of private building owners, but, irrespective of financing conditions and type of building owner, building schemes had to be planned for one year at a time, because the administrative powers of the Ministry of Housing did not reach any further. When, in spite of these quite unreasonable conditions, a readjustment of the building process has nevertheless been successfully commenced, this is due to capable and far-seeing technicians and contractors and, probably not least, to the collaboration between these two economically independent parties – a collaboration which is an unknown phenomenon in most other countries.

Finally, in 1960, the first hesitating steps were taken on the part of the government to provide a basis for long-term planning within the building industry. As a modest start a financial basis was secured which made it possible to start the building of about 2000 dwellings a year for four years, so that altogether this long-term plan comprised the building of 7500 flats. These 2000 flats correspond to about 6 per cent of the total annual production of dwellings, or about 13 per cent of the annual production of rented housing. The object of the establishment of this quota and of the conditions which had to be fulfilled to allow for its application to a building schema will appear most clearly from the special circular issued by the Ministry of Housing. The introduction to this circular runs as follows:

"The object is to increase the building capacity and to attempt to reduce the costs. It is endeavoured to obtain these aims by planning the buildings from the start with a view to the application to the greatest possible extent of pre-fabricated components in order thereby to obtain maximum economy of labour and materials and on the whole to obtain maximum productivity. Production of this type will enable a greater use of machines to supplement and increase the effectivity of the labour force available and will make it possible to utilize the productive apparatus throughout all seasons. It is emphasized that the aim is to obtain an increase in the productivity of all trades, a more comprehensive aim than that of facilitating the use of non-traditional building methods in which the emphasis has hitherto been laid on the use of constructions other than ordinary brickwork construction".

However modest such a plan for the building of about 8000 dwellings over a four-year period might seem viewed from outside Denmark, the parties to building were here for the first time granted the opportunity to plan for a period of some duration, as in this case a number of dwellings which was considerable according to Danish conditions was released for building over a period of several years, irrespective of the political and economical development throughout the period. The idea behind this arrangement was not primarily to effect the building of 7500 dwellings, but to create possibilities for the development of new productive apparatus or for improvements in the utilisation of the existing apparatus. Since a number of smaller building schemes would not be able to serve as the basis for manufacture on an industrial scale of individual building components, the circular particularly emphasises that

"the individual building schemes should be comprised by the same production programme so that components used for each individual scheme may be part of an aggregate production for a greater number of dwellings. To make this possible it is necessary that the building owners cooperate with a view to coordination and adaptation of the individual projects within the period concerned to the extent to which it will be necessary for production-technical reasons."

In the summer of 1960 the first of these schemes was started:

The Ballerup scheme	comprising about 1700 flats.
The Gladsaxe scheme	comprising about 1900 flats.
The Albertslund scheme	comprising about 1500 dwellings.
The South Jutland scheme	comprising about 1800 flats.

These four building projects have already contributed considerably towards the development of the building industry in Denmark, both directly through the training of the operatives who are taking part in the work and indirectly through the results which have been obtained in connection with these building schemes, from technical as well as economical points of view.

It is a common feature of these four schemes that right from the very start of the planning it has been endeavoured – in agreement with the wording of the circular – to apply prefabricated components to the greatest possible extent; but otherwise the building schemes differ considerably, as will appear from the following brief survey of their characteristics:

The Ballerup Scheme consists exclusively of four-storey blocks. In addition to the use of prefabrication it has been an important object during the planning to determine component dimensions which at the same time were suitable for industrial production and gave a considerable freedom with regard to the plan of the dwelling. The blocks are planned on the basis of a modular grid with a distance between the grid lines of 30 cm in the longitudinal direction of the building and of 120 cm across the building. All floor components are 120 cm wide, while wall components are available in two widths, 120 cm and 180 cm, respectively. On the basis of these components not less than 26 different types of flats have been planned. The fronts of the houses as well as bearing walls and floors are constructed from prefabricated components, the fronts of components consisting of timber frames covered on the outside with asbestos-cement.

The Gladsaxe Scheme differs from the Ballerup scheme in that it consists of multi-storey houses, the majority of the 1900 flats being situated in 16-storey blocks, the principles of construction being the same, however. Also in the case of these blocks all bearing structures consist of prefabricated components, the necessary rigidity being obtained by means of pre-stressed reinforcement in the joints at right angles to the longitudinal direction of the building.

The South Jutland Scheme differs especially with regard to building owners from the other schemes. This scheme, which comprises about 1800 flats, is, as the above-mentioned, built by social housing societies, but the buildings are distributed over a larger area and over altogether five towns within an area of 80 by 80 km. Considerable efforts towards coordination are thus required from the building owners. This scheme serves to show that smaller towns whose building programmes are not sufficiently large to constitute productive units may also benefit by industrialisation and mass production. For this scheme electronic data processing has moreover been applied extensively in connection

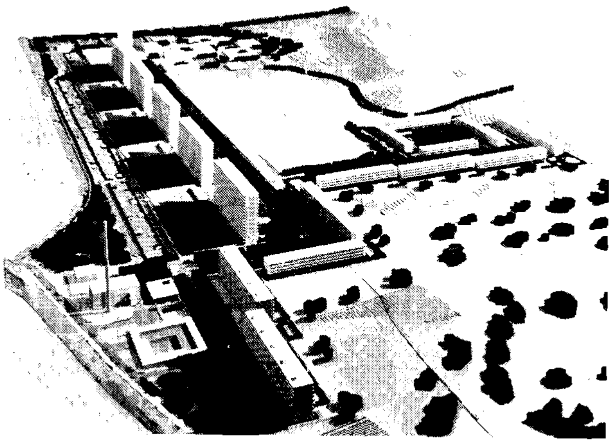

Fig. 1. The Gladsaxe scheme, one of the housing projects mentioned in this paper. The 1900 dwelling units are erected over a period from 1963–66, for which period a scheme of financing with continuous investment has been guaranteed by the state.

with a descriptive bill of quantities (refer the contribution by Bjørn Bindslev: Data processing as a key to overall communication and feed-back. Group C).

The Albertslund Scheme consists, unlike the above-mentioned schemes, exclusively of one- and two-storey houses, viz. about 1000 atrium houses and about 500 two-storey terrace houses. This scheme represents a first attempt to utilize prefabricated components also for the building of one- and two-storey dwellings. Not only outer walls, roof structures, fixtures, etc., but also the foundations are prefabricated. Mention should especially be made of the close cooperation which, with regard to this scheme, has taken place between the town-planners and those responsible for the architectural and technical aspects of this building project.

Results and experience gained

One of the chief objects of this aggregate plan of 7500 flats was, as already mentioned, to create a basis for the establishment of a permanent industrial production apparatus. It was a requirement to the production that individual components should possess "general applicability" and should be of modular dimensions, so as to enable their application in other building schemes. Among the permanent productions which have been established on the basis of the described schemes mention may be made of two factories which produce concrete components, one situated in Sjœlland and the other in Jylland. The former, which is the most highly mechanized factory for concrete components in this country, produces exclusively floor and wall components for dwelling houses. The latter has hitherto produced floor components only. In addition a highly rationalised factory for light components for outer walls has been established in Fyn. At the moment these three factories produce exclusively for the above-mentioned building schemes, but later on they will be able to supply material for other building schemes. Moreover, manufacture on a smaller scale of kitchen components, light partitions, roof components, etc. has been commenced.

Another of the objects was a reduction of the amount of labour required and of the duration of the building time. With regard to the Ballerup and Gladsaxe schemes the following surveys of man-hours and building times are available:

For a flat with a gross area of 90 sq.m altogether 950 man-hours or 10.6 hours per sq.m were spent; out of these 510 hours were spent on site and 450 hours in the factories and workshops which supply components, man-hours required for transport purposes being included. Man-hours spent in the manufacture of parts which are traditionally supplied in finished condition, for instance radiators, have not been included in the survey.

The duration of the building time has been reckoned from the time when earth works and basement construction were completed and until the time when the first tenant moved in.

For a normal block of the Ballerup scheme of four storeys and 48 flats the building time from the completion of foundations to the completion of the whole block so as to be ready for occupation was 77 working days 3½ months.

In the case of the Gladsaxe scheme the building time for a block containing 130 flats in 9 storeys was 6 months from the time when the erection of components started until the first tenant moved in.

For an evaluation of these numerical data it is important to bear in mind that the results obtained are due not only to the extensive use of prefabricated components and mechanized production methods, but at least equally much to the preceding planning of the course of the operation throughout all of its stages: production, deliveries, erection, finishing processes and occupation. In the building schemes mentioned here the building time was subdivided in 4-hour periods, and the operations which were to take place in each individual 4-hour period were determined in detail. It cannot be emphasized too strongly that satisfactory results are obtained only after thorough planning down to the smallest details.

As regards the duration of this four-year plan experience has shown it to be too short, and that it is impossible in the course of such a period to reap the full economic benefit from industrialisation. This plan, according to which the building of 7500 dwellings was commenced in the course of a four-year period, was succeeded by another plan comprising 9000 dwellings to be started throughout a period of three years. As a result of this it has been possible to continue the Ballerup scheme, extending it by another 2000 dwellings. In addition to the above-mentioned great savings with regard to building time and labour, this direct continuation of the scheme has ensured such an economy that the cost of the second section of the Ballerup scheme has been found to be lower than that of the first section. Also in connection with the planning and construction of other larger schemes experience has shown that it is necessary to be able to plan for a longer period than 3–4 years, and that a period of at least 5—6 years from the commencement of the planning to the start of the last section of the scheme is necessary to ensure continuity as regards production, planning and construction. This results in a total duration of an individual schema of about 8 years from the start of the planning and until the last tenant has moved in.

Towards industrialised building in rural areas

By R. Koiransky (France)

General changes in the market

The evolution of French agriculture advances steadily. It is now possible to imagine a general picture of what it will be like around let us say 1970. The Association pour l'Encouragement à la Productivité, founded especially by those branches of industry (machinery, chemicals, cattle foods etc.) keenly interested in development, to promote and watch over this evolution, discovered a few years ago that housing will rapidly become one of the most important problems to be solved, despite the fact that the total number of farms will decrease by between 50/60%, to a total of about 800.000.

In brief, its studies show that this need for new dwellings will appear as both a result of and a cause for this evolution:

- Evolution of general space planning, with development of some boroughs, will bring a new type of rural life, involving a new style of relations between town and country;
- development of industry, trade and tourism in the country will alter the ideas of the rural population;
- evolution of land management, with gathering of small units into bigger ones will bring the need for a new localization of dwellings;
- dwellings of decent comfort standard will be the condition of skilled workers for remaining in agriculture;
- increase of output will partly provide the necessary assets for building these dwellings;
- this will occur in the period when old farmers will be replaced as farm managers by exacting younger ones.

It will be necessary, then, to build rapidly these new dwellings of a better comfort standard.

Meanwhile, the total output of traditional building will diminish, due to workers leaving the building sites to work in the new factories. The cost of such building will rise in comparison with new methods of industrialisation, so that traditional building methods no longer provide an answer to the problem.

Such inequality could have very severe results, both on social and economic grounds. APEP tried to bring the attention of house-builders to this point, but the contractors were too much occupied with major schemes to be undertaken in urban regions to invest money in difficult and perhaps unsuccessful studies.

Two large forward-looking firms, les Ciments Lafarge and la Compagnie de St. Gobain, in an attempt to solve the problem, approached APEP with the idea of forming a non-profit making organisation: the Comité pour l'Etude et la Promotion de l'Habitat Rural (CEPHR), having as its object the study of new solutions, and ways of putting them into practice.

Inquiry about the new needs and their consequences

It was first necessary to get a more accurate conception of the needs and wishes of the farmers themselves, since successful industrialisation is only possible if the consumer is finally satisfied. It was necessary to know how the farmers of 1970 viewed their own dwelling problems in 1960.

Accordingly a complex inquiry was organised in such a way as to show how farmers of the 1960's, still living in the conditions of 1935, would organize their own living in 1975. Not all farmers were able to answer the inquiry, but groups of young and skilled farmers, together with the consultant architect of CEPHR (not himself a specialist in agriculture), through "brain-storming" sessions with plans and models, were encouraged to express their own wishes (often subconscious) and ideas. Some ideas appeared to be rather far removed from actual dwellings, but were related to them, as for example, schooling or shopping.

General trends were discovered:

The general features of this 1970/75 farmer's house will be:

- greater area than in town, especially for kitchen and living room;
- two entrances, one a "dirty" one with simple shower, boot cleaning and dirty clothes space;
- bathroom with shower, but space for a bath to be put in later;
- an office and small visitors-room with separate entrance;
- large store-room;
- large garage for two cars;
- possibilities of change and enlargement.

Young farmers have no prejudice against modern solutions. They feel they are (or will be) quite responsible and skilled managers, and definitely refuse "cheap" dwellings. They are ready to pay for it (as far as they can). It will be a house of a standard rather higher than the one currently admitted today, but it must be built for a price not too much exceeding what is already paid for houses of today. This is only possible if large-scale programmes are undertaken, and because of the decreasing number of farms this cannot be expected from agriculture alone. Assuming that half the 800,000 existing farm dwellings are unsatisfactory, the majority of these can be improved. Therefore we can expect a maximum of only 100,000 new dwellings, spread over several years, and over the whole country. Because of the necessity of making available a choice between at least two types of houses, and two building processes, it can be estimated that the maximum output for one builder would be 300 houses a year, which is economically insufficient. Moreover these figures are theoretical maxima, and are likely to be less in practice.

In fact, as regards building, there is no difference between a house for a farmer and a house for, let us say, a signal-man. So the same technical building processes can be used for both of them, as far as they can be adapted to different plans. It must also be possible to obtain agreement from the different interested Public Offices both from the financial point of view as well as from that of standards.

The solution therefore lies not in prefabricated houses, but in the use of elements in variety, which could be fitted with different internal equipment, and which would cause no difficulty in rural areas during transportation and assembly, capable, if necessary, of being erected by local contractors without skilled labour, and without heavy trucks and cranes. If these conditions could be fulfilled, rural building problems would be solved. As the house for farmers seems to be of a higher standard than the others, a solution for it could fit in with the general needs. How could this solution be obtained?

Searching for the good building processes

Up till now, the problem has been considered in technical and economical terms. In the long run, these terms will be the most efficient. But now, and for a long time, nothing can be done without Government control and financial aid, the rules of which have sometimes more influence than technical and economical needs. It is necessary to abide by these rules or to get them changed. As far as farm dwellings are concerned it appears necessary:

- to enlarge the present limitations on area, and to narrow down some technical specifications,
- to produce cost reductions within the limits of financial aid granted by using large building programmes.

It is not yet possible, due to the market not being free, to produce this second requirement in the normal way.

It was decided to offer proof that larger and better dwellings could be built according to these financial rules. Experiment was then necessary, from the result of which could be calculated the cost level which could be expected after a sufficient opening of the market. The experiment chosen was to build one unit through an already existing system.

The choice of the process to be used was done theoretically, from the list of agréments delivered by the Centre Scientifique et Technique du Bâtiment. But there was a stumbling block: as this first unit had to be an experiment, it was necessary to obtain the cooperation of the builder, both for this special unit, as for later adaptions that would be needed. Not only the process had to be a good one, but, more important, the builder had to be "forward looking" and able to understand the profit of working to-day for a long term benefit. It was then decided to start a competition. The quality of the process would be appreciated from the documents submitted.

The competition was limited to the dwelling unit, garage and store-room not included. It was thought that these parts of the building could be included in "adaption to the ground" which seemingly ought to remain in the field of traditional building.

As for the adaptation to various plans, it was decided to give to the competitors a theoretical plan drawn by the consultant architect and to see if the proposed building methods could follow it without great differences. The technical qualities were judged from technical documents included.

The result was not very satisfactory. Although the competition was largely advertised, only some 50 builders sent a proposal. Among them, one third was struck out as too far from the plan or lacking of basis. One third was not admitted as not able to answer the needs: too heavy elements, too low quality,... 15 methods were accepted for a second step, as it was necessary to have a field as large as possible. Among these 15 methods, there was one based on expanded clay ready mixed concrete laid in situ into normalised forms, all the others were prefabrication, generally with concrete, two or three with wood, one with metal.

All methods were based on closed systems.

Architects enter the competition

All these methods had already been successfully used. So it was certain that the scheme would not fail on a technical difficulty. It was necessary to continue, however, since it was imperative to obtain a relaxation in the limitations laid down for area. According to law, the whole scheme had to be approved by the government, and the plan, whether for a single unit or as a type plan, had to be drawn up by an architect. Since farmers could not be expected to pay separately for architect's designs, the second solution was required. A type plan, however, had to observe the regulations at present in force. It would only be possible to circumvent the regulations if the type plan was among the best submitted.

Accordingly an architectural competition was started, one of the specifications being that one of the selected systems must be used in the design. This stipulation was strongly opposed on the grounds that it limited the architect's freedom of design, but previous experiments had already shown that without this limitation the result would be that builders would refuse to apply the system chosen by the architect on the grounds that the market was unknown to them. Although this stipulation resulted in some well established architects refusing to enter the competition, many young architects sent in designs, some thirty in all.

A jury composed of architects and officers from ministeries of Agriculture and of Housing selected five schemes, paying little attention to costs involved, since it was for experimental purposes.

Before publishing the results of the competition, a meeting was organized with competitors and members of the committee. The problem was largely discussed and it appeared that the trend towards industrialisation of rural dwelling was perfectly admitted by some architects, but that many points were still to be solved, especially as far as the part played by them is concerned (cf infra).

Different trends could be found. Some plans were very classical, with a square house. Others, rather new, showed an "exploded" house, night and day areas quite separated, the "technical block" (washroom, kitchen....) being the junction part. In every case, future extension was foreseen.

5 plans were selected, in such a way that these different trends could be utilized in one house. First prize went to M. Thellier, architect at Montpellier, whose scheme was based upon a brick and concrete process: Veran Costamagna. The cost for it is roughly estimated at a level very near the current one. Most of the other industrialised systems were more expensive than traditional building, as was to be expected. The difference is not, however, great enough to continue over a long period.

From the prototype to the large market: problems to be solved

It is thought that thus can be solved the question of planning and building for one house. But industry cannot think of each customer as a single case. Industry does not sell before making, it makes before selling. A sale's promotion campaign must be planned.

This is not too difficult when building cities or "grands ensembles", as there is but one customer for hundreds or thousands of dwellings; it becomes the main problem in rural housing, as there must be one contract for each house. Besides, making the elements and erecting them are quite different: the first one takes place in one plant, according to fitted planning and programme, independent of weather conditions; the second takes place on many sites, according to variable demand (and moreover "breakable" demand, as the customer is lost as soon as satisfied) and with concentration during the fine season. These oppositions between demand and production can be solved only with a market organization able to attack the many problems to be solved.

First of all, finance. It is not the same for the manufacturer and for the customer, and an aid from government brings another difficulty. In traditional building, the builder begins to work, that is to buy cement, to pay workers, and so on, when the customer has already found credit, and payments are made according to the speed of the work. Industrialisation means on the contrary that the manufacturer must make a big investment, not only in machinery and tools, but also in ready elements waiting for an order before knowing the customer. What about help from government? Must it be aid for the customer, or aid for the house, already half built? Must it be aid for the single house, including specific expenses for ground, water, power, and gas piping? Or aid for the type, for which an agreement could be given once, and which would make study of the scheme easier? Or must there be two forms of help?

Law

One point that emerges from the study is the fact that at the present moment technique must be adapted to laws and regulations in force. Would it not be more efficient to adapt the laws and regulations to modern techniques of tomorrow? In France we see that new methods of building, including new approaches to technical, financial and other matters, can be approached only by the way of existing laws, with the result that, even if the new process is cheaper in itself, the building is more expensive than traditional building. The same thing must occur in every country in which special financial conditions depend on following technical specifications.

Trade structure and organization

It is not possible to buy a house in the same way as a car. You buy a car in the stores of the seller, it is yours, and you may and can use it at once. Buying a house to be built is to buy a plan, to buy elements of the house, to buy the work of erecting them.

Nowadays, plan, elements and erecting are sold by different persons. Generally speaking, the customer asks the author of the plan to choose, order and control the man responsible for erecting, and this one buys the elements. What happens with industrialisation? Plans are already made. An author for the plan is not necessary except for the ground adaptation and the control of erecting. Furthermore, the parts of elements and erecting work in the total worth of the house bring the greater responsibility upon the manufacturer of the elements. So that it appears that the general scheme of today is not fitted for industrialised methods. Is any other scheme possible?

We see at once that the role of the architect will change. On the one hand he will plan the element, for which the manufacturer will be his customer (and the payer). The architect's role will be both that of designer and supervisor.

We can see too that the contract between the manufacturer and the "contractor" must be different to what it is now, whether the contractor buys one house from the maker and erects it under his own responsibility, or the maker asks a contractor to erect it and remains responsible as far as the final owner is concerned. As industrialised systems need from the contractor a perfect knowledge of them, the second way would seemingly result in more efficiency. Are we going towards a market organization with agents for manufacturers, as we see it now in the car industry? It probably will be so, as industry needs very tight cooperation between manufacture and selling.

It is not possible in such a short note to enlist, moreover to treat, all the questions involved with industrialisation of rural housing, as the very point is that it will bring such large changes in the market that it is practically impossible to definitely forsee them. Experiments have been done in other countries, according to different schemes adapted to particular uses and ways. The problem is not the same in countries with different political and economical systems, according to whatever kind of efficiency is thought better. What seems important to the authors of this paper is that efficiency means being able to give to the family inhabiting the house something fitting in with their needs and wishes as far as possible. Is this not, in fact, the true aim of all building?

Future contracting systems

By L. Ranhem (Sweden)

The forms of co-operation between client, professional advisers of various kinds and contractors have been keenly debated in many countries during the last few years. The background is the structural changes in the construction industry which, in this connection, concern not only the building companies, but the whole chain of activities: design, construction, production of materials and building. The structural changes have meant increased use of pre-fabricated and standardised products—which in turn has made assembly work the most dominating activity on the building site— and increased mechanisation. These changes are the expression of a continuous industrialisation process.

It is of great importance to all those who take part in the creation of a building and who are thus responsible for the result, to find such forms of co-operation that the most favourable result is obtained, to the client and, consequently, also to the society.

In this paper the demands on suitable contracting systems for house building will be dealt with and a few lines of development described.

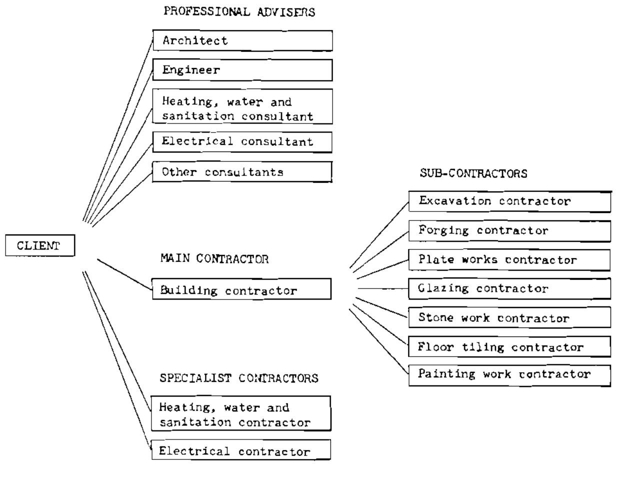

Fig. 1. Split contract

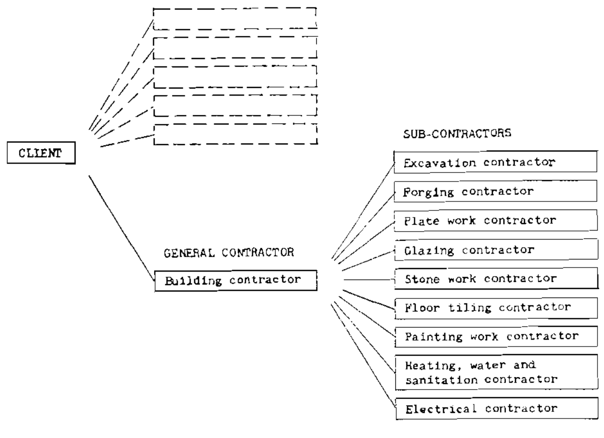

Fig. 2. General contract

Contracting systems

In this connection the contracting system implies the manner in which the contractor is engaged in the project. With regard to the mode of payment distinction is made between firm price contracts and cost plus percentage contracts. A number of intermediate forms exist. The contracting system may also be regarded as a form of co-ordination of the activities of the client, the various professional advisers and the contractors. From that point of view distinction is made between split contracts, general contracts and package deals. Besides the proper building work the general contracts also comprise heating, water, sanitation and electrical installations etc. The package deal comprises design and construction as well. Distinction between various contracting systems may also be made on the basis of the tendering procedure used: open or selective tendering, public opening of tenders, "licitation" (the Danish type of procedure) etc.

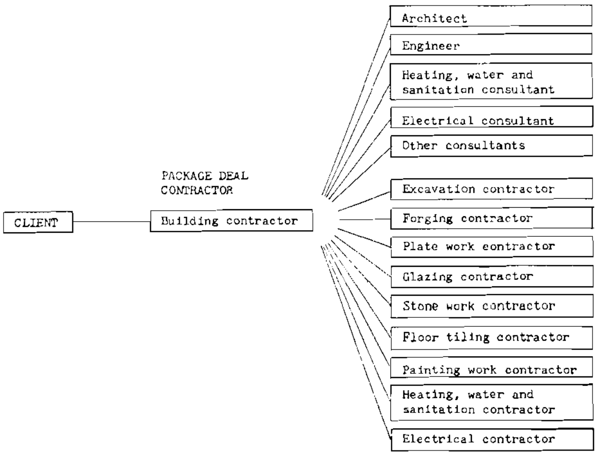

Fig. 3. Package deal.

Demands on the contracting system

Different types of work place different demands on the contracting system. In this paper the matter will be dealt with from the house building point of view, mainly the construction of dwellings, offices and other commercial buildings, industrial buildings and schools.

The contracting system must be instrumental in creating a final product of high quality. The client wants to have the building which—with regard to function, operation economy and price—is the most advantageous. In the long run this coincides with the interests of society, i.e. that maximum benefit is derived from the total productive resources available.

Below, the contracting system will be dealt with from this point of view which also means that it will have to be adapted to the requirements connected with industrialised building. The fundamental feature of industrial activities is *repetition*, the economy of large series. This has been the most important cause of the rise in our standard of living. Repetition gives lower fixed costs per unit, it gives a time-and cost-saving running-in-effect and it offers a more favourable basis for rationalisation. However, by tradition the various activities connected with the execution of a building project are split up amongst a number of independent persons or companies: client, professional advisers of various kinds, contractors, suppliers and producers of material. *Co-ordination* and *detailed planning* are necessary to achieve the benefit of the economy of large series. Repetition and co-ordination give the basis for increased efforts as regards product development —plans, design and construction of the building—as well as development of building methods. If, furthermore, the recognized demand for competition is taken into account an appropriate contracting system should thus offer possibilities of:

- competition
- repetition
- co-ordination and planning.

Competition is of vital importance for economic progress. Competition is the basis of and the most important motive for the entire contracting business. Competition may find various expressions. Price and quality are the most important competitive factors. The competitive factor may be present even if it is not a question of competing for an individual object, but of performing a good job at a low price in order to be remembered in the future.

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L. Ranhem

At the start of the actual building work – i.e. the production on the building site – building costs are more or less fixed. The competitive tenders submitted by the contractors can only to a very small extent influence the total final cost. On the whole, it has already been determined by the design given to the building by the architect and the engineer. The problem is therefore: How to create contracting systems according to which competition will be stimulated for the design of the building and not only for the production? The client is interested in obtaining a solution – covering the whole project – which is as cheap and good as possible.

Competition regarding the design of a building means, quite naturally, that more than one person is working with the same project, i.e. a duplication of work whch may seem uneconomical. Thus, if such a development shall be justified from the point of view of national economy, the advantages of competition must counterbalance the increased costs of tendering.

The demand for planning and co-ordination of the entire building process is a result of the above mentioned structural changes as well as a prerequisite for the continued development towards increased industrialisation. Industrialisation is an effort to develop efficient methods of production by repeating operations in factories, in drawing offices and on building sites and by co-ordinating various activities within and between companies.

The work of the architect, the engineer and the contractor must be co-ordinated. The design of the building must admit of good plans and make economical construction of frame, finishing work and installations as well as efficient methods of production possible. Likewise, construction must be adapted to design and method of production etc. Thus, it is not a matter of onesided adaption of e.g. design and construction to modern methods of production, but a mutual dependence and a continual exchange of experience. This co-ordination becomes really important in connection with industrialised building, particularly in the case of serial production. Serial production also makes long-term planning necessary. If such planning shall be of value, it must be based on a higher degree of certainty of judgment than is generally attainable on the heterogenic contracting market today. The market is geographically split up and the demand is more or less concentrated on individually designed projects which are to be started immediately and completed in the shortest possible time. A prerequisite for large series and long-term planning is, therefore, that the demand is limited to fewer variations and that the invitations for tenders cover longer periods. If this is attainable, it will be possible for the companies – by further concentration on certain types of buildings and on certain geographically limited markets – to create continuity and stability in building activities.

Lines of development

It may be said that the contracting system must be adapted to the continued building industrialisation. The extremes of this process of adaptation are represented, on one hand, by the package deal – in which case design, construction and production are co-ordinated by the 'package deal contractor', who is often the building contractor and on the other hand by a contract which is still more split than the traditional one, in which case the client is responsible for the integration of design, construction and production.

The package deal implies that the contractor – for the account of the client – undertakes to design, construct and produce a building at a firm price and within a fixed time of delivery. The basis for the tender are the requirements regarding function, layout and standards stipulated by the client in the building programme. Thus, the contractor assumes the entire responsibility in relation to the client. Design, construction and production are adapted to one another in order to attain the most advantageous general solution. Thus, in comparison with the traditional, split contract, a more favourable basis for a solution, which gives the client the most advantageous general result, is created. This is achieved by a proper balancing of the requirements of design, construction and production. In the traditional split contract, these activities are often regarded too isolatedly and are separately made the object of the most favourable solution which, as a rule, is not the same as the most favourable general result. The fact that the building companies develop building systems means that the constructional and productive solutions are repeated and developed from one object to the other. The package deal makes competition between such building systems possible which ought to be of great advantage in the house building field. The companies develop a variety of plans and types of flats which make various combinations easily obtainable according to the prerequisites and requirements in the actual case. The knowledge of the specialists is better used. It is possible to invest more on constructional and development work, since the costs can be spread over a large number of objects. The design and construction work in connection with the tendering procedure thus becomes more simple.

The nature of the design work carried out by the architect will also undergo changes. Today, it is to a great extent concentrated on the individual object. Tomorrow, it will be more for the design of series of objects. Plans and types of flats will be worked out which will subsequently be repeated in various combinations.

Another consequence of this development is that building methods, materials and detailed design will be carefully tested before serial production is started, simply because the effects of a wrong choice would be considerable.

It will be possible for the contractor to give the client an idea of design and quality by referring in his tender to previous works. What has been said above thus implies that the design, construction and planning work for the individual object is reduced. Furthermore, since part of this work may be done after the building work has been started, it should be possible to reduce the building time from programme to completion.

A client carrying out extensive and continuous building activities may solve the problems of co-ordination and planning by integrating design, construction and production himself. The volume of his building work must be large enough to secure continuity and production in large series. It will then be possible to place long term orders for materials and pre-fabricated components and to make separate arrangements regarding assembly work, fittings and various installations. This procedure entails a further splitting-up as compared with the traditional, split contract. The competition between suppliers and specialist contractors is maintained, but the competition between different general solutions – made possible by the package deal – is lost.

For "tailor-made" buildings, such as certain industrial, office and commercial buildings, comprehensive design and construction work is required already in connection with the tendering procedure, if the package deal procedure is to be used. In some cases the package deal competition may still give the most favourable result. In other cases it is more advantageous for the client to select one contractor only and negotiate a package deal with him on the basis of earlier merits or use the traditional contracting system. An intermediate form between the general contract and the package deal – called e.g. general contract based on early selection – might also be possible. The competition regarding the individual object would be maintained and the disadvantages of extensive tendering work would be reduced. The demands for co-ordination, planning and competition would be met. The procedure may briefly be described as follows: The client himself or with the assistance of his professional advisers prepares the project until the "functional design" is ready, i.e. until plans, layout and demands on quality have been decided upon. At this stage tenders are invited, which will thus comprise construction and production. Drawings, e.g. on the scale 1 : 100, and specifications regarding quality, materials and workmanship are used as a basis for the tenders. In certain cases it would probably be rather difficult to select sub-contractors at this early stage; therefore, this will have to be done later in consultation between the client and the general contractor appointed. This system makes it possible for the contractor to co-ordinate construction and production. The possibilities of planning purchases and production will be better than in the case of the traditional, split contract. This form of contracting will probably be most suited for certain types of industrial, office and commercial buildings.

The package deal, which comprises the "functional design" of a building and which means that the client is offered a finished product, developed and designed within one and the same company, would probably not be suitable in the case of schools, hospitals and other buildings with complicated functions. The above mentioned intermediate form between the general contract and the package deal might then be a suitable alternative.

General contracts based on early selection means that the contractor's undertaking is not limited to production alone but that it does also comprise construction. Increased responsibility is thereby placed on the contractor. To a still greater extent this is the case with regard to package deals where the functions of the building may also be included in his task. The contractor then assumes responsibility not only for production and construction; he is also responsible for the proper functioning of sound insulation, heating and heat insulation etc. The willingness and the resources of the contractor to assume this responsibility will probably be decisive for the development of the contracting systems mentioned.

The responsibility and possibilities of the investor in the development of building

By N. Salicath (Denmark)

Different types of investor

The position of the investor and his influence on the building process varies very much according to the different types of investors. The individual person who builds a house for himself maybe only once in his life, and the big organizations building annually homes by hundreds or thousands are the two extremes with numerous variations between. The following paper deals with the bigger investors working on a continuous basis.

The key-position of the investor

Under the usual organization within building, the investor starts the whole process and influences its course in many respects. In most other industries production is normally carried out irrespective of the individual client and the products are sold after the completion of the production process. In building, however, production is normally not started until the client gives his order and his individual specifications are the basis of the whole production.

Thus, the investor holds a key-position being both the starting point and the end point of production. The developing industrialization within building may in different respects change the character of his influence but his position will still enable him to play a decisive role affecting the trend of development. In many countries, however, the investors do not themselves sufficiently realize their possibilities and have not established the organizational basis which is necessary both to support and profit by development.

Co-operation between the investors

The role of the investor is most clearly recognized with regard *to the individual project* where his decisions will to a large extent be decisive for the work of all the other parties involved in the building process. The bigger investors are, however, in a position to influence *general development* too by the multitude and continuity of their activities.

These possibilities may, however, be multiplied by a well organized co-operation between the investors, aiming at a common accumulation of experience, knowledge, and other resources, a joint planning of their activities on a long-term basis, and a united collaboration with research, production and authorities. Very often the investors, for instance non-profit housing societies, are working within local districts where no firm collaboration is established with other investors, even those acting in neighbouring districts, and within the same district several investors may be found who in fact compete instead of co-operating. This disunion of resources very considerably weakens the inherent strength of this group. Within several other fields of community life experience has clearly stated the necessity to combine forces where problems, for technical or economic reasons, have shown to be too complicated to be mastered adequately by individual persons, firms, or organizations. This experience has only to a small extent been used by the building-investors.

A new organizational structure of the investor-group

An effective co-operation between the investors presupposes some sort of organizational basis, securing an execution of activities across institutional, local, and other limits. The pattern of such an organization should be derived from an analysis of the main functions to be performed by the investor, with the clear aim: to place the individual function at the level within the structure where it may most effectively be executed. This may in different respects lead to a higher centralization of functions and combination of activities, making possible at the same time a greater view over the whole field and a further exploitation of the advantages of specialization.

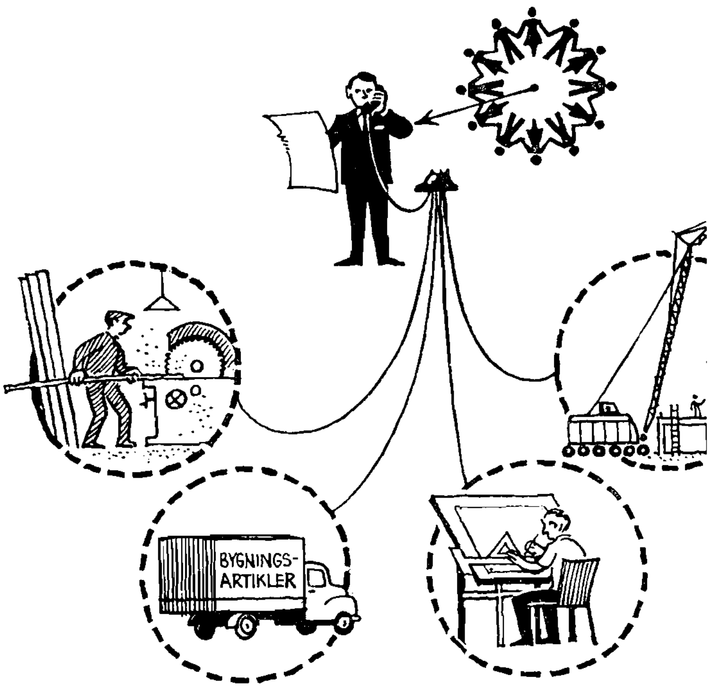

Fig. 1. The investor has a key-position, both as a representative of the consumers and as a factor able to influence the whole development within building at its different levels. A firmly organized co-operation between the investors will multiply their possibilities in these respects.

The main functions of the investor

A distinction should first be made between two main functions: the planning and execution of building on one side and the administration of the completed houses on the other. These two functions are of a quite different character and their performance requires completely different qualifications. Moreover, the most important functions of the investor will be the following: formulation by the investor group of a general housing and building policy as a background to the individual projects; performance of research or development work; the initiative to start the projects; the formulation of the building programme, determining in the individual case the size, type, quality etc. of the building; the planning of the building; the procurement of building sites; the raising of capital; common purchase of building materials directly by the investor.

The place of the functions within the organizational framework

The guiding principle to determine the level at which the different functions should be placed within a common organization must be the following: to which extent does the function need to be based on common, accumulated experience, on specialist knowledge, on bigger capital resources, on big plans or large quantities, and to what degree will more or less local contact, knowledge, and responsibility be essential?

An evaluation of the functions from this point of view leads to the conclusion that some functions should be organized on a very wide basis—in smaller countries, at any rate, on a nationwide basis. Others should be performed by sub-organizations working on a fairly large basis – large enough to profit from the advantages of a considerable continuous activity, for instance comprising the planning and construction of some two thousand dwellings annually, but not bigger than enabling the organization to overlook the special housing requirements within the region. Other functions again, for instance those where a closer personal contact with the residents may be of value, should be entrusted to smaller, local organizations.

The nation-wide organization

On a nation-wide or equally wide basis should after this be organized the following functions: the formulation of the guiding principles as to housing qualities and building practice which must be followed by all the co-operating investors in their practical work; the over-all planning of the activities of the investor group for the next following years; the performance of development work and different sorts of research in collaboration with the research institutes (for instance: investigations of housing requirements, the living habits of the residents, the practical value of the completed dwellings, compilation of statistical data); common designing, consisting in the development of standardization and type-plans for houses, rooms, or building components which in full or partly can be used by the members of the organization, on the other side permitting them to accomplish the plans with individual designing; assistance to the members to acquire building sites and to raise capital for building; the organization of common purchase of building materials and components, enabling the investors to influence the production industries according to their long-term requirements and to get pricereductions based on purchase in big quantities; establishment in some cases of production industries of their own; fixing of principles of collaboration with co-operative or private building firms; general information and propaganda activities for the members and the residents.

The regional organizations

The actual planning and execution of the individual projects require a far closer contact to the place where the housing needs arise than can be achieved by the central organization. On the other hand these activities should not be carried out by several small investors in each town or small district. There are two main reasons for this: building can be planned and executed far more effectively by bigger organizations with more experience, trained personnel, capital resources etc., and the general responsibility for the housing situation should be entrusted to organizations covering regions where housing problems across the municipal boundaries are getting more and more common with the development of transport facilities, the appearance of big undertakings attracting labour from greater distances etc.

Such regional organizations should therefore perform the proper investor functions; the resolution to start the project, the raising of capital, the purchase of building site, the formulation of the building programme, the individual designing which may be wanted to supplement the type-plans, the carrying out of the project.

The local organizations

As mentioned above a distinction should be made between the two main functions: the building activity as such and the administration of the completed houses. The local organizations should still have an influence on the first said function as they will have a practical feeling of what is needed and wanted from construction. This influence should, however, be channeled in the way that they together form the board of the above-mentioned regional organizations which, considerably better on a common basis, will be qualified to carry out this function. The administration of the completed houses could, however, better be entrusted to the local organizations, which can take care of the personal daily contact with the residents and follow problems in connection with maintenance etc. The local organization should therefore take over the completed houses as owners and have the full responsibility for their use both in respect of letting, maintenance, and other sorts of management.

Conclusions. The importance of the investor is a double one: he has a special responsibility in representing the consumers who, within big building generally, have no direct representation, and he has possibilities not yet sufficiently realized to influence the whole development within building. In fact all rationalisation begins with the investor. A re-organization of the investor group along the lines described above is an attempt to enable it to take up this responsibility and give it effect in practical work. Details in the organizational framework may vary but the main line of concentration of resources and efforts should be of a general value. A development along such main lines is beginning to take shape within the non-profit housing societies in Denmark.

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Industrialisation and the changing pattern of the building industry in East Germany

By R. Schüttauf (East Germany)

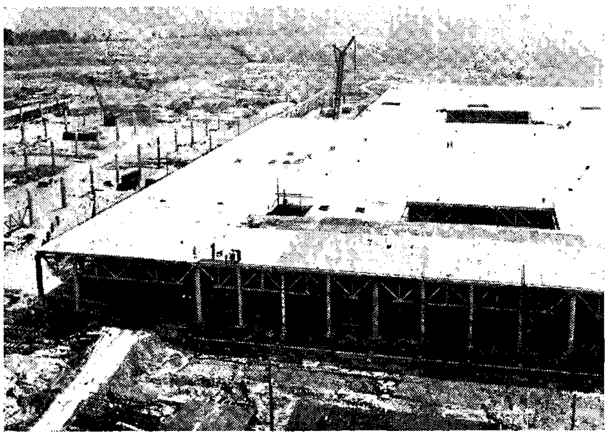

Fig. 1. Erection of a single-block factory using only basic structural units.

The basic principles adopted in industrialising building, the resulting qualitative changes, and some of the experiences gained in East Germany form the scope of this paper.

Large-scale transition to off-site factory prefabrication has sparked off the process of specialisation, concentration and combination as well as of mechanisation of labour – a process that has changed the traditional building site into a place where finished buildings and structures are assembled from precast units. In the course of this process the building industry discards its former passive role of supplying structural shells only and becomes the producer of complete industrial plant ready to take up production and complete housing estates ready for occupation. The building industry thus takes an active part in ensuring that investments will bear maximum results.

It has proved quite impossible to cope with the ever rising demand for buildings using traditional methods in the GDR. Achieving maximum economic results from investments necessitates the development of the productive forces based on the process of comprehensive industrialisation of building.

There are no principal differences between the process of industrialisation in building and the process of industrialisation in other branches of economy. There are, however, some specific peculiarities, arising from the type of end product the building industry turns out. The principles of industrialisation the GDR adopted are as follows:

- maximum precasting and finishing of the structural units as well as of equipment sub-assemblies in stationary prefabrication plant, all units complying with the Modular Unit System which allows for an optimum in precast construction;
- large-scale mechanisation of all building and assembling operations and eventual automation of all operations in the prefabricating industry with the aim of increasing productivity, abolishing heavy manual work, and raising the standard of quality;
- introduction of scientifically based forms of organisation on the principles of flow-line production;
- long-term planning of all investments in order to achieve the most expedient forms of regional concentration and coordination as well as the most economical concentration of financial means and capacities;
- concentration and specialisation of the design offices which is a necessary precondition for designing standard structural sections and standard buildings.

One of the most essential prerequisites to industrialising building is the establishment of a highly efficient building materials industry, in particular of a completely new concrete products industry. The following figures give an idea of the development of this branch of the building industry.

TABLE 1. Increase in the output of concrete products in the GDR.

	Output in 1000 tons	Index 1955 = 100
1950	280	–
1955	1660	100
1958	4390	264
1961	7860	473
1963	8400	505

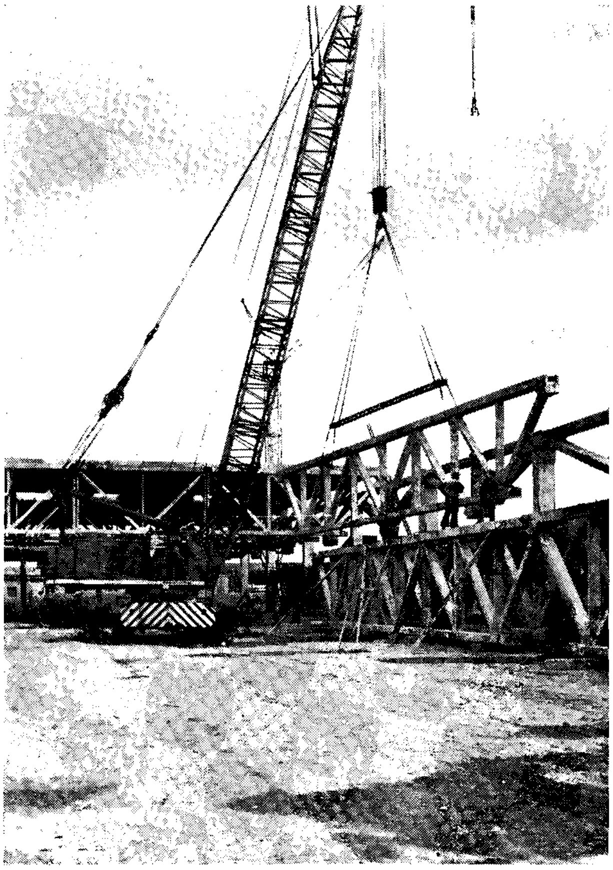

Fig. 2. Lifting a precast prestressed concrete truss into position.

The concrete industry has developed into an independent and efficient branch of the GDR's building materials industry and is now the heart of the evolving prefabrication industry for the entire national economy.

Three criteria characterise the concrete industry, i.e. 1) Mass and series production of standardised products conforming with the Modular Unit System; 2) Employment of standardised precasting techniques based on the group method using standardised sets of machinery for all processes. The precasting, haulage and erection standards are themselves based on the standard designs for building sections; 3) Specialisation, concentration and cooperation among all prefabricating plant in order to supply contracting organisations with complete building sections within economical haulage radii.

By boosting the concrete industry it was possible to raise the percentage of precast construction correspondingly. The following table indicates the share that precast constructed industrial and residential projects have in the GDR's total output in these buildings since 1960:

Fig. 3. Positioning a waffle-type roofing slab.

TABLE 2. Precast construction in industrial building and housing.

Year	Industrial construction	Housing construction
1960	8.8%	44.5%
1961	10.3%	59.3%
1962	15.7%	70.8%
1963	17.3%	77.2%

The percentage of precast building construction is scheduled to increase systematically over the next few years, and this again is the key to increased effectivity of investments. The GDR's building industry has been equipped with a great number of modern machines over the past few years. The gross value of the plant and equipment rose by 140% in 1962 compared to 1958. This includes a particularly large number of multi-purpose excavators, tower cranes, truck cranes and similar key machinery.

The process of mechanisation again necessitated a switch-over from conventional methods of organisation to new, scientifically proved industrial methods. Housing construction gave evidence that continuity is an essential factor in determining the proficiency of precast construction and mechanisation. The increase in productivity possible due to the high degree of prefabrication and mechanisation in industrialised building is only fully effective when production is organised scientifically according to the flow-line principle.

In 1959 the flow-line principle was introduced on a broad scale in housing construction. Of the new flats built in 1963 in the GDR 77.2% were prefabricated (Table 2) and were erected on the flow-line principle. The substantial increase in productivity attained already in 1960 with this method is shown by the following figures:

TABLE 3. Increase in productivity in housing construction.

System	Dwelling units per worker	
	1958	1960
Traditional brickwork	0.7	2.0
Large block system	1.5	3.0
Large panel system	1.8	3.5

All these measures naturally had a positive influence on the cost of construction. In 1963 the price of one square metre in flats of identical size and grade was 86.0% of what it was 1958.

The experience gained with the flow-line principle subsequently led to a series of Government decrees that promoted the introduction of the flow-line principle in all spheres of the construction industry.

In order to promote industrialisation a number of medium-sized contracting firms were fused to form a smaller number of large integrated contracting organisations that operate on a regional or specialised basis for industrial building, housing and agricultural building, and special types of construction.

At present there are six such integrated organisations for industrial building, three for special types of construction, and organisations for housing and agricultural building in all districts of East Germany. A similar development is taking place in the precasting industry.

A planning and scheduling method know as the Complex Flowline Method has been devised to coordinate prefabrication, haulage and erection of the structural units, of the finishing units and of the technological equipment into one integrated planning system.

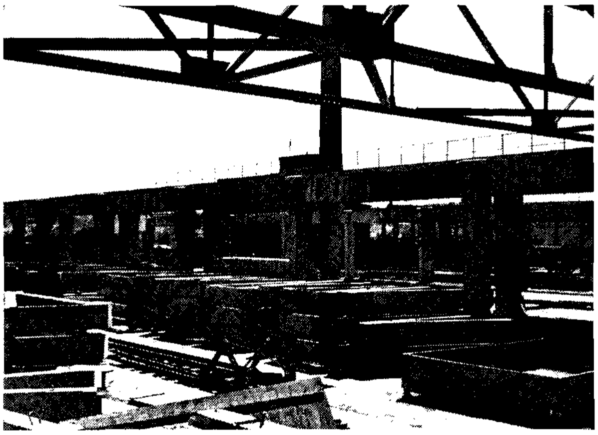

Fig. 4. View of a concrete factory for precasting structural units for industrial buildings.

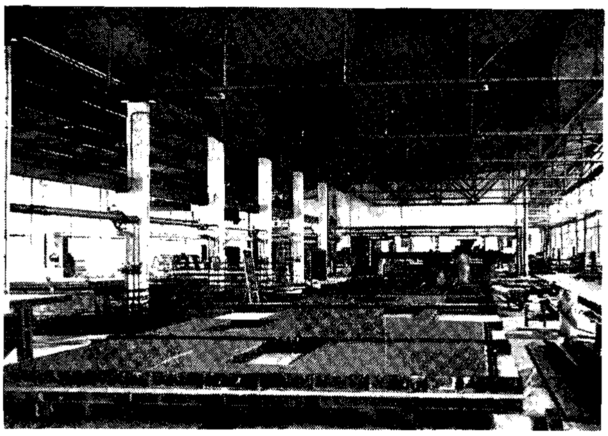

Fig. 5. Interior view of a stationary concrete factory for prefabricating large-sized panels for industrialised housing.

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At present the Complex Flow-line Method is the most advanced method for planning the construction of large industrial projects. It ensures the continuity and uniformity of all constructional, special, and equipment-assembling operations with the maximum utilisation of the standard sets of machinery.

The eventual goal is to achieve a method of operations planning that is as exact as those now customary in other stationary industries. This, however, can only be done with the aid of modern mathematical methods and computers as an extremely large number of factors have to be taken account of due to the intricate and often changing conditions peculiar to large construction sites.

Based on the Critical Path Method (CPM), detailed methods for determining the optimum construction period and ensuring that all work is carried out continuously have been devised in the GDR. After these methods have been tested sufficiently they are also to be used for operations control and for carrying out short-term adjustments in case of any irregularities.

It is the responsible design office's duty to see to it that the Complex-Flow-line Method is adopted for any investment project from the very first stages of design work on. As a rule, the actual scheduling work will be carried out by the various sub-contracting design organisations for the mechanical equipment.

The general contractor is fully responsible for the entire plant until it is ready to be handed over and to take up production. These organisations are independent by law and have the right to issue directions to all sub-contractors.

Conclusions. In the past, industrialisation of the building industry in East Germany aimed at setting up an efficient concrete industry, at large-scale mechanisation of both the precasting operations and the site erection, standardising the principal technological lines, introducing industrial methods on a large scale to housing construction, introducing industrial scheduling methods on the principles of series and flow-line production, standardising building designs, structural systems and methods.

Establishing large integrated-type and specialised contracting organisations, prefabricating plant, and design offices is a direct outcome of the above mentioned elements of industrialisation and the next step toward all-out industrialisation.

All these measures taken together will finally lead to achieving the maximum effectivity of investments.

Future aims and present stages of industrialisation

Methods and indices for international comparison

By G. Sebestyén (Hungary)

The author proposes to discuss the following points:
what industrialisation and its aim means,
the present level of the building industry in different countries,
by what means and indices the stage of industrialisation attained by the building industry of different countries can be compared,
what conclusions can be drawn from the surveys made.

The contents and aim of industrialisation

Industrialised construction means:

- large-scale use of machines in the building processes,
- large-scale use of factory produced building components,
- concentration in the construction industry; the steady flow of demand and execution; the use of up-to-date planning and programming methods,
- research in the design and the production processes of buildings,
- carrying out large-scale construction works including repetitive on-site processes and using standardized building components.

The future aims of industrialisation in construction are:

- a substantial increase in productivity of labour or the substantial reduction of manpower necessary to carry out the large-scale construction programmes (especially the reduction of high skilled specialized workmanship),
- to speed up construction, so as to reduce its dependence on climatic factors,
- to reduce costs of buildings,
- to secure standardized high quality of products.

As a generalization it can be assumed that only the changes to be realized via industrialisation enable the construction industry to fulfill its obligations.

Present stages of industrialisation

The first factor of the industrialisation of the construction industry is the general development in the extracting and manufacturing industries. The level of industrialisation in a certain country is greatly affected by the level of the development of the whole national economy.

The organisational concentration can be considered as the next very important factor affecting industrialisation. Naturally, the concentration achieved in the construction industry only in itself is not sufficient for industrialisation but it gives rise to extremely favourable conditions. Both the developed industrial background and the concentration of the building industry are needed for industrialisation. These—and other—factors affect the level of industrialisation in individual countries.

Indices and methods to measure and compare the levels of industrialisation

The industrial background can be characterised by indices like national income per capita, production of steel (plastics, electric energy, cement) per capita. The degree of concentration can be described by the average number of workers per enterprise. The actual technical level can be characterised by the relative quantity of up-to-date materials, components, building machines etc. used in the building industry.

The efficiency of alternative technical solutions of the same problem can be compared by calculating certain indices. e.g. when comparing different technologies of manufacturing cement the labour consumption and the heat energy per 1 ton of cement are of primary importance. The best indices characterise the best solutions.

As a result of technical progress the actual value of the indices changes in time. Assuming that we found out how to measure the technical level of existing alternative solutions of some technical problems, we could define at any moment the technical level of the most efficient solution of the given problem. These points form a line or a curve, which has by no means a regular shape. It shows periods of stagnation, periods of slow development and periods of quick revolutionary development.

Decision policy problems and conclusions

Industrialisation proceeds not only through research by one organisation but also by relying on an exchange of experience within and between countries and by adapting and perfecting the knowledge thus obtained. Development based on evidence from outside sources is of vital importance, particularly in smaller countries, where full-scale research cannot possibly be carried out in every field but available resources have to be devoted to those projects from which most profit is expected.

We are often confronted at a certain moment with the problem: what kind of solution would lead to the maximum development and most further the industrialisation process?

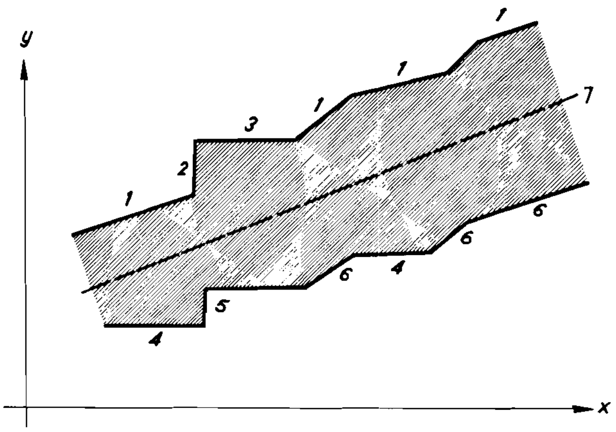

Fig. 1. The industrialisation process.
y – Index of technical level
x – Time (years)
Shaded area – Indices of prevailing technical solutions for one certain problem
1 – Period of gradual improvement of the best solutions
2 – Introduction of revolutionary new techniques
3 – Stagnation of best solutions
4 – Stagnation of worst solutions
5 – Elimination of certain obsolete techniques
6 – Gradual improvement of the worse solutions
7 – General raising trend of technical level (level of industrialisation)

Naturally we can decide to do research work ourselves if the existing solutions do not suit us and if there is sufficient probability for success. The decision must take into account the possible gains and risks (Fig. 2).

Some of the factors affecting the decision are:

$$\varphi_1 = \frac{\text{Volume in the own country}}{\text{Volume in the most advanced countries}}$$

$$\varphi_2 = \frac{\text{Volume in the own country}}{\text{Volume of possible exports in investigated fields}}$$

$$\varphi_3 = \frac{\text{Possible results by own research}}{\text{Existing results abroad}}$$

The decision would be in favour of own research if the values φ_1 and φ_3 are big and that of φ_2 small. As can be seen this is a complex decision problem where complex decision models are required.

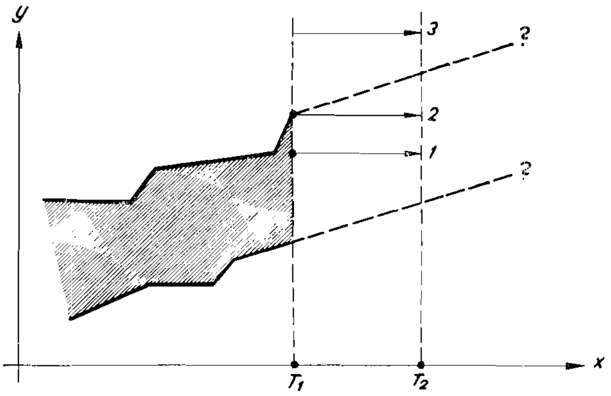

Fig. 2. Decision problem in introduction of new techniques
y — Index of technical level
x — Time (years)
T$_1$ — Date of decision-making
T$_2$—T$_1$ = Period necessary to realize the adopted decision (e.g. establishing a new factory)
T$_2$ — Date of introduction of new technical solution
1—3 — Possible decision patterns:
1 — To introduce the newest and probably best solution unchanged
(Risk: at the moment of decision-making sufficient actual experience may be not yet available)
2 = To introduce the proven best solutions
(Risk: it may become obsolete during the period of introduction)
3 — To introduce a completely new solution based on foreign or own research
(Risk: the actual performance may be much worse than expected)

Conclusions. Industrialisation in the construction industry is spreading. It is a rather slow process which will take many years yet and which requires a considerable capital outlay. It calls for the simultaneous use of a wide range of modern techniques. The levels and stages of industrialisation can be characterised by different indices. More research is needed to define models helping government and industry in decisionmaking on industrialisation.

Standardisation as a basic condition of industrialised building

By J. Sittig (The Netherlands)

The problem

Industrialisation of building consists of a number of co-ordinated activities in the technical, economical, commercial, financial, legal and political fields. This paper is only concerned with one single aspect of the process of industrialisation, but one which is a basic condition for any form of industrialisation: the standardisation of the products to be manufactured, sometimes called "variety reduction". For during the pre-industrialised period there exists neither the necessity nor the possibility of producing long series of virtually identical goods: they reach the user in an infinite number of types, even if the designer is trying to imitate his predecessors.

On the other hand, industrial production, that is to say division of labour, mechanization and automation, cannot exist without the possibility of producing long series of interchangeable articles; the reduction of the infinite variety of types to a small, sometimes extremely small, number of types — in effect, standardisation — is the first, the most important and perhaps the most difficult step towards industrial production. The difficulty of standardisation is connected with the fact that it sets up a completely new pattern of satisfying the demand, and affects the user as well as the manufacturer and the retailer. Standardisation therefore is a psychological attitude before it becomes a technical measure.

That long series and thus standardisation are necessary for the manufacturer in order to be able to organize his production process cheaply and efficiently, is a truism. The stronger the standardisation, the cheaper the product.

Therefore, if the manufacturer's wishes were the only influencing factor, every standardisation would be a radical standardisation leaving only one single type to be manufactured. This of course is not the case; it is another (implicit) truth that standardisation and variety reduction, if carried out too far, clash with the user's interests.

For that reason the manufacturer curbs his desire to standardise indiscriminately and radically, and provides an intuitively chosen number of types to satisfy the demand of the user. Moreover, the chosen types themselves are defined without a scientific method, but based on tradition and wishes of the users which reach the manufacturer more or less at random.

The aim of this paper is to discuss a scientific method of standardisation and variety reduction which can be applied to the standardisation problem in the building industry.

Adaptation losses

Our starting point is the idea that a functional study of any building leads to a set of requirements which makes the building ideally suited to the purpose for which it is to be designed. This ideal set of requirements, also called "situation of demand" is unique. It can be imagined as a point in *n*-dimensional space if there are *n* relevant requirements corresponding to n relevant elements of functional need.

The uniqueness of such a set of requirements implies that under the reign of industrial production the demand is normally satisfied by a set of properties not co-inciding with the set of requirements.

Industrial production therefore leads to certain losses (financial, psychological, hygienic...) because the user does not exactly get what he needs.

We call these losses "adaptation losses" or "losses due to "maladaptation".

Example 1: kitchen dresser. If we look e.g. at the kitchen dresser as a working surface for preparing food etc., a good design will lead to an optimum height of this dresser above the floor, dependent on the bodily dimensions of the user. Generally speaking, the taller the housewife who works in the kitchen, the higher the kitchen dresser ought to be.

Now it is quite impossible to provide kitchens which are adapated to the dimensions of the housewife who actually works in them. The best we can do in a given country is to design kitchens which are as well adapted as possible to the statistical population of housewives in this country [ref. 1]. Say that housewives have a stature varying from 145 to 180 cm, then we must choose from this range a "model housewife" and adapt to her the dimensions of our design. That of course implies that all other housewives have to work at a dresser which is not ideally adapted to them and is either too high or too low. In both cases adaptation losses occur in the form of an increase of the working load.

In principle, these adaptation losses are measurable and hereby it becomes possible to plot the adaptation losses as a function of the actual stature of the user. This loss function generally is not symmetrical; that is to say losses occurring with a person who is 10 cm too tall are not the same as in the case of a person who is 10 cm too small for the design.

This property of the loss function generally forbids the use of the average of the population of users as a model.

If, as in our example, a dresser which is *a* cm too low is worse than one which is *a* cm too high, then one feels that the kitchen dresser must be designed to a greater height than that corresponding to the average housewife; in other words the model to be taken should be taller than the average of the population.

A rational solution of this problem can be obtained in the way shown in figure 1.

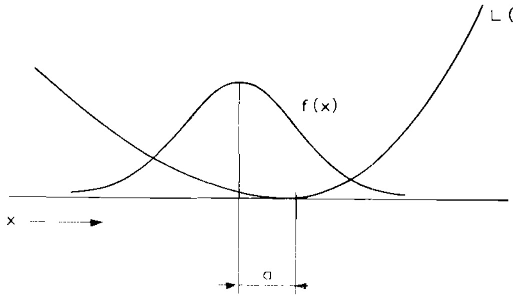

Fig. 1. Optimum height of kitchen dressers
f(x) .. frequency distribution of relevant bodily dimensions
L(x).. loss-function
a .. independent variable

The loss function is drawn on an axis giving the corresponding bodily dimensions of the user. That is to say that "10 cm too high" does not mean that the dresser is 10 cm too high, but that it is designed for use by a person who is 10 cm taller than the actual user.

On the same axis the frequency distribution of the potential users is drawn in such a way that the value "zero" of the loss function corresponds with a value of the frequency distribution which differs *a* cm from its average.

In our case there is only one degree of freedom which we take up by choosing a certain value for *a*. The best design is defined by that choice of *a* that results in a minimum for the total adaptation losses over the frequency distribution of potential users. In a formula:

$$\xi(L) \quad \int L(x \mid a)\, f(x)\, dx \rightarrow \text{minimum}$$

If the loss function L (x) and the frequency distribution f (x) are known, this mathematical problem is perfectly soluble by analytical or numerical means.

Example 2: Prefabricated factories. [ref. 2] Taking as another example the prefabrication of factory buildings and the like, we can ask what span or spans should be provided for this kind of buildings. In a given case the necessary span depends on the dimensions of machinery, products and transport which must find a place in the building. Say that a functional study of a production process gives the result that the span needed is 12.8 m. In the case of prefabricated buildings the probability is very small that such a value forms part of the product range provided.

What happens therefore is that one has to sidestep and prescribe a span which is greater than the 12.8 m which were needed and from this application of something which is not ideally suited to the purpose, again a loss in adaptation arises.

Adaptation losses in this case occur because one has to buy elements which are not only longer than necessary, but which also have a heavier section because they are longer*.

By use of these longer elements one gets more floorspace, but this additional space has, generally speaking, a smaller value than the floor space which is functionally necessary.

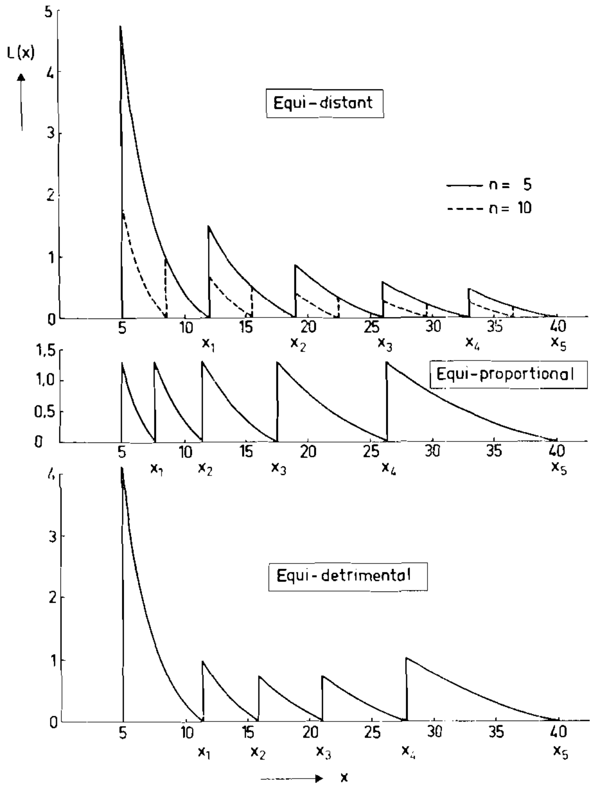

Fig. 2. Optimum spans for prefabricated factory buildings
Three different loss functions
$x_1, x_2, .. x_n$ .. standardised spans
L(x) .. loss function

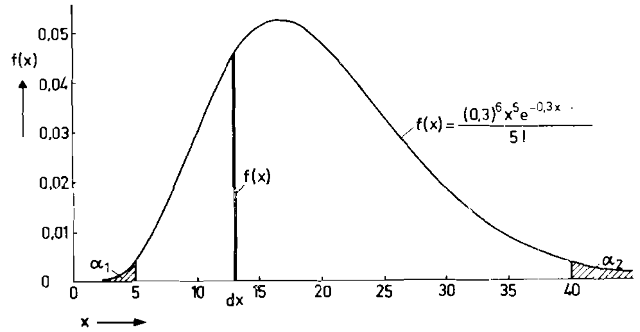

Fig. 3. Optimum spans for prefabricated factory buildings
Frequency distribution of demand
x .. span needed
f(x) .. frequencies

Figure 2 gives the loss function. It is, of course, dependent on the spans $x_1, x_2, \ldots$ which we propose to provide. The solution is similar to that in our first example insofar that we try to arrive at a standardisation which results in minimizing the adaptation losses over the frequency distribution of applications (figure 3). Only in this case we must choose not one, but as many parameters as there are types to standardise. The formula becomes:

$$\xi(L) = \int L(x \mid x_1, x_2, \ldots x_n)\, f(x)\, dx \rightarrow \text{minimum}$$

The standardisation procedure differs from that used in our first example because we are confronted with a two-step decision problem. On the one hand we have to decide on the number of types (spans) to be standardised, on the other hand we have to decide on the values for the spans to be standardised.

We already described the second decision procedure. This gives us the optimum set of 1, 2, 3 ... n types (optimum in the sense of minimizing total adaptation losses).

It can be shown that adaptation losses over a given frequency distribution decrease as the number of types to be standardised increases. On the other hand, cost of production and distribution increase with the number of types.

Under certain conditions (which seem to be fulfilled in practice fairly often) there exists a minimum of the sum adaptation losses plus production cost, situated at n types where

$$1 < n < \infty$$

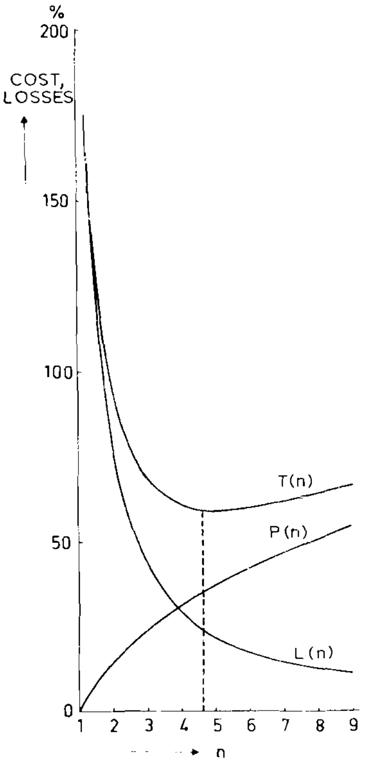

Fig. 4. Optimum spans for prefabricated factory buildings.
Optimisation of number of spans to be standardised
n .. number of standardised spans
L(n) .. adaptation losses
P(n) .. cost of production and distribution
T(n) .. total cost

Figure 4 gives the solution (with an optimum at n = 5) in the case of prefabricated elements for factory buildings.

Conclusion. Although the theory of optimum standardisation, the basic elements of which have been discussed in the preceding pages, is not exclusively meant for application to building, it may be considered as especially suited to the standardisation problems in the building industry.

For, whereas a wrong, that is non-optimum, standardisation e.g. in the clothing industry leads to economic losses, the relatively short life of the products concerned is a limiting factor to the amount of adaptation losses.

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* If we define α span used/span needed ($\alpha \geqq 1$), then if the weight of the element needed is p, the weight of the element used is p.$\alpha^{7/3}$.

Buildings on the other hand, and groups of buildings (towns) have an extremely long life. Adaptation losses due to wrong standardisation decisions taken in 1965 will still exist in the next generation and will then be even greater than they are now because of the changes in the functional requirements which result from the everlasting changes in men, machinery, materials and methods.

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Technical and economic conditions required for building with prefabricated components

By W. Triebel (West Germany)

The aim of all endeavours to achieve progress in building techniques is to make it more economical or rationalised. Building is better organised if, with the same expenditure, (office, workshop and site, products and equipment), better or more building is accomplished; this is also the case if the same amount of building is carried out more cheaply. In any case the effort-result ratio or building cost-building value ratio should be improved.

Concentrating on cutting down expenses without paying any heed to the extent of the drop in building value would not be an improvement in rational building. Nor would an attempt to obtain higher building value with no consideration for the relative higher expenditure. To accomplish building rationalisation both factors, expense and value, should always be kept in mind.

Modern methods and techniques (even building industrialisation, mechanised site work and prefabrication of component units) are not the final goal of building development. However, they are means to an end.

There is really no technical process which offers all the advantages and is cheaper than the others. But, in regard to many technical processes, there exist a number of requisites to make them advantageous and contributive to development. The required conditions for prefabricated component building to be of advantage and of promise have not always existed, nor do they obtain everywhere. However, such conditions have existed for some years in many European countries.

Building by means of prefabricated components differs from other methods, also aiming at rationalisation of and a rise in production, in that it tends to transfer work from site to factory. Building components, as perfect as possible, are to the greatest extent fabricated off the site in fixed shops: they are then assembled on the site by the simplest possible operation. One tries to avoid the drawbacks of time, changing building sites and their temporary installation. Instead, there is a tendency to avail oneself, to a greater extent than hitherto, of the advantages of fixed industrial building fabrication. In this way, the primary conditions are taking shape, which make the application of the above methods suitable and consequent.

There is an inclination to reduce building site work. Therefore such methods will prove convenient where it is necessary to reduce site labour. Thus, they may be applied if the necessary capital investment is available. Furthermore it is essential that these installlations operate at maximum capacity and are fully written off. In other words their worthiness depends on the practicability of large production of the same components.

Consequently, there is a fundamental case for building by means of component units

- if it is required or useful to cut down work on the building site;
- if means are available to establish the necessary factories, and
- if there is a demand for large quantities of the same or similar elements.

The above conditions have till now been important for fixing the time for introduction and the scope of prefabrication in particular countries.

Building with the use of component units has been known in European countries for a long time. In England, in the 18th century, buildings were prefabricated for erection at key points overseas. In the 18th century too similar buildings were made and used for military purposes in Austria. In the 19th century large-size wooden elements were used in the United States. They were partly imported from Belgium, Germany and New Zealand. At first it was only for limited jobs. A process of this sort was introduced in Germany and applied until the end of the 19th century. Buildings were erected following this process by means of large wooden components, fully prefabricated. A patent was taken out in 1919 for a German process for the prefabrication of large concrete wall components. Between 1927 and 1929 buildings were erected, using such prefabricated components, in several German cities – Berlin, Frankfort and Munich.

Building with prefabricated components could not be introduced, at the time, either in Germany or in other countries, generally speaking, and in the long run, since the three prerequisites were not yet there. And this promising start led to nothing as, starting in 1930, the world economic crisis, with mass unemployment, shortage of capital and building trade recession, created adverse conditions for prefabricated components building. During that period building with prefabricated components went on only on a restricted scale.

However, after the second World War, these important conditions obtained in many European countries, so that building with prefabricated components was then introduced in France, in Sweden, in Denmark and in the Soviet Union. Many countries, followed suit as and when similar conditions, calling for building industrialisation, were established.

Such conditions did not exist in the Federal Republic of Germany after the war. They developed, however, during the 1956–58 period. In 1958, prefabrication of components for building flats was resumed and intensified. The first buildling component factory was set up in 1959. Two others were started in 1960. Now, some 140 factories in the Federal Republic turn out large concrete, reinforced concrete or brick-made components for the full building range. At the same time about 130 firms produce prefabricated components for private houses, mostly made of wood or similar material.

The introduction of building by means of prefabricated components in other countries, where the method is still unknown, how much such method will account for in total building, and the result to be expected of building rationalisation, will always depend on the three requisite conditions:

- the necessity to save work on the building site or to build more with a limited labour force;
- the possibility of setting up new factories or making extensions to existing ones;
- the continuous demand for large amounts of the same or similar building components.

Trade Unions and the development towards industrialised building

By H. Umrath (The Netherlands)

Modern trade unions are aware of the fact that economic growth is necessary for a higher standard of living. Therefore they are in favour of new developments when and where they will promote human progress. This means that new methods and techniques must not be contemplated in isolation but in relation to the man who must handle them and the needs of society as a whole. In addition, a degree of priority must be accorded to those whose needs are most urgent, be they individuals within a nation or countries within the family of nations. Used in the framework of imaginative policies based on long-term programmes, new developments in the building and construction industry can become important instruments contributing to the solution of the social and economic problems which face us today.

These were the conclusions of our paper "The social framework of new developments in the building and construction industry" to the 2nd CIB Congress, formulating conditions which in the opinion of the Free Trade Unions must be fulfilled in order to insure the intended effect of higher production of industrialised building.

Trade Unions as consumers' representatives

The International Federation of Free Trade Unions, ICFTU and its National Centres represent a large part of the consumers of services produced by the building industries, of which housing is the most outstanding one. Moreover, building activities are fundamental for economic growth and social progress, important aims of the Free Trade Unions. Consequently, they contribute in the formulation of building and housing policies both in international and supranational organisations such as the Committees on Housing, Building and Planning at UN Headquarters and at ECE in Geneva, the ILO, the EEC (Common Market) etc., and in the steering bodies for programming and planning housing and other construction activities in various countries. Like others, their representatives soon recognised that the growing needs for modern human settlements can only be satisfied by an expanding and up to date construction industry, producing in the framework of medium- and long-term programmes. This principle was inserted in ILO Recommendation 115 concerning "Workers' Housing" and unanimously adopted by the 45th International Labour Conference. Section IV of "Suggestions concerning Methods of Application" enumerates "Measures to Promote Efficiency in the Building Industry." It starts as follows:

"Workers' housing programmes should be carried out on a long-term basis and should be spread over the whole year, in order to obtain the economies of continuous operation."

Housing output alone has to be increased from 7 to at least 10 per 1,000 inhabitants p.a., i.e. by 30 p. ct. in many industrialised and even much more in developing countries. Moreover, often the growth of building capacity is too slow; in Holland, for instance, during the period 1954–1964 capacity expanded by 3½ to 4% p.a., compared with a growth of demand for buildings of 7 to 8%.

Industrialised building in the wide sense, will have to make a decisive contribution to the solution of this problem. Nevertheless, we think that at the outset of this paper attention should be given to one or two other measures to increase construction activities.

There is a tendency to see in industrialised building the *only possible way* to increase sufficiently the industry's production efficiency and total capacity. On account of experiences in national and international bodies we are afraid that such an absolute approach is rather widespread and just for that reason not without danger. Though a change from the way of thinking of craftsmen to an industrial mentality is needed, this does not mean that mechanisation and capital investment alone will solve the problem everywhere. At the 2nd CIB Congress we underlined the necessity of the "social frame-work" within which such a technical development must take place. This certainly means that long-term policies must guarantee the full and uninterrupted use of the increasing capacity. This condition has been underlined time and again by both sides of the industry, lastly by the ILO Subcommittee on the Regulation of Employment in the Construction Industry. (See ILO, Notes on the Proceedings of the 7th Session of the Building, Civil Engineering and Public Works Committee, May, 1964). It is at least as important "that the pace of economic expansion is primarily determined by organisation, management and other elements of quality, which are of more influence on expansion than investment activities." (G. Deurinck, in "Technical Progress and Common Market," Conference Papers, Brussels, 1960, vol. II, p. 52.) In an industry which has to execute millions of small jobs for maintainance and repair work in remote villages, and has to construct huge multi-purpose installations and whole new towns, training and use of sheer brain power is perhaps more important than elsewhere. Therefore, "industrialised building," as understood by many people inside and certainly outside of the industry, can never be the *only possible* road to efficiency and thereby higher output. Even in highly industrialised countries, investment in human resources from top to bottom is necessary if capital investment, where appropriate, is to pay at all.

In all those – mostly less developed – countries, where there is not only need for housing and other buildings, but an even more urgent need for employment, it will be bad economic and social policy to give industrialisation of the construction process priority before the development of an efficient conventional industry. In many instances it has been demonstrated that putting unemployed people to work at building sites is one of the most useful multi-purpose projects, with such results as training their skills and introducing them into the organisation and discipline of an industrialising society, development of a construction industry indispensable for economic expansion, and creation of new homes and other buildings, including factories. Even though the ultimate aim should be to advance towards industrialised building, in developing countries with a permanent surplus of manpower the immediate aim should be the creation of an up to date conventional construction industry. There are already too many instances where, on account of a high degree of mechanisation paid with scarce foreign currency, economic growth did nothing or little to diminish unemployment. (See R. M. Mwilu, We would be glad to help, Free Labour World, Brussels, July-August, 1964).

Trade Unions as (employed) producers' representatives

Technical progress and new building techniques, time and motion studies and payment by result systems, prefabrication and industrialised construction systems, have had a prominent place on the agenda of many conferences of the International Federation of Building and Woodworkers, its affiliated unions, and meetings of ILO. A general survey of this development prior to the 7th Session of the ILO Building, etc. Committee in May, 1964, can be found in the report on item 2 of the agenda of that meeting: "Technological changes in the Construction Industry and their socio-economic Consequences."

The 10th Statutory IFBWW Congress (Lugano, 1963) formulated its viewpoint on "New Techniques." (See ILO Report, p. 38). After endorsing technical progress, the statement underlined the fact that traditional trades are needed in growing numbers as maintainance and repair increase permanently in consequence of the growing stock of buildings. In addition, history of architecture tells that no style is permanent, so that demand for skills which are less used today may be much larger in times to come.

Following a joint suggestion of labour and management, the ILO Building etc. Committee discussed – as already mentioned – "Technical Changes," at its 7th Session in May, 1964. An important feature of this exchange of experiences was that there are a number of industrialised countries – mostly outside Europe – where at present the capacity of the construction industry is more than sufficient to meet present demand. Moreover, in the parallel discussion on "The Regularisation of Employment in the Construction Industry," it was recognized that "during the post-war period, the construction industry in certain countries has suffered a new type of instability. In their efforts to cope with inflationary pressures and international balance of payment problems, governments in those countries have at certain times placed short-term restrictions on the economy as a whole and on the construction industry in particular, with resulting idle capacity in the industry and unemployment of its workers."

The employment situation in the Italian building industry in 1964 is a recent example of the fact that even in very dynamic economies stability has not yet been achieved. Therefore the problems of unemployment or redundancy in consequence of the introduction of industrialised and other labour-saving techniques played a large role in the formulation of the conclusions of the ILO Subcommittee on Technical Changes. The whole set of these unanimously adopted conclusions is certainly of great value for the participants of the 3rd CIB Congress. As they are available at the ILO, Geneva, on request, only the following points, which seem to be of special importance for this meeting are mentioned here:

- much emphasis is given to international co-operation;
- the safety aspect is strongly underlined:
- specific steps are recommended in order to avoid resistance towards innovation;
- full and frank explanation should take place before new techniques are introduced;
- workers who become unemployed in consequence of innovations should be compensated for any financial loss which they may suffer;
- joint consultation between employers and workers with regard to safety can facilitate the safe introduction and operation of innovations;
- contractors, architects, and members of other professions concerned, as well as foremen and workers should get adequate instruction to acquire and/or increase their personal skills and technical knowledge;
- workers should be enabled to keep abreast of technical developments and to be retrained without financial hardship;
- the number of workers to be recruited to the construction industry at any given time should not exceed the number which – in the light of all such information as may be available with regard to long-term employment prospects and with regard to the repercussions of technological changes thereon will offer each worker who enters the industry the prospect of a full career, under satisfactory conditions, in this industry.

On October 26 – 27, 1964, IFBWW held a special conference on "New Techniques in the Construction Industry," followed by a joint ICFTU/IFBWW conference on "Housing for the Millions." The discussions underlined once more the constructive approach of the workers' representatives to the problems under discussion at the 3rd CIB Congress. It was decided to charge a permanent committee with the task of informing the affiliated unions on new developments and experiences with new techniques, their effect on working conditions and future building trends. Steps will be taken to promote co-operation in this field between the international organisations of employers and workers, especially in view of the jointly adopted recommendations of the last meeting of the ILO Building, Civil Engineering and Public Works Committee.

Industrialisation and activities of trade union-owned housing and building enterprises

In a number of countries trade unions of building workers and/or national federations belong to the pioneers of new techniques, including industrialised building. As owners or promotors of co-operative and other non-profit housing societies, they opened almost all over Europe, in many parts of the Americas, and in Israel, the possibilty of mass-production of window-frames, doors and concrete elements for projects of hitherto unknown proportions. In recent years, in countries like Sweden, Israel, and the Federal Republic of Germany, they designed and constructed whole new sections with up to 10,000 dwellings, using and often developing new techniques of planning and building.

In Sweden Svenska Riksbyggan, a combination of designing, contracting, and non-profit housing enterprises erected one of the first factories producing large concrete elements and complete bathroom and kitchen units. They also standardised the windows, doors, cupboards (closets), and other wooden equipment used in the about 7,000 dwellings constructed every year. Total output p.a. about $ 70 million. Svenska Riksbyggan, the Swedish Trade Unions and Sweden's large Federation of Housing and Saving Co-operatives HSB, are equally represented in a tri-partite committee co-ordinating research and experiences. The ultimate aim of this co-operation is the improvement of standards by use of efficient methods of financing and building, prefabrication of elements and equipment, long-term planning, etc.

Shikun Ovdim and Solel Boneh, the housing and construction enterprises of Histadruth, the Trade Union Federation, laid the foundation for the very efficient building industry in Israel, the country with the highest annual output of dwellings, i.e. 15 and more per 1,000 inhabitants. Solel Boneh, with a staff of 30,000, performs 40% of the total building volume in Israel, and formed Joint Construction Companies with seven developing countries, training at home and abroad tens of thousands of unskilled people for conventional and industrialised building methods. Solel Boneh pioneered in many development areas, using standard plans and industrialised building schemes.

Shikun Ovdim established new settlements all over the country, thus combining the "distribution of population policy" with the construction of modern neighbourhoods. In most regions its work was centrally organised with more than 75% of the dwellings built under large-scale schemes, including 11 garden cities and 100 large workers' quarters.

Shikun Ovdim and Bank HaPoalim (Workers' Bank) established the Housing Mortgage Bank, the second largest real estate credit institution in Israel. As housing is a complex enterprise of planning, financing, constructing and administrating, co-ordination and new techniques in all these fields are part of a "building economy" leading towards "industrialised building" in the widest sense. The "Labour Economy" of Israel is one of the oldest examples of such an efficient interplay of the various sectors connected with housing, building and planning.

Another example of this kind can be studied in the Federal Republic of Germany. Here the trade union-owned group of housing enterprises "Neue Heimat", with its affiliates "N. H. International" and "N. H. Kommunal," and the construction company "Bauhütte" are co-operating with trade union-owned "Bank für Geheimwirtschaft," one of the largest German private banks, an important insurance company, and the consumers' co-operatives.

Through its local regional branches, "Neue Heimat" built more than 210,000 dwellings in recent years, of which more than 30,000 were for owner-occupancy. A research team is engaged in influencing the price level through rationalisation of building methods, standardisation and construction of prefabricated buildings. Centralised planning of large-scale projects and joint purchase of building materials are contributing to the policy of keeping rents of well equipped dwellings as low as possible.

"Neue Heimat Kommunal" is intended to construct and rent public facilities like schools, universities, hospitals for municipalities. "Neue Heimat International" started with activities in France and Italy, via joint Franco-German and Italian-German enterprises. It also considers one of its tasks to promote social housing in developing countries. The present annual turnover of N. H. is about $ 150 million.

With $ 20 million or so of construction p.a. and 3,200 employees, "Bauhütte" is one of the largest building enterprises in the Federal Republic of Germany. Technical progress is promoted by new techniques and organisation methods, good working conditions and social installations on the building sites.

Similar trade union-owned or assisted enterprises promoting, building and managing modern residential quarters can be found in many industrialised countries. The first examples are emerging in the less developed regions; in a number of cases assistance is given by European and North-American unions. In their endeavour to construct and administer well-equipped housing and related facilities, they contribute in various ways to the development towards industrialised building:

a.) projects of many hundred, sometimes up to 10,000 dwelling units open opportunities of the "economies of scale" by standardisation and organisation;

b.) long-term planning, supported by financial backing of other parts of the "Labour Economy," channel buying power into the building industry and create continuity, the basic condition of industrialised building.

c.) together with other non-profit organisations, they create an element of competition and price consciousness in a market where more often than not sellers both of building and of housing services have a very strong bargaining position.

A 14

J. van Zwet

The effect on production method and size of series on building time and building costs of blocks of staircase entrance appartments

By J. van Zwet (The Netherlands)

This paper concerns the organization of traditional house-building in series as applied on behalf of projects organized by Foundation Ratiobouw and the effects thereof on building time and building costs.

The basis used is a standard project consisting of a number of identical blocks of staircase entrance appartments, comprising eight flats per block per floor and three floors.

Work units and tasks

By house-building in series is understood here the building of a complex consisting of a number of identical units. These units can consist of a single dwelling or of a combination of different dwellings or parts of dwellings.

One or more of these units, comprising in all from 2 to 6 adjacent dwellings, are arranged to form a "work unit". These work units are worked on in turn, each as a whole, by successive teams, which each has its own task. Work units, tasks and composition of the teams are arranged in such a way that the greatest possible specialization attainable under the prevailing conditions in the building industry is realized.

The building operations are performed in accordance with a previously drawn-up plan, in which it has been carefully laid down how many plan days after commencement of the work the various teams will start and complete their task on the various work units. By plan days is understood the days on which — as will appear afterwards — work will be performed. Assuming that in the Netherlands this will be on an average 200 days per year, one plan day there represents on an average 365:200 = 1.825 calender days or 52:200 = 0.26 calendar week or 12:200 = 0.06 calendar month.

In order not to stretch the building time unnecessarily each team will commence its task on a work unit as soon as the preceding teams on this work unit have reached a stage in their tasks where the teams are no longer in each others way. An important consequence of this is that the same "working time" — the same time available for dealing with one work unit — must be fixed for all teams. For, if a subsequent team should spend less time on a work unit than the preceding teams, this team would each time have to wait until these preceding teams have advanced far enough, or would have to start so much later on the first work unit that it would not catch up with the preceding teams until the last work unit, with the result that the building time of the first work units would be extended by a long waiting time. If on the other hand a later team should spend more time on a work unit than the preceding teams, it would get more and more behind, with the result that the building time of the later work units would become increasingly longer.

Building units, production methods and work time

In order to make the teams perform the same operations as often as possible, so as to build up the greatest possible routine, the dwellings on the different floors are worked on by the same teams. These teams will then not first work on all the dwellings of the first floor, then on those of the second floor, etc., seeing that in order to reduce the loss of interest to a minimum, it will be desirable to complete blocks on which work has already been started as quickly as possible. Hence, the teams will interrupt their task on each floor to proceed to the next floor as soon as construction of that floor has advanced far enough. This is the case, for example, with our standard project as soon as the poured concrete floor has hardened sufficiently to permit of work being carried out there.

The work is so arranged that when passing to a following floor the teams have just come to the end of a block on a preceding floor. Let us assume, for example, that the intervals at which successive teams follow each other up in the construction of the standard project are such that twelve plan days after work has commenced on a floor the next floor can be poured and that three plan days after the pouring operation this floor has hardened sufficiently to permit of work on this next floor being commenced. To this end the following symbols are used:

W: the number of dwellings per work unit;
T: the work time, the number of plan days the teams spend on the performance of their task in respect of one dwelling;
B: the building unit, the number of blocks of a floor on which the teams perform their tasks before proceeding to a following floor.

The pouring of the floor then takes WT plan days and thus work can commence on a floor $12 + WT + 3 = WT + 15$ plan days after work is started on the preceding floor. In those $WT + 15$ plan days the teams on the preceding floor have completed work on B blocks, which — seeing that a block comprises eight dwellings per floor — has taken 8BT plan days. The work will now be organized in such a way that

$$WT + 15 = 8BT$$

and thus $T = 15{:}(8B - W)$ plan days.

Once the work unit W and the building unit B have been determined, the work time T will thus also be fixed. In determining W and B allowance will have to be made, however, for the fact that practical experience has shown that it is not desirable to make T greater than approx. 1 plan day or smaller than approx. 1/3 plan day. It follows from this that for our standard project the following production methods are possible, of which I and VI must be regarded as extremes:

Production method	I	II	III	IV	V	VI
W = work unit in dwellings	2	4	2	4	2	4
B = building unit in blocks	2	3	3	4	4	6
T = work time in plan days = 15:(8B-W)	1.07	0.75	0.68	0.54	0.50	0.34

The building time

With an organization as detailed above the building time is split up into two periods, which can be referred to as the "induction time" and the "delivery time". The induction time runs from the beginning of building operations up to the time at which the team performing the last task starts with this task on the first work unit.

For the standard project this induction time has been calculated for production methods I to VI inclusive at 298, 302, 272, 287, 266 and 265 plan days.

The delivery time runs from the time at which the last team starts with its task on the first work unit up to the time it has completed this task on the last work unit. This delivery time therefore amounts to as many times plan days as there are dwellings in the project.

With a project such as this one the first dwelling, therefore, is completed after a little under eighteen months, but after that from 1 to 3 dwellings are completed on each plan day, depending on the production method.

The building costs of the main contractor

The building costs of the main contractor only have been calculated, as no reliable information is available regarding the costs of work usually performed in Holland by sub-contractors. In any case these costs are not of such great importance in this connection, because it seldom occurs that sub-contractors work according to a systematic organization plan and the majority of them make very little use of the possibilities of saving time and money by an efficient organization when working on large series.

The *material costs* per dwelling of the main contractor are independent of the production method and practically independent of the size of the series. Based on the prices ruling in the first quarter of 1962, they can be estimated for the standard project at *f* 6100 per dwelling. Of the *equipment* used in house-building the formwork and placing equipment occupy a separate position, because it can only be used a small number of times, so that with larger projects the quantity of this equipment required simultaneously is used up a number of times. This equipment can therefore be referred to as "consumption equipment", unlike the other equipment which, after having been used in the building operations, will normally not yet have been used up and can therefore be termed "utility equipment". The consumption equipment can also be considered to include the toilets, which after completion of the work can be regarded as worthless.

To start with, the costs of utility equipment per dwelling consist of the initial capital outlay divided by the number of dwellings for which it can be used before it becomes useless and worthless. Added to this there is the amount by which the part of the utility equipment which has not yet been used up at the end of the work has on an average decreased in value more than would correspond to the number of times it has been used. In addition to the costs per dwelling, the "variable costs", there is yet a further amount of "fixed costs', which must be divided pro rata over the dwellings.

Of the *utility equipment* only a part is used during an operation. This equipment is then brought up towards the time at which this operation commences and it is taken away as soon as it has been completed. Hence, it is used for a time equal to the delivery time, thus proportional to the number of dwellings of which the project consists.

The other utility equipment is used for more than one operation, thus longer than would correspond to the number of dwellings. On the basis of standards per unit of time present the costs of the former equipment therefore consists solely of "variable" costs per dwelling and those of the latter of "variable" costs plus an amount of "fixed costs". A similar reasoning applies for the *costs of management, supervision, care of personnel, laying out and clearing the building site, etc.*

Hence, these costs also consist of "variable" and "fixed" costs. The costs of direct *labour* are more complicated. As a result of the routine built up the production per manhour rises according as more dwellings are added to those already produced. It is true that this will not enable the work time to be shortened, because as mentioned earlier – this work time must remain the same for all teams and the production per manhour does not rise to the same extent with all teams. It is possible, however, to thin out the teams according as the production per manhour rises.

There is still a lot of uncertainty about the trend of the number of manhours which a certain task will take each time it is performed – the improvement curve, learning curve or routine curve.

For a fairly large number of tasks in house-building, selected arbitrarily from a number of accurate calculations of actual costs, it was found that the number of manhours y spent on the xth set of eight dwellings could be represented extremely well by:

$$y = 1250 + 853\,x^{0.712},$$

a formula according to the model advocated by Dr. de Jong in various publications. It is true that this striking agreement can be due to chance, but for lack of a better method this formula has been used as a basis – albeit with the greatest possible reservation for calculating the labour costs in respect of repeated operations.

Moreover, a number of corrections have been applied in view of the fact that experience has shown that with present conditions in the building industry the greatest productivity is achieved with a work time of approx. two thirds of a plan day. Both a longer and a shorter work time results in an increase in labour losses; moreover, with a shorter work time a larger number of workers perform the same task and the individual worker therefore performs this task less often and thus acquires less routine.

Finally, a *loss of interest* at the rate of 5% per year has been taken into account in respect of the costs incurred less the costs which bear on dwellings already completed. The results of all these calculations have been laid down in the attached table.

No allowance has been made for such items as "turnover tax" and "profit and risk". The turnover tax is 3.09% on all types of costs and also the item Profit and Risk can only be approximated by starting out from a fixed percentage. These items, therefore, do not make any change in the relationship between the various types of costs with various production methods and sizes of project. Hence, for our purposes there is no sense in taking them into account.

The effect of production method and size of series on building time and on the costs of the main contractor

Induction time and work time are shorter according as the building units are larger and the work units smaller.

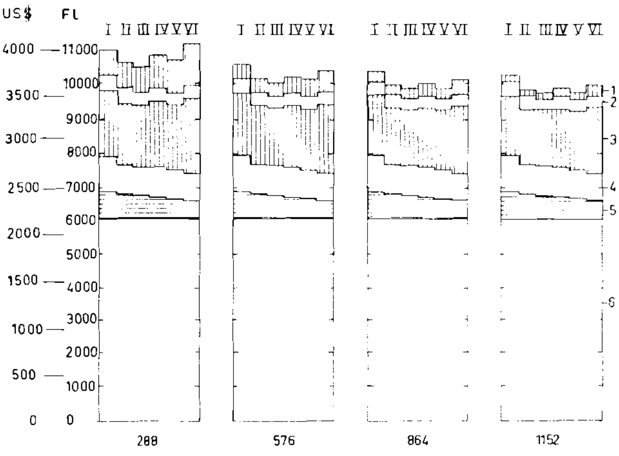

Fig. 1. Main contractor's costs per dwelling for various serial sizes and production methods

I
II
III
IV
V
VI
Production methods

288
576
864
1152
Serial sizes in dwellings

1. Share of fixed costs
2. Interest
3. Labour
4. Management
5. Equipment
6. Materials

For every additional dwelling of the project the building time is extended by one time the work time. The average building time per dwelling is shorter according as the number of dwellings of the project is greater, because the induction time is then divided over more dwellings.

The materials costs per dwelling and the variable costs of the consumption equipment are independent of the production method. The fixed costs of this equipment are proportional to the quantity used simultaneously and this quantity is roughly inversely proportional to the work time. Hence, these fixed costs are higher according as the work time is shorter, thus according as the building units are larger and the work units smaller.

As regards the costs of the consumption equipment and those of management, etc., more equipment and personnel must be present simultaneously according as the building units and work units are larger. However, as large building units have the effect of considerably shortening the work time and the variable costs are proportional to the work time, these variable costs are in the end lower according as the building units are larger. The induction time is also shorter with larger building units; this difference, however, is much smaller. Consequently, we generally see that fixed costs of consumption equipment and of management, etc. associated with the induction time rise when the building unit is increased in size.

As explained above, the labour costs are lowest with a work time of approx. $\frac{2}{3}$ of a plan day.

Finally, a shortening of the induction time and of the work time—thus enlargement of the building unit and reduction of the work unit—causes the loss of interest to become smaller. Summarizing, it is evident that an increase in the size of the building units generally results in:

1. shortening of the induction and the work times;
2. an increase in the fixed costs of equipment and management, etc.;
3. a reduction of the variable costs of equipment and management, etc.

With respect to the results mentioned under 1 and 3 an increase in the size of the work units generally has the opposite effect, but the same effect with respect to the result mentioned under 2.

As the fixed costs bear less heavily according as the series is greater, production methods involving large building and work units, thus high fixed costs, become proportionally more economical with large series. Even then the drawback of higher labour costs remains, so that production methods with medium-size building and work units appear to be the most economical also with large series. However, the differences in costs between the six production methods are fairly small, especially in the case of large series.

Hence, other considerations than costs, e.g. availability of workers or of equipment, desired duration of the building time and the like, might well be decisive.

Government policies and the development of the building industry

By Y. Palm (United Nations Economic Commission for Europe)

Background

One of the most serious problems facing governments all over Europe today is the incapability of the building industry to keep pace with evergrowing demands for construction work of all kinds. In most countries available labour resources have been exhausted and the scope for mechanisation and "everyday rationalisation" of site work has already to a large extent been utilized to raise the capacity of the building industry. At the same time, there are growing demands for industrial buildings and public works, necessary to allow for a further growth of the economy, combined with rising needs for housing and social service buildings such as schools, hospitals, assembly halls, etc.

The sector that has suffered the most from the insufficient capacity of the building industry is often housing. The hard fact is that the present rate of dwelling construction in many countries is not much higher than what is necessary to prevent a deterioration of present housing standards. The production level must in some cases be raised, not by 10 or 20 per cent, but by 200 or 300 per cent, if an acceptable rate of improvement is to be achieved.

Attention should be drawn also to the enormous task of modernizing and maintaining the already existing building stock in order to achieve acceptable qualitative standards. If all resources now spent on new construction were reallocated to the modernization of the present building stock, it would still require between five and twenty-five years to catch up with the backlog in rehabilitating old buildings to an adequate standard. Moreover, substantial and increasing resources in terms of capital expenditure, but particularly of skilled labour, will have to be spent on maintenance and repair. A stage has already been reached in some countries, where more than half of the available building labour force is engaged in this sector of building activity. The demand for modernization and maintenance should not be neglected, since this would create serious economic and technical as well as social problems in the future. It is also important to recognize the close relationship between the standard of new constructions and the expenditure on their future maintenance.

Problems of the building industry

The main problems of raising output in the building industry emerge from the specific character of the building product. The expensiveness, long lifetime and complexity of a building give rise to an almost unlimited variation in demand and to serious problems of continuity in production. The fact that the building is fixed to the ground on which it stands implies a wide dispersal of construction and calls for a mobile industry. In market economies, the demand for buildings is also affected by the ups and downs of economic development and the production process also influenced by the intervention of a number of public authorities. The complex nature of the building creates serious problems of co-ordination and collaboration between a number of trades and professions. The heaviness and bulkiness of the product give transport an exceptionally important role in the production process. Finally, the expensiveness, durability and the long time necessary to produce the building create problems of finance and maintenance and call for long-term planning. Mistakes occurring during the design or production of the building are therefore difficult, or at least extremely expensive, to correct.

The possibilities of increasing the output of construction depend mainly on the availability and productivity of materials, labour, capital and developed land. Seen from the point of view of the building industry proper, materials account for the greatest share of building costs, followed by labour and capital, respectively. Figures on the percentage share of materials in total building costs, however, throw no light on the importance of raw materials in building production but merely indicate the extent to which building operations have been transferred from the building site to prefabrication plants. The main problem of today in most countries is not the availability of building materials but the cost of transporting them. The main way of increasing labour productivity in building lies in the further development of prefabrication implying transport over longer distances. Savings in the transport field cannot therefore be achieved by shortening transport distances but have to be attained through reduction in the volume or weight of materials, or both, and by improvement of transport productivity.

The shortage of labour constitutes the main incentive towards rationalisation and industrialisation of building. Besides a better utilisation of the labour force through continuous production all the year round, the main possibility of achieving a higher production level with the available labour force seems to lie in further rationalsiation and mechanisation of building operations, the transfer of operations from building site to factory, better supervision of site work and better work planning and control. Favourable results of such measures have already been attained in the post-war period and further improvement could be expected.

The capital intensity in the building industry is low in comparison with other industries. This is, however, partly due to the fact that much of the investment in building production is put in the building materials industries rather than in the building industry proper. Since in the last decade much of the site and transport operations have been mechanised, this development could be expected to accelerate further.

Over-all responsibilities of governments

The first main responsibility of governments in the building field is to make sure that construction of all kinds is acceptable to society from the point of view of health, safety, fire protection, appearance, dimension, location, and so on. Building by-laws and regulations on a local, regional and central level exist in all countries. In many countries, the diversified and restrictive character of these regulations constitutes a major obstacle to technical progress in the building industry. It is necessary, therefore, to reconsider, reformulate and extend the coverage of these building regulations with a view to setting up national building codes based on performance standards. Governments can also substantially contribute to the development of the building industry through organizing or promoting research and development work in the building field, as well as by providing objective testing service and facilities for approval of new materials and methods.

Apart from the measures aiming at securing adequate quality of buildings, governments should also make sure that sufficient means and physical resources are being devoted to housing construction to prevent this sector from being squeezed out by the demand for other buildings and works of a more "productive" character. This can be done by central planning, building licensing, financial or tax incentives, etc. In market economies, it is important also to make sure that total demand for construction does not extend the capacity of the building industry, which would lead to inflationary rises in wages and prices.

Governments can also actively promote better production conditions, higher labour productivity and better economy in building production through the concentration and pooling of demand, the typification of design based on research into functional requirements, and the standardization, dimensional co-ordination and mass production of building components. Results in this field will also considerably increase the possibilities for internal and international trade, implying a wider choice and a stable price level.

Promotion of labour productivity

Whatever divergences of opinion might exist between different countries as to the necessity and scope of government intervention in the building field, there is a concensus of view that the production of buildings must increasingly adopt industrialised methods. This was concluded at the ECE Seminar on the Building Industry, held in Prague in 1964, where "it was unanimously agreed that the industrialisation of building is necessary to overcome the gap between the needs of society and the capacity of the building industry. Recognizing this, the Seminar also agreed that it would be useful to develop all other methods of building in order to expand building capacity according to demand." [1]

But to define "industrialised methods" of construction as distinguished from other methods is not an easy task. It would seem, however, that the objective of all government measures in this field is very much the same, namely, *to promote the production of more buildings with the same amount of labour and without increase in building cost.* Some countries set themselves a slightly more modest goal by aiming, in the first instance, at reducing labour consumption per unit on the building site, while others are more ambitious and strive to attain not only less total labour consumption per unit but also substantial savings in building cost.

Common to all countries are the efforts made to improve labour productivity. This can be achieved, first of all, through the application of industrial principles of organization, i.e. the production in series of identical products under the responsibility of one single body, and the application of specialization in the production process. Secondly, higher labour productivity may arise from the use of more advanced production technology, i.e. a substitution of the production factor capital for labour: this amounts to an increased degree of industrialisation. Finally an improvement in labour productivity can result also from rationalisation and training, i.e. from small ameliorations and adjustments in organization and equipment and from increased capacity in the labour force, without any change in the principles of the production process.

Industrialisation of building production

If the building is chosen as the object of industrial production, it follows that a set of production lines have to be established, each line specialized in manufacturing in series one specific type of *identical buildings.* It also follows that the planning, organization and execution of all the different stages in the production process of each system should be assembled under the responsibility of one single body.

Organization of production in this way facilitates close collaboration between the different specialists engaged in the same production process and ensures a rhythmic output. Moreover, since all the co-ordination required, physical as well as organizational, takes place *within* the same enterprise, each such enterprise can work highly independently. There is no need, therefore, to come to countrywide or regional agreement as to the co-ordination in terms of dimensions and joints between components used in several parallel production processes. Furthermore, it is possible to achieve a very high degree of prefabrication, because the size, equipment and level of finishing of the building components will be restricted only by the transport facilities available.

On the other hand, the degree of industrialisation of each production line will be determined by the length of the series of the particular building type produced. Even if demand is unified as far as possible, by means of typification of design, and fed continuously into the industry through big collective client organizations, the unavoidable dispersal of building activity, combined with the difficulty of transporting large building components over long distances and the variety of needs for different types of building serving different purposes, will – to some extent, at least – restrict the possibilities of achieving long series of production. There is also some danger that too little attention will be paid to the continued pursuit of technical progress, because all concerned devote their energies to the execution of current tasks. Often, too, the single producing enterprises operate on a scale too small to permit optimum mechanisation in all the branches which they represent, nor may they have the equipment to undertake all the experimental work required.

Bearing these circumstances in mind, it seems natural to consider the possibility of using the *building component* as the starting point for efforts to increase the degree of industrialisation in the building branch. If this approach is adhered to, it can radically increase the scope for producing a wide variety of buildings without unduly impairing efficiency in the production process. According to this alternative, efforts are concentrated upon achieving production runs, of as long a duration as possible, of *identical components.* This can be attained by making components as far as possible universally fit for use in different types of building and through a strict limitation of the variants permitted for each type of component.

So far, efforts in this field have mainly been directed towards the standardisation of expensive and/or easily transported components or equipment which do not create too serious problems of co-ordination. It is recognized, however, that substantial savings of labour on the building site cannot be achieved unless open prefabrication is extended to include large structural components. Theoretical, organizational and technical problems connected with the introduction of standardised structural components have long been studied at a national and international level. It appears that the solution of these problems is now within reach and the time is ripe for a major advance. Thus, all countries are now engaged in finalizing national rules and recommendations on dimensional co-ordination in building.

There is no doubt that at the point when "closed systems" of housing prefabrication were introduced in different countries, they frequently amounted to a revolution in labour consumption, particularly on the building site. In their more advanced forms, closed systems sometimes required no more than half of the manhours per dwelling called for in "traditional" construction. It is significant, however, that in closed systems of prefabrication once the organization and principles of the system have been established and the production machinery set in motion, it becomes very difficult to make radical changes in the production method and economically wasteful to do so. In order to amortize the production machinery, it is normally necessary to produce 1,000 to 2,000 dwellings per year and to maintain this production rate for at least five years.

As time passed, the more flexible methods of "traditional" construction steadily attained higher productivity through rationalisation and mechanisation and through extended use of openly produced standardised components. In this way the difference between the labour consumption of the two methods diminished, and the size of contract where the two approaches achieved the same total labour consumption steadily increased. The big jump in this development took place when standardised and mass-produced components were introduced for structural purposes. This step has already been taken or is on the way in all the socialist countries of eastern Europe. Strenuous efforts in the same direction are being made in western Europe too and in some countries the manufacture of modular structural components has already begun.

Looking to the future, it may be of interest to quote some of the conclusions reached at the ECE Seminar on Changes in the Structure of the Building Industry held in Prague 1964. "The great value of 'closed' systems of industrialised building is recognized. It could be expected that they will continue to be used in the foreseeable future. At the same time, the needs of society call for the greatest possible flexibility in the design of buildings. In the long term, these needs can best be met by 'open' or 'catalogue' prefabrication. It is expected, therefore, that the two approaches will exist side by side for many years to come. It is possible that the long-term trend would be towards the use of interchangeable factory-made components." [1]

It is unlikely that the extended use of openly prefabricated components will completely squeeze closed systems out of the building market. But their share of the market will be restricted to a limited number of frequent building types which are suitable for production in very long series. This means that closed systems will have to concentrate on large contracts in big urban centres or they will have to develop building methods based on very light materials, enabling them to market their products more independently of transport distances. The possibilities in the latter respect can already be seen in the manufacturing of detached singlefamily houses made up from plastics and aluminium (the Netherlands, Western Germany) or wood and lightweight concrete (Finland, Sweden). The use of such methods has already given rise to some international trade in fully prefabricated buildings.

Rationalisation, mechanisation and repetition

Apart from the more radical policies aiming at an increased degree of prefabrication according to industrial principles, labour productivity in building could also be substantially improved through the promotion of better organization, rationalisation and mechanisation of transport and site operations. As to the promising results which could be obtained through proper organization of repetitive site work, reference is made to a specialized ECE study recently published: "Effect of repetition on building operations and processes on site". [2]

Conclusion. All the measures discussed above, involving a much better organization and a much higher capital intensity in building production than hitherto undertaken, will not only contribute to a substantial increase in the capacity of the building industry but will also stabilize building costs and in the long run perhaps even decrease them. Governments have a pivotal role to play in this development.

References

1 "Proceedings of the Seminar on Changes in the Structure of the Building Industry, held in Prague in 1964". (ST/ECE/HOU/13), United Nations, 1965.
2 "Effect of Repetition on Building Operations and Processes on Site" (ST/ECE/HOU/14), United Nations, New York, 1965.

Group B
Integration of Design and Production

Final report from the group rapporteur Dr. J. C. Weston, Director of the Building Research Station, United Kingdom.

It has become one of the accepted cliches that industrialisation involves, among other things, the integration of design and construction; rarely, however, are the possibilities, problems and consequences of this integration considered.

Traditionally, the industry includes three more or less distinct parts: – the materials and component producers, the designers and the builders. Separate from the industry but interacting with all its parts is the client, and as we move towards industrialisation, it becomes increasingly necessary for us to take a synoptic view and to consider not only the industry itself but the consequences to it of actions by its clients. Each of the main groups within the industry is complex in itself and there is some measure of overlap between them. But the increasing attention being given to industrialisation as a means towards increasing productivity has emphasised more sharply than has hitherto been realised that the decisions of architects or component manufacturers can have serious consequences on site productivity. It is easy to suggest that if the architect were made more aware in his training of the problems of site construction, the problem would be solved, or again, if the component producers employed more architects, or if there was more use of an all-in service. Indeed, there are those who suggest that the vertical integration of the industry could provide the complete solution, (that is, having one organisation responsible for design, production of components, and site erection). But this form of organisational integration does not exist in advanced industries like electronics, motor cars, or aircraft, where there is a high degree of job specialisation.

Even if a degree of organisational integration comes about and designers and builders are part of the same team, certain basic problems remain. The groups engaged in the construction industry all suffer from what the French call "déformation professionelle"; that is, they see the world and the buildings in which they are concerned in very different ways. The architect is dealing with layout and the relation between spaces; with the functions that are to go into them and with the components that enclose them. In considering costs, he thinks of the various elements, wall, floors, partitions, services, that make up the building. The builder on the other hand, dealing with precisely the same building, sees it as a series of operations and activities to be carried out in a proper sequence. His crucial problems are the supply of site supervisors and the organisation of the work. The information that he gets about costs is related to work operations rather than to constructional elements.

Not only do the designers and the builders see the world differently, but they are trying to maximise different and conflicting things. The architect, for instance, designing a housing scheme, needs a good deal of variety of plan forms in order to meet the social needs of the future occupants. He needs variety to meet the varying conditions of sites; he probably demands more variety than he actually needs, but this is by the way. The builder and the component producer on the other hand abhor variety. They want long runs to provide the repetitive use of a limited range of standard items in order to achieve the very real savings that come from repetition. This conflict has to be resolved by a compromise, which is not made any easier by the different "languages" in which the dispute is conducted.

We are, therefore, faced, in encouraging the integration of design and production, with serious problems of communication. We need better ways for the designer to communicate his intentions to the builder; we need better feedback of information from the builder to the designer and from the component producer, and we face the problem that although they all speak about the same things, they use different languages to do so.

How then is this language barrier to be broken down and the conflicts between design needs and production needs to be overcome. One of the most powerful tools for this is, of course, the process of development. By this I mean the organisation by the client of his work into a large and continuing programme which can justify the setting up of an inter-disciplinary team to make a thorough study of the needs; to produce type designs; to build them and to modify them in the light of user and production experience. Such development brings about a high degree of integration of the various parties to the building team, and frequently it includes the client or someone representing him so that this needs may be fully considered.

In order to develop more precisely some of these points in the light of the papers submitted, and the discussion at the Congress, it will be useful to consider the problems under various headings:

1) The overall view
2) the role of the client
3) Development
4) Communication
5) Conflicts
6) Research

The overall view

One of the most important ways in which we can bring about the integration of the various facets of building, is by showing the participants how, frequently without realising it, they interact on one another. Network analysis has provided us with a powerful tool for this purpose and is encouraging workers to look increasingly at the whole process and at all the things which must be done by the participants from the conception to the completion of the project. A good example of this is provided by K. Hiraga and O. Furukawa (Japan, A.3.).

Another important aspect of the overall view was provided by P. Hillebrandt (U.K.) who, speaking as an economist concerned with policy formation at government level, stressed the need for better information about the resources needed by different forms of construction. Such information must be detailed and show, for instance, the particular types of manpower required -carpenters, plumbers, bricklayers, ; comparisons expressed in money terms are not particularly helpful.

Another economist, E. Verniers (Belgium) emphasised that if building was to catch up with developments in other industries it was essential to coordinate efforts between designers, producers and clients. He pointed out that the automobile industry was far more self-contained than building without having become a "closed system" lacking in variety.

Role of the Client

The client provides the framework within which the industry operates and if he realises the importance of scale and continuity of production, he can do much to provide a situation in which productivity can be increased and costs reduced. Interesting cases of client involvement are provided from several countries and are reported in the papers of M. Kjeldsen (Denmark, A.5), W. J. van Nieuwkerk (Netherlands, B.14) and V. Jurik (Czechoslovakia B.11). The advantages which can be gained are real enough. There is, however, not always as much appreciation by the clients of the possibilities as there might be, a point well made by J. van Ettinger (Netherlands B.5).

He states: "Continuity in the building process can only be obtained if the central, regional and local authorities allot and clear the necessary building-areas in time and create, perhaps together with private investors, the financial possibilities of that timely acquisition of land, of site preparation and of building itself.

Long-term development planning is necessary, a realistic policy in the sphere of saving and investing (quality level!) a physical planning to avoid waste in the use of land, and a building policy aiming at continuity together with a corresponding financial policy".

Development

Continuity of production facilitates the devotion of resources to development so that the barriers between design and production can be broken down and woven together towards a commonly acceptable solution. V. Jurik (Czechoslovakia B.11) sets out very clearly, the form which development usually takes.

"1. On the basis of the results of social research in the field of capital construction, and research in the field of the material basis of construction, preliminary studies (designs) are prepared.

2. These preliminary studies are utilized for the preparation of experimental designs to be used in experimental construction in which the function of the building is verified from the viewpoint of performance as well as from that of the technical characteristics of its individual structures.

3. Evaluated experience from experimental designs and sites supplemented with an economic balance of the means of production, decisions pertaining to the components, structures and technologies to be used and the price limits is used for the specification of a typification problem.

4. On the basis of the approved typification problem typified designs are prepared. Simultaneously the material and production basis is built up so as to be completed at the time of approval of typified designs.

5. Approved typified designs are verified in the so-called verification series of buildings built on the basis of the new typified designs. The construction must be evaluated and the experience gained used for the improvement of typified designs.

6. Finally mass construction of buildings based on the new typified designs is ensured."

S. A. Roe (U.K.) pointed out that this development process requires a thorough study of all aspects of a design and its production consequences; materials, manufacturers, handling, storage, transport, erection sequence and methods. A particularly significant insight to the process was provided by R. Tucker (U.K.) who felt that the aim in development must be to identify those elements which are "creative" in the design and those which are "routine"; to separate in fact, the tools of design (its routine elements) from their use. E. Levin (U.K.) distinguished between the problems of designers of components and the designers of buildings. The former has to consider the functional requirements of his particular part of the building and the production problems of the manufacturer, while the latter is concerned not only with the functional problems of the components but also with the requirements of the building as a whole and with the inter-relation between components produced by many designers.

A particularly interesting example of the application of these ideas in practice is provided by a school development project described by Ward (U.S.A. F.34). In this, most of the participants' roles had been changed without affecting their status. Other cases deal with the development of particular components; A. M. Gear (U.K. B6), H. Rettig

(East Germany B.16). In his paper, Gear emphasises particularly the merits of continuous development in providing a feedback of information, a point further made by R. Hugsted and R. Wiig (Norway B.8).

Several other examples which arose in discussion illustrated the widespread nature and different ways in which this development process can operate. In example Auberbach (Canada) outlined the development of a highly specialised air traffic control facility requiring consideration of architectural, structural, economic and functional aspects. A. H. Anderson (U.K.) showed how a commercial concern had been able to integrate technical design of industrialised building with construction. His organisation functioned quite specifically as developers of the system and provided a design service to architects and production advice to builders without, in fact, engaging directly in either the manufacture or erection of components.

A feature of development in relation to specific building types is of course that it facilitates the evolution of type plans. The development process, related as it is to a continuing programme of work, enables the social needs to be studied in detail; designs to be produced and then by the feedback of information both from the builder and from the user, alternative, modified designs can be produced. The continuing nature of the process is emphasised by S. Janicki (Poland B.9) and V. Jurik (Czechoslovakia B.11).

But who ought to take part in the development process? It is clear from the papers that different situations have produced different groupings, but it is evident that someone experienced in costing is an essential member of the team. This point is discussed by J. A. Denton (U.K. B.3). The increasingly important role of the services engineer was made by Mulcahy, (Ireland) while Burgess (U.K.) felt that there was need to train production orientated architects rather than having production staff directly in the team.

Communication

The improvement of communication between design and production is probably the greatest single step that can be taken to encourage improved productivity. That its importance is realised, is emphasised by the number of papers which deal either directly or indirectly with it. A significant contribution is made by J. C. Jones (U.K. B10). In discussing systematic design methods, he comments that they "are intended to make the design process more public so that a number of persons of differing experience can collaborate more readily in the design of complicated projects." He goes on to point out the far reaching consequences which such methods might have for instance in "altering the architectural design schemes so that many of the decisions at present made in the form of sketch design are deferred until the human requirements, structure, services, insulation, site and constructional problems have been accepted in stages and mutually adjusted."

This paper in fact stimulated particular interest. S. D. Kaplan (South Africa) had used precisely the same method in a recent project. P. Mouterde (France) enlarged on the ideas presented and it was clear that the study of the design process as an operational system would repay further study.

More directly related to the problems of integration is the question of drawings. What sort of drawings should the designer send to the site? S. Tyren and H. Akerblad (Sweden B.18) stress the need for the design to be related to production methods, and the same point is considered by H. Ritter (Switzerland C.19).

Contract documentation generally, is of course, an important form of communication and its problems are discussed by L. Ranhem (Sweden A.7), J. Coiffard (France C.4) and F. Nielsen (Denmark C.14).

The development of electronic data processing has opened up new possibilities of communication, and just as it is possible to translate languages by computer, so it may be that the computer can provide the bridge between the "Weltanshauung" of the designers and the builders. So far only the first steps have been taken in this direction. Its importance is stressed by C. Ugander (Sweden C.23) and in more detail by B. Bindslev (Denmark C1.).

Conflict

I indicated earlier that interaction between designers and producers is essentially based on a "love-hate" relationship. The conflict between variety and variety reduction is real, but it is frequently further complicated by conflicts of personality. Fortunately there is no indication of this in the papers to the Congress but there are several forceful notes on the problem by architects J. Duret (Switzerland), M. Gout (Netherlands), A. G. Heaume (France), and J. H. van den Broek (Netherlands) and members of the Union Internationale de Architects (B4), and in the colloquium of the U.I.A. (B.19). That a fair balance can be struck is indicated by L. Bergvall (Sweden) and E. Dahlberg (Sweden F.2). A very useful discussion of the nature of the problem particularly in relation to the design of large panel construction is provided by K. Lachert and T. Perzynscki (Poland B.12) and on a more theoretical basis by Z. Kleff (Poland B.13).

This section of the subject stimulated a number of participants to point out the need to consider the training of the architect—D. A. G. Reid (U.K.), L. M. Migone (Argentina), B. C. L. Christianes (Belgium). A most effective cry from the heart about architectural training came from Ben Sira (Israel) who could not see the need—or rather saw great danger—in the "cocktail designer" who was a mixture of architect, engineer, town planner and builder. He saw the need for integrated personalities who, while still specialised had "a humility as a prerequisite for a thirst to learn, respect for other disciplines, trust in other members of the team and submission to leadership towards betterment and improvement of man's surroundings". He was less concerned to assert the right of the architect to lead the building team and felt that leadership was a matter of personality rather than particular calling.

Research

Clearly the C.I.B. Congress must serve, among other things, to identify problems requiring further research and development. The papers and discussion suggest that more work is needed on

a) The overall study of the process of design and production by the application of techniques of network analysis on the broadest scale.
b) The resource requirements of differing methods of design and construction.
c) The role of computers in communicating information.
d) The operational study of contract documentation; its content and requirements.
e) The study of the operational consequences of design decisions in production in order to feed back information to the designer.
f) The operational study of the design process.
g) The role of the component producer and industrial designer.
h) The architectural problems of producing adequate variety from a limited range of components.
i) What do we mean by 'variety' in components from the viewpoint of manufacture?

Summing Up

In our papers and discussion about the integration of design and production we recognised clearly that as we move towards industrialisation there can be no iron curtains between the various participants in the building process, the designers, the producers of materials and the builders themselves. It was clear that many people are beginning to see the building process as a coherent system and to recognise the importance of development as a continuous process with a constant appraisal of achievement and feedback of information at all stages. This can, we feel, be one of the most important ways to the better use of resources and to improved productivity.

Some of our members saw the need to rethink the training of architects, engineers and builders so as to bring about a better understanding of each other's problems and potentialities. Indeed we came, I think, to agree with Ben Sira that we needed as much as an integrated process, integrated personalities who, while remaining specialists in their own discipline had sufficient breadth of vision to respect and understand their colleagues in the building team and to collaborate with them effectively.

We saw that in a changing world in which our industry operates we must be prepared to accept new roles and even changes of status in the interest of optimizing the whole structure.

As research workers we strongly appreciated the need for more research studies – for better operational understanding of the processes of design and construction and of the consequences of interaction between design and production. We need to understand better the problems of bringing the marriage between the social and architectural need for variety and the manufacturer's need for variety production. But above all we saw that research too must change if it is to be relevant to the problems of to-morrow – not yesterday. Kierkegaard once spoke of the man who woke up one day to find himself dead without having lived! If, as research workers, we do not keep the direction of research changing with the needs of the times, we may wake up one morning to find the world has been rebuilt without us.

Influence of new production methods on site, on design under local conditions

By Y. Ben Sira (Israel)

Israel is a developing country with a considerable range of building production methods, from the conventional and the partly mechanised for vertical haulage, to the fully mechanised sites, including cranes of considerable variety of performance and application, also sites provided with properly designed concrete mixing plants, mechanically fed, hauled and placed into position, as well as three regionally-located ready-mix concrete plants within reasonable distance from centres of building activity. There are also semi-industrialised production methods, combining use of large panels with special facing, cast, cured and stored on site and hauled into position, together with transverse vertical supporting walls cast in situ in special steel precision formwork, while haulage and placing in position of both large panels and extensive formwork is carried out by suitable cranes.

Naturally, this large range of methods is also accompanied by a corresponding range of quality of direction of operations, from the intuitive reflections of the foremen on site, through conventional time-tables drawn up by the contractor, to the elaborate processing of direction, by charts, of flow of materials and operations, by one of the accepted modern chart methods.

There is also the beginning of industrialised production of large and small elements, especially for housing to be assembled on site, —two already in operation, with three more shortly to begin production. At present, 60% of all housing is directly produced, sponsored or financed by Government agencies, and 40% by private enterprise. The position, at present, is as follows: of the 40.000 dwelling units built in 1963 (16 per thousand of population) 75% are of the partially mechanised, essentially conventional construction (mainly Govt. housing), 20% are of fully mechanised production (mainly used in private enterprise and in the execution of large Government contracts), 5% are of assembled housing (Government sponsored only) and partially industrialised, combining site-prepared panels and in situ cast walls, used both in private enterprise and in Government large contracts.

A recent comparative analysis of labour hours per square meter, is given as follows:

Total work-hours per square meters

	pre-fabricated	Partially mechanised	Fully mechanised
a) Skeleton, incl. plastering	3.92	11.76	9.56
b) Finishing works	3.73	5.70	5.66
c) Administration and Miscellaneous	1.02	2.72	2.72
TOTAL	8.67	20.18	17.94

The projected plan for the next five years, envisaging a growth of housing production of 8% per annum, aims to the following distribution of production methods:

- 20% partially mechanised (vertical haulage only and use of somewhat primitive concrete mixers);
- 60% fully mechanised, as described above
- 20% assembled and industrialised on site.

Naturally, the higher the mechanisation and industrialisation, the higher the percentage of scientifically directed production.

Estimated expected annual growth of population is 3.5%, half by immigration and half by natural growth. Present number of building operatives is 80,000—nearly 10% of total employment and it is expected to grow at the rate of 3% per annum, with anticipated considerable turnover, as skilled operatives and foremen are attracted to the other industries, while large proportions of unskilled immigrants are attracted by higher wages in the building trade.

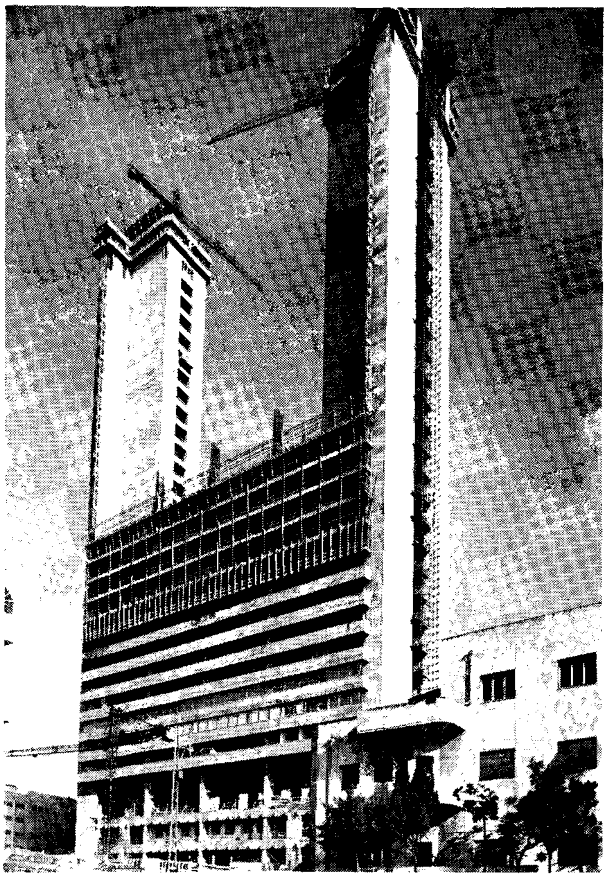

Fig. 1. Migdal Meir skyscraper; a Rassco project.

Estimated overall increase of productivity is about 10% per annum, in the next 5 years by ever larger numbers employed, increasing higher percentage of mechanised and industrialised production as given above, and introduction of standardised elements and more rational direction of operations.

Now as to effect on design, considerable progress towards industrialised building and modular construction, or, at least, dimensional coordination can be noted in a number of factories. However, as regards housing, a number of unfavourable factors are to be taken into consideration:

- the conservative attitude of the consumers, on the one hand, with their main objections directed against inflexibility to space changes, in case of precast walls, units or large panels and against functional inadequacies such as increased condensation or noise, or difficulty of driving nails into walls for pictures or the like. There are also emotionally based objections to larger groupings on the grounds that they blur individuality;
- industrialisation and mechanisation require high degree of repetitive use of formworks, precast elements, standardised dimensions, etc..., all tending to emphasize monotony of environment, especially noticeable in new areas only partially developed;
- difficulties of enforcing standardisation in a pluralist and dynamic society for fear of loss of individual recognition;
- the policy of directing accruing population to outlying areas, leads to greater geographical dispersal of building sites, thus hindering opportunities to concentrate large projects whose variety of grouping might eventually save them from monotony, while insufficient development works leaves environment at least temporarily, emotionally unsatisfactory;
- private enterprise pandering to higher income consumers' tastes, often combines highly mechanised equipment to impress prospective purchasers, with low effectual use of plant, to conform with current fashions of large living-rooms (floor cast in situ).
- The greatest difficulty lies, however, in the unresponsiveness of the designer or the architect, to the challenge of modular construction, requiring joint efforts between constructional and

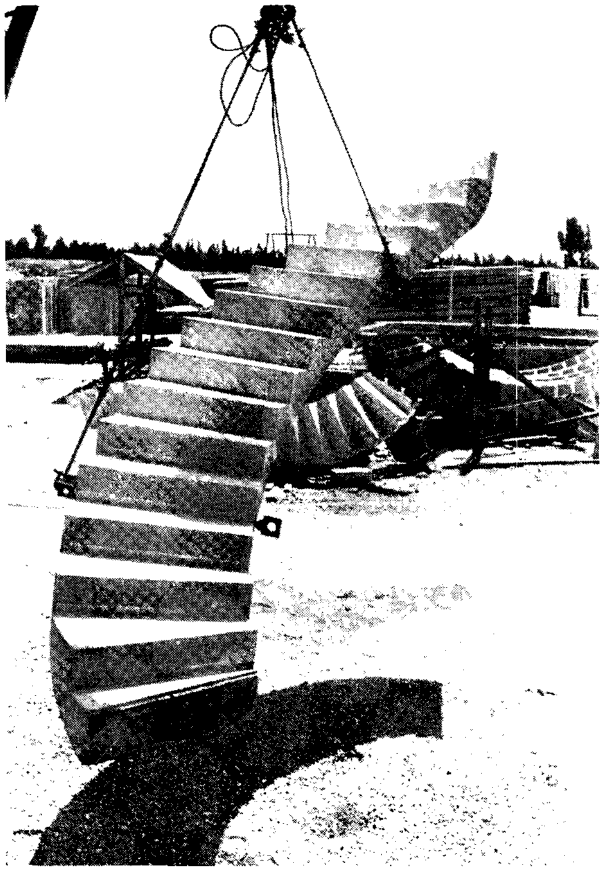

Fig. 2. A prestressed staircase; produced by the Mabat factory.

production engineer, on the one hand, and the architect, on the other hand, with carefully worked out plans for efficient production of emotionally and functionally satisfactory housing, breaking away from monotony.

– there is further the lagging in enforcement of standardisation by overworked Government offices, inadequately staffed, the paucity of means allocated by Government and industry for research, and lack of well trained technical personel and machinery.

– on the other hand, Government responsible for 60% of the housing activity, should be in a position to enforce standardisation of many elements and demand from contractors higher mechanisation with competitive time-table and scientifically directed operation, as well as gradually bringing up to the required quota fully industrialised building.

In spite of all those disadvantages, the following progress can be recorded:

– considerable degree of joint architectural and engineering effort in design instead of mere engineering virtuosity, applied to pre-conceived architectural design;

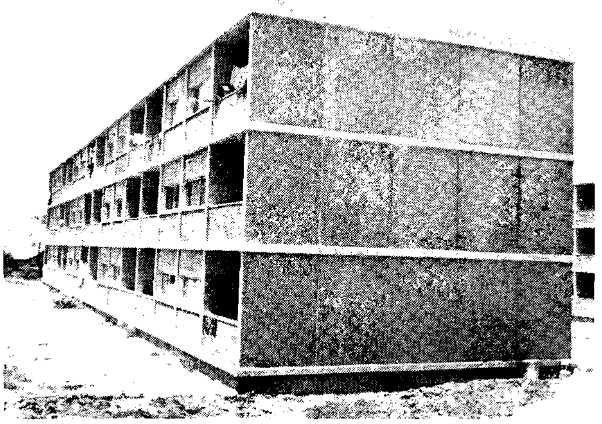

Fig. 3. Prestressed popular housing; a Mabat project.

– introduction of standardised formwork in raised lower flooring, in swelling earths;

– introduction of prestressing in treacherous soils to obtain more determinate substructure, even in popular housing, using prestressed beams over two parallel rows of piles, to support three and four storey buildings;

– introduction of metal or sheeted formwork with adjustable telescopic supports, as well as raised formwork in silos or services' towers in tall buildings;

– recently recommended standard sizes for doors and windows in Government built, sponsored or subsidised housing, and a change over from timber to aluminium and, recently, to plastic shutters;

– standard stairs or floor cement tiles to be enforced in Government housing;

– placing large contracts over protracted periods, to encourage installation of mechanised equipment and use of standardised elements, precast on site;

– increasing quota of fully industrialised building for assembly on site;

– facilities for import of mechanical equipment (however, indiscriminate variety unfavourably reacts on maintenance and there are also considerable losses of idle time, and inadequately exploited plants);

– proposed central depot of mechanised equipment for hire, as recently advocated by the Contractors and Builders Association, might prove far more effective;

– encouragement of central concrete mixing plants and proper equipment for supply of ready-mix concrete to site.

An analysis of survey findings proved cost of haulage on site, especially horizontally, to be very high indeed, in all types of production. In a recently analysed mechanised project, the following haulage quantities were performed by a suitably selected crane. (In a three-storey house – 12 dwelling units – 2 staircases).

Principal materials of construction	Utensils used for Transport	Maximum Capacity of Utensils	Quantities used in project
Concrete	containers	0.5 m^3	170 m^3 (30% in foundations the rest in skeleton).
Iron	cable or platform	0.5 ton	9 tons (10% in foundations)
Structures	cable	120 m^2	650 m^2 (mostly in skeleton)
Cement (construction, plastering and tiling)	containers	0.5 m^3	80 m^3 (10% in skeleton)
Blocks	baskets	0.5 m^3	160 m^3 (id.)
Floor-tiles	baskets	12 m^2	600 m^2 (finishing works).
Carpentry	cable or platform	20 pieces	200 pieces id.
Stairs	id.	2 pieces	70 pieces id.
Pre-stressed elements	id.	10 pieces	100 pieces id.

The crane, together with other mechanical means of production, further provides flexibility and adaptability to use of new materials and the increased use of a lengthening list of precast elements and is especially adapted for hauling and placing in position of large scale formwork, in most types of buildings, as well as in spatial roofing. The crane proved, therefore, the greatest incentive to influence designs for greater use of repetitive elements, leading eventually to dimensional co-ordination.

The conventional timber formwork gradually gives place, as already mentioned, to more permanent formwork at least clad with metal sheeting, especially where timber is scarce and skilled manpower expensive, leading to standardised formwork for repetitive economical use; combined with proper haulage facilities, this also must lead to dimensional co-ordination, especially, on partially industrialised production methods on site.

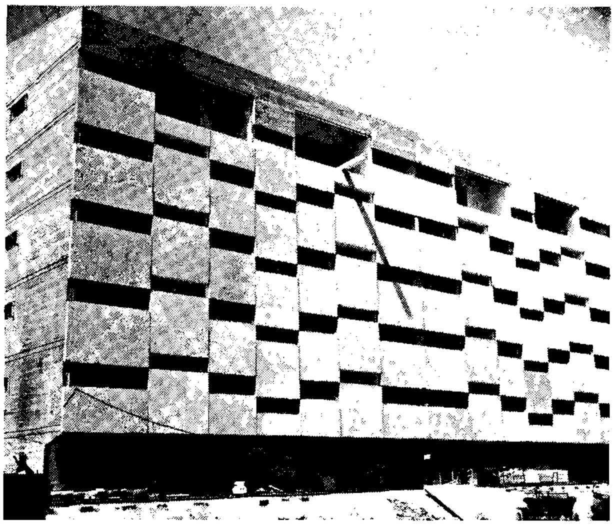
Fig. 4. Precast panels; a Rastrum project.

In a recently analysed housing project of 3 and 4 storey buildings, concrete presented 35—40% of total cost of skeleton. The formwork costs' break-up was as follows:

	Pillars	Walls	Beams
1. Cement	17%	27%	25%
2. Aggregates	8%	13%	12%
3. Costs of preparations and casting in situ	15%	14%	13%
4. Formwork	60%	46%	50%

10% economy in formwork shows, therefore, a 4 to 8% saving in cost of concrete. Recent experience proved that in standardising formwork and using durable materials and facings, savings can be as high as 50%, thus resulting in saving some 20—30% of cost of concrete or 8—12% of overall costs of skeleton.

Conclusions. The definition "towards industrialised building" taken in its broadest sense, namely, the introduction of a rational approach to production, entails, inter alia:

a. joint planning by architect, constructional and production engineer, as mentioned above;

b. use of Government sponsored or subsidised housing and of all mortgage organisations, for the enforcement of standardisation and rational production;

c. encouragement of independent research, financed and sponsored by the Government, the Industry, the Building Operatives Association, the Housing Associations and Contractors Associations and the Association of Engineers and Architects of Israel, who might be all represented on the Board of Governors of this Research Organisation, which should, however, be set up as an independent body for co-ordinating Research, Standardisation of Building elements, dimensions and practices, and engaged in the propagation of knowledge on the lines of the Building Centre of Rotterdam, or similar organisations, elsewhere.

B 2

L. S. Blake

Control in the production of concrete units for industrialised construction

By L. S. Blake (U.K.)

The main requirements for precast units in industrialised building are:

dimensional accuracy—to enable units to be interchangeable, and easy to fit together and to ensure that joints between them function correctly and are of satisfactory appearance

strength and durability—during handling, transporting and erecting as well as throughout the life of the building

quality of finish—to produce a uniform and high quality finish to external walls and a finish ready, without other preparation, for decoration on internal surfaces.

Effective control requires well trained personnel who are aware of the designer's requirements and who fully understand the factors, such as variations in materials and in the processes themselves, which affect the quality and uniformity of the final product. A considerable proportion of this paper, therefore, is devoted to discussing the various factors affecting quality. The author has drawn widely upon the experience of others in several countries, but the section dealing with quality of finish is based mainly on recent research by the author and his colleagues[1].

Dimensional accuracy

Before the details of a building can be finalized, the designer must decide the tolerances that must be achieved in manufacturing and erecting the components. It is important that the tolerances be realistic and no closer than strictly required; it is sometimes argued that components made to fine tolerances are easier and cheaper to erect, but this is not true if realistic tolerances have been applied at the design stage.

It is uneconomic and theoretically impossible so to control the production of units that every dimension of every unit will fall within the specified range. This is because nominally identical dimensions vary in such a way as to approximate to the Gaussian or normal distribution. For example, if the standard deviation for a series of measurements is 2 mm., 68% of the units can be expected to be within ± 2 mm., 95% within ± 4 mm. and 99.7% within ± 6 mm. of the mean. It is sometimes suggested that the tolerance should be three times the standard deviation because theoretically this implies that only 1 in 300 units need be rejected. In practice, the rate of rejection would be considerably greater because each unit must comply with the appropriate tolerance in each of three co-ordinate dimensions and such additional factors as angularity and warp must also be taken into account.

TABLE 1. Suggested tolerances—based on existing published information (from "Joints between precast concrete elements"—a thesis by Jan Halvorsen, Birmingham School of Architecture)

	Type of Production		
	on site	in factory	in highly mechanized factory
Mould tolerance	± 3 mm	± 1.5 mm	± 0.5 mm
Production tolerance	± 8 mm	± 5 mm	± 2 mm
Erection tolerance	± 6 mm	± 5 mm	± 4 mm
Total tolerance	± 10 mm	± 7 mm	± 4.5 mm

Mould tolerance refers to the accuracy asked from the carpenter or fitter

In order to determine the standard deviation for a production, at least 100 components should be measured to an accuracy within 10% of the range of differences between components. Only a limited number of such measurements has been published for the production of large slabs but, from these measurements, suggested tolerances have been derived and are given in Table 1. Scandinavian experience suggests that, for a given method of production, tolerance is independent of size within the range 50 cm. to 300 cm; in East Germany, however, proposed standard tolerances increase progressively with the size of the unit.

Factors affecting dimensional accuracy: The main sources of error in dimension are: errors in the mould dimensions at the time of casting, errors due to incorrect filling of the mould, and changes in dimension of the unit after compaction in the mould.

Dimensional accuracy is largely dependent upon the design and manufacture of the mould; it must be sufficiently rigid to ensure against deformation due to pressure of concrete and due to handling in the factory. It is also important that all mould parts be rigid so that they do not have to be forced to fit together and that joints be designed in such a way that errors during assembly are obvious. It is preferable for mould parts to be handled mechanically during stripping and assembly operations to reduce the risk of damage. Before each casting, a thin film of mould oil should be applied to all mould surfaces, including those butting together at joints, in order to eliminate the need for rough cleaning treatment which might damage the mould.

Vertical casting moulds should be designed on the basis of limiting deflection for a pressure equivalent to the full hydrostatic value. In practice, the actual pressure will be lower than this value because of arching effects but the hydrostatic value will provide an adequate safety factor. For the most accurate production, steel moulds or steel and concrete moulds are essential. Timber moulds may be used for less accurate work, although they should be faced with steel and the timber impregnated to limit dimensional changes due to changes in moisture content. For production lines giving tolerances in the order of ± 5 mm. or more, there is some evidence that the effect of the difference between steel and timber moulds is small compared with that of the quality of control.

The effect of variations in filling is important for units cast horizontally where considerable skill is required to maintain the tolerance in thickness. For units cast vertically, similar care is required to ensure accuracy in height. Final screeding of these surfaces must be done some time after completion of vibration so that the effects of slumping can be corrected.

Changes in dimension due to shrinkage and temperature can be of the same order as that of the tolerance but variation beween similar units due to these changes is extremely small. The manufacturer must allow for these changes when deciding upon the nominal dimensions for the mould and the dimensions of a unit should be related to its age and temperature. The degree of warp in a panel is mainly dependent upon the manner in which the unit is cured and stacked. Any heat used in curing should be applied symmetrically and every effort should be made to provide uniform conditions on both sides of the unit when stacked. All units must be adequately supported to avoid permanent warping due to bending.

Careful positioning of fixing devices is essential and they must be secured against movement during concrete placing operations. All connections should be checked individually after de-moulding. Ducts, lighting points and other features cast into the panel must also be checked as routine procedure before any concrete is placed.

Methods of measurement: The checking of large units, and also of the moulds in which they are cast, require instruments giving an accuracy within ± 0.2 mm. for most accurate production and ± 0.5 mm. for other work. Single measurements of length and height provide little guide to the accuracy of a unit; they need to be supplemented by measurements of diagonals, to determine angularity, by measurements of planeness and straightness of edges. The comprehensive measurement of a large panel is, therefore, a complicated operation and although various instruments have been devised for the purpose, none is convenient for routine use. A more satisfactory method under development involves the use of photogrammetry.

Although the development of more satisfactory methods of measuring large panels is desirable, it is likely that the main control over dimensional accuracy will remain as control by measurement of the mould and by inspection of the various processes. With well designed moulds it is unnecessary to check measurements more than, say, once in every 10 castings.

Strength and durability

Control methods for the production of concrete mixes with specific properties are so well known that there is no need in this report to add to existing information on the subject. In fact, because, apart from special finishes, only one type of concrete is required for all products, the control of concrete in this work is relatively simple. Frequently, the main criterion for the strength of concrete is that of sufficient early strength to allow early demoulding and handling. In some cases, steam curing methods are applied and here, once the heating period required for a particular production method has been established, the control required is to ensure that the temperature is maintained over that period.

Control over the location of reinfocement is facilitated by the use of spacers. It is sometimes difficult to ensure complete compaction around spacer blocks and, therefore, some manufacturers prefer to adopt alternative methods. With horizontal casting, the concrete can be placed and compacted in separate layers, with the reinforcement, ducts and other services placed between the layers. Insulation material is best incorporated in this way. With vertical casting, the reinforcement can be positioned accurately by the use of timber battens which are withdrawn progressively during placing of the concrete.

External panels are usually of sandwich construction incorporating a layer of insulating material between two concrete layers. It has been shown by experience and by experiment that the risk of condensation occurring in the insulating layer can be neglected but, nevertheless, it is recommended that a good quality insulating material be used and also that ties between the concrete layers either be of non-ferrous material or, if steel is used, it should be completely protected against rusting.

Quality of finish

Two main aspects of quality of finish require attention. First, all interior surfaces must be free from irregularities and blowholes so that they can be painted or papered without preparation on the site. Secondly, finishes applied to or incorporated on external faces of panels must be of good quality and uniform one with another. The attainment of high quality internal finishes is one of the most important advances towards greater speed and economy of building; the elimination of plastering can make a reduction in cost of the order of 10% compared with traditional methods of building and contributes greatly to the speed at which a dwelling can be completed. The need for good quality external appearance is always important but it is especially important in those countries where the competition with traditional methods of building is greatest.

Internal surfaces

Vertical casting: The elimination of surface irregularities demands that the moulds are rigid and that the form faces are smooth and clean. The colour of the concrete is of no importance because it is to be covered but the elimination of blowholes is important. For this the following recommendations[1] can be made.

(i) Mixes should be relatively rich in cement and the aggregate should contain a low proportion of fine—rather than coarse—sand. The workability of the mix should be high but this can be obtained with a relatively low water content because of the high cement content and the low proportion of sand.

(ii) The concrete in any mould should be placed as fast as possible, consistent with full compaction being attained. Vibration must be applied continuously during placing operations and high frequency vibrators are preferred. In any mould, concreting must be completed within one hour of the start of concreting in that mould. Vibration should be applied directly to the concrete and not to the moulds, except where vibrating tables are used for horizontal casting; the practice of placing 1 m. or more of concrete before inserting an immersion vibrator is unsatisfactory because concrete at the top of the layer becomes compacted before air bubbles can rise from the lower part.

(iii) The type of mould release agent used is of paramount importance. Water soluble emulsions (oil in water) and straight oils should not be used because the former produce a porous dusty surface which may give rise to difficulties in painting while the latter encourage the formation of blowholes. Cream emulsions (water in oil) and mould oils, both containing about 2% of synthetic surface activating agent, give the most satisfactory results but emulsions may require to be applied more than 4 hours in advance of concreting to be fully effective. These oils should be applied uniformly and in a thin film; the rate of application should not exceed 6 m^2/l and application should preferably be by spraying or by roller.

(iv) For best results, the form face should be absorbent—standard hardboard gives excellent results. It is realized that the use of absorbent linings in a mould complicates mould assembly operations but there is no doubt that they do contribute greatly towards the elimination of blowholes. A point in favour of the use of special linings in a mould is that they prolong the life of the mould; they can also simplify mould cleaning operations.

Horizontal casting: The elimination of blowholes in units cast horizontally is relatively easy but the recommendations regarding mix design, type of mould oil and lining given for vertical casting also apply to horizontal casting. The main difficulty is in obtaining an upper face as smooth as the lower moulded face. The achievement of a smooth upper face is largely a matter of skill—it is essential to place the concrete uniformly and then to screed or float the surface after completion of vibration.

External surfaces

Not all the techniques available for the production of special surface finishes on concrete are suitable for rapid production in the factory. A survey of these techniques in relation to their suitability for large panel construction has been made by Monks[2], who concludes that, although speed of casting precludes the use of some techniques, at least one method was found acceptable for each type of finish for both horizontal and vertical casting.

For surfaces which are to be tooled or given an applied finish, the recommendations for internal surfaces should be followed, because these are aimed primarily at the production of surfaces without blowholes. For concrete finishes obtained direct from the mould face, for example profiled, ribbed or plain surfaces, the main aim must be to produce concrete of uniform colour, for which the requirements are as follows.

(i) The mix should be relatively rich and contain a high proportion of fine sand. Mixing must be thorough—an increased mixing time is beneficial—and the colour of the aggregate, especially the sand, controlled by ensuring uniformity of supply; it is beneficial, whenever possible, for the colour of the sand to match that of the cement.

(ii) An impermeable mould face, such as plastics, steel or impregnated ply or oil tempered hardboard should be used. If steel is used considerable care is required to avoid staining due to rust.

(iii) Mould cream (water in oil emulsion) or mould oil containing a minimum of surface-activating agent should be used and applied at a rate not exceeding 6 m^2/l.

(iv) Curing conditions must be kept as uniform as possible for all units. Vertical stacking is preferred because, with horizontal stacking, separating battens will cause permanent marks on the surface.

The remarks concerning curing and stacking apply equally to all types of finish.

Final inspection

Before being loaded on to the lorry for delivery to the site, each panel should be inspected to ensure that it is completely ready for erection. Points requiring particular attention are:

- that the panel is free from damage or blemishes which would impair its performance or appearance;

– that steel fixing and levelling devices are complete with all necessary nuts or bolts as required and that the threads are undamaged;

– that all panels are well supported and secured in such a way as to ensure against damage during transit.

Conclusion: Apart from routine tests to control concrete quality and the measurement of moulds and the final product, control in the production of large panels is entirely a matter of inspection of processes. To do his work effectively, an inspector must fully understand what properties are required of the product and also what are the most important factors affecting those properties. It is essential, therefore, when discussing control of production to devote considerable attention to the reasons for controlling the various operations. New methods of producing large panels are being developed such as by extrusion and pressing. Whatever the process, the control of quality will always depend upon good inspection and skilled operatives; neither can be obtained without training and education.

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Planning and design for industrialisation

Need for an International Building Agency

By J. A. Denton (U.K.)

My aim is to try to demonstrate why countries like Britain, who may be more advanced in certain fields of industrialisation than in others, should come together through the medium of a permanent agency in order to benefit from regular exchange of experience. The fact that representatives of so many nations are present at this Congress indicates a universal desire to achieve adequate, satisfactory, shelter, to meet the needs of the deprived, expanding populations and improving social structures. I must use Britain as my yardstick, my experience barely extends beyond its shores. I am a Quantity Surveyor so I present the measure of my reasoning in four main divisions:

1. Development trends, probable demand to year 2,000.
2. Changes in recruitment and training at all levels.
3. Current and future planning and design techniques.
4. Need for International Building Agency to secure uniform approach and prevent duplication of effort.

1. Development trends, probable demand to year 2,000

It is estimated that by the turn of the century a further 4,500 square miles of land in England and Wales will have been built on and that our population of 51,000,000 will become 70,500,000 fifty years hence. Statistics indicate the following trends in housing and road development:

Stock	1911	1964	2000
Housing (permanent dwellings)	7,750,000	17,000,000	20,000,000
	1909	1963	2000
Roads (in miles) England, Scotland, Wales	175,463	198,455	238,455

The workload confronting our building and civil engineering industry is immense. Apace with demands for more housing and roads is the need for additional educational, health, commercial, shopping and industrial accommodation, improvement and/or expansion of airports, docks, railway facilities and water, electricity and gas undertakings. Renewal and reconditioning of existing property of this kind is in urgent demand. Assuming the life expectancy of a dwelling is up to 80 years at least 10,000,000 have to be built or a vast proportion markedly reconditioned within the next 35 years. Our present aim is a gross output of 400,000 new permanent dwellings a year. Present production is 370,000. One of our leading planners points out that ideally a new town for 50,000 people is needed every seven weeks, or multiples thereof. The present level of capital investment in building and civil engineering is around £3,000,000,000 per annum and 1,712,000 operatives are available to meet demand.

This labour force is distributed as follows:

Number of operatives employed per size of firm	Employing firms (including sub-contractors and specialists)
1 – 10	47,194
11 – 50	13,179
51 – 99	1,796
100 – 249	983
250 and over	524
	Total 63,676

It is felt, due to the high level of employment generally, there will be no significant increase in the number of operatives recruited into building so that, if production is to be increased to meet future demand, it must be accomplished by the adoption of new methods applied by the existing force. Building systems and rationalisation of traditional methods will have to be accepted. In the compact island of Britain we are going to be obliged to exercise great care in the economic use of land and this will influence future development densities.

If the planning principles laid down by Hugh Wilson at Cumbernauld and those advocated by Professor Colin Buchanan for existing towns are more widely adopted, then accomplishing this segregation of pedestrians from traffic, in high density developments, will further strain our labour resources.

Here again it would appear that increased production from present man power may be achieved by the use of industrialised methods for building foot and road bridges and underpasses, many of which are highly repetitive in character.

It has been said "construction must be at the very core of economic growth – every field of production requires building of some description. It so happens that construction is just about the most complicated of them all; it is not so much an industry as an amorphous group of industries. It includes large concerns and a vast number that employ one or two men, or even operate as one man firms. All are necessary for providing the varied building service the country needs. Somehow, in this economic growth that we all seek, each one has got to be harnessed in such a way that the industry as a whole can contribute its maximum performance."

2. Changes in recruitment and training - all levels

Only a brief outline of our current thoughts can be given.

Contractors. Responsible contractors are aware of the need for future entrants to possess higher academic standards and for marked expansion in the number of courses available at Universities and Colleges of Advanced Technology in order to ensure adequate skilled management is obtained. It has been said that in the not too distant future these graduates may become recognised as Chartered Builders and clients will safeguard their interests by seeking their services. Some Members of Parliament feel voluntary registration at least, and if not successful, compulsory, should be secured to achieve satisfactory standards. Reputable contractors are determined to preserve the high standards set by masters and craftsmen of the past, when progress was made at a more leisurely pace, even though they no longer directly control all the skills embodied in current manufacturing processes.

Operatives. Our new Industrial Training Act requires all builders to contribute towards the cost of apprentice training. The newly appointed Industrial Training Board are carefully assessing basic training needs as a result of the change from time-honoured craft practises to those now implicit in rationalised traditional and industrialised methods. Thousands of men will have to assume the new responsibilities to meet demand. Whether they be termed erectors, fixers, semi- or multi-skilled craftsmen the employers' federations and unions will have to review demarcation and training period agreements. In order to utilise all man power to the full the acceptance of new classifications for operatives, such as multi-skilled craftsmen representing all the trowel trades, fixers and erectors concerned with installing components, from prefabricated plumbing, heating and electrical systems to complete roof, floor and wall components, is essential. Some acceptance is already evident but complete acceptance will best be obtained by clearly demonstrating that new training methods will quickly adapt operatives to new responsibilities and with the long term work-load higher rewards, commensurate with the increased output required, will automatically follow.

Professions. It is felt that our most promising development is the trend towards establishing joint education of architects, engineers, quantity surveyors, planners and builders, within our

Universities. One suggestion is a basic three year degree course which will be taken by those who later specialise in a two year course leading to a master's degree. It is hoped this will achieve the fundamental purpose of uniting the skills which go towards creating environmental design. Many are in favour of this; particularly if students obtain earlier knowledge of the workshop floor through joint training with builders coupled with the "why" as well as the "how" of construction methods.

Having enjoyed seven years experience in Cumbernauld's multi-professional team helping to create what learned visitors from all over the world consider to be one of the most advanced new towns of its kind in Western Europe, I have formed the opinion that many of the team members are capable of assuming responsibilities which, though commonly held in the past to be the architect planner's responsibility, can so relieve him to concentrate on the important principles of design, that much time can be saved in the process without detriment to the ultimate development.

By establishing this method of approach during the training process, in concert with our future builders, I firmly believe that the benefits will be reflected on a much larger scale in future projects to the real advantage of the clients the teams will serve. The bringing together of truly independent professional advisers (as proposed for the Quantity Surveying profession in Western Europe at the 1964 Brussels Conference of R.I.C.S. and Belgian Surveyors) capable of giving direct advice to the architect planner or engineer convener, and through non-technical management or direct to the client, will best serve the interests of future developers.

3. Current and future planning and design techniques

Building economics. There is an increasing awareness in Britain of the need for a Building Economics Research Unit so that prediction of demand for buildings is properly made to avoid bottlenecks or idle resources. Sir Harold Banwell's Committee in its recent report on The Placing and Management of Building Contracts describes the quantity surveyor as the building economist of the industry. In the sense that quantity surveyors are highly skilled in budget estimating, giving cost advice during design and contract stage in order to meet project target costs, this is correct. They are not, however, expected to have knowledge of all of the econometric techniques involved in predicting demand and financial influences affecting the industry as a whole.

I should like to see a Quantity Surveyor and Economist, working as co-directors of a unit, towards this end. One would hope that our Treasury, the industry, and fees from special reports and inquiries undertaken by the unit could provide the necessary financial resources. It has been said that such economists have to consider many tasks, including:

- cost analysis and planning;
- predicting demands for buildings and skills and materials that arise from the industry; predicting the supply of these skills and materials, and their prices;
- investigating efficiency and productivity, the need of working capital and effects on the industry of any shortage, the sources of mortgage funds and other loans to clients;
- investigating the impact of technical innovation on all of the above;
- examining relationships between building activity and the rest of the economy;
- devising methods of regulating the economy without causing unnecessary havoc in the industry.

It is obvious that our industry will have to know how much of the future workload can be borne by those contractors only geared to carry out traditional building and by those having industrialised systems. Equally, the load must be properly distributed in accordance with the whole of our resources. If the industry is not so informed and the load properly distributed then (a) the cost of building will be put out of balance (b) manufacturers and merchant suppliers will not have supplies available on time.

More recently the Royal Institution of Chartered Surveyors has established a Building Cost Information Service for use by the whole of their quantity surveyor members. The Quantity Surveying Techniques Working Party of the Institution are at present studying Cost Planning as it is used throughout the profession and those members who subscribe and supply cost analyses for buildings of all classes to B.C.I.S., who are thought to be most aware of Cost Planning techniques, have been invited to give evidence to the working party engaged on such research.

System built housing. The number of systems at present available in Britain and likely to prove effective are:

single and two storey—approximately 50.

low rise—more than two storeys—no lifts—approximately 20.

multi-storey high blocks with lifts—approximately 30.

Many of these may need some modification before they are fully acceptable. In addition, there are many more under consideration by various firms. With most systems the realistic production costs are still unknown even to the sponsors and in many cases they are largely dependent on the scale of orders received. There is some danger that if available orders are spread between too many firms and systems, few if any will achieve maximum production economy. It has been calculated that efficient traditional construction requires some 2,000 man hours to build a flat in a tall block and an efficient concrete panel system of industrialised building would require 500 man hours on site, 300 in the factory for concrete components, and a further 300 for other factory work, a total of 1,100 man hours. We are just beginning to see a breakthrough in the industrialisation of tall blocks of flats and at least one system has recently sprung into being which has been seen to reduce costs by almost 20% compared with traditional, construction time by 46% and the number of operatives required by 48%. The market for these is restricted to between 6% of the total housing output. By far the greatest demand is for one to four storey development.

Tendering and design. At Cumbernauld we have experimented with two-stage competitive tendering procedures aimed at bringing either the system or traditional builder into the design team at the earliest stage in design in order to produce acceptable and fully pre-planned negotiated tenders. A report on our experiences was submitted to the Treasury and considered by the Banwell Committee.

My paper "Competitive Negotiation: Experience aimed at increasing productivity in the construction of Cumbernauld New Town" (*Chartered Surveyor*, December 1963) details the tendering and design methods adopted. The yardstick for evaluation appears to be a comparison of system costs with traditional. The real measure should be the amount we, as a nation, are prepared to pay to meet demand within the limit of total resources. That is why I feel an Economic Advisory Unit is urgently required to ensure true "value for cost" is obtained at national, rather than local, level. My Institution is urgently investigating future techniques in order to ensure that "value for cost" reports can be promptly presented to clients, such reports giving an accurate assessment of the relative merits of building systems having regard to speed and efficiency of pre-planning and erection, costs in use and comparison with traditional building costs.

4. Need for International Building Agency

Our new National Building Agency will comprise architects, civil and structural engineers, quantity surveyors, builders' estimators, physicists, economists and mathematicians, production and planning engineers, services engineers and building technologists, organised in a series of teams. Their duties will include liaison with individual clients and consortia in public and private sectors, with a view to co-ordinating and extending the demand for advanced building methods.

Full professional services will be available for developing new building techniques on a pilot scale or for special local circumstances. They will be available for assessing building systems and components for clients and sponsors in terms of functional performance (stability, durability, insulation values, etc.) architectural potential, man-hour content and costs. They will offer advisory services to industry, to clients, and the professions, on all aspects of industrialised building including the rationalisation of traditional practice, and management techniques. They will assist other organisations, professional and industrial, in training courses in modern building techniques. The Agency has been set up as a private company registered under our Companies Act with the Board of Trade and limited by guarantee by the Treasury. It has no share capital and, therefore, cannot make a profit in the commercial sense. It is financed initially by a Grant-in-Aid from the Treasury. The N.B.A. is empowered to charge fees for its services but this is permissive. No doubt as far as private and commercial sponsors and firms are concerned a fee will be charged for advisory services. They will not compete with private consultants; on the contrary, wherever possible, their employment will be recommended.

Responsibility for organisation and direction of N.B.A. is vested in a Chairman and Managing Director, a Deputy Chairman and Chief Architect and twelve Directors. Their collective skills and experience is representative of many aspects of building development.

Examination of the United Nations publication "Cost, Repetition, Maintenance Related Aspects of Building Prices" (Economic Commission for Europe, Geneva, 1963) embraces comparative costs submitted by twenty countries, related to the trend towards industrialisation of building. In relation to housing costs in European countries the report states "despite considerable differences within and between countries, the pattern of costs and types of problems arising are very similar, and a common approach to the recording and analyses of building costs is not only possible, but desirable".

I feel that there is a real and urgent need for the establishing of a permanent International Building Agency.

Its purpose – to secure the proper and expedient organisation of a systematic exchange of information between nations. CIB was created at the instigation of the United Nations for this very purpose and has proved itself effective, within the compass of its present resources, in doing this on a limited scale. I firmly believe its activities should be expanded so that its potential can be fully utilised. CIB could and should become the world's building information centre with a reference system than can immediately make available to enquiring nations suitable treatises, or names of experts who can give personal advice, on specialised subjects. I have little doubt that it could rapidly become the vehicle for promoting wider trading interests between nations. It could be a centre more capable of predicting supply and demand than any of the few now established on a fragmented basis in an attempt to meet the individual needs of particular countries.

The introduction of an I.B.A. would prevent what history may otherwise show to have been one of the greatest economic follies of the twentieth century. The gross and unnecessary dissipation of the wealth of individual nations due to their complete failure to prevent the duplication of planning, design and research effort. On the other hand it could become recognised as the centre through which real opportunity to secure advancement at a more accelerated pace has been achieved.

Many of my colleagues in Britain feel that if opportunity did exist whereby, to quote one example, an approach could be made to an international information centre so that contract documents prepared for executed projects in a particular class, by various nations, could be obtained, this would prove to be an invaluable service. If layouts, detail drawings, specifications, schedules of rates, conditions of contract and other relevant matter could be analysed by a team, such as that proposed by our own National Building Agency, then much useful information would become available. Naturally each receiving nation would have to apply its own working arrangements in order to obtain a real appreciation of all that was involved; by the time the documents had left the microscope I feel that some very useful discoveries would have been made. The receiving nations could then return their findings to I.B.A., so that one of the most comprehensive collections of data, in this respect, would rapidly spring into being for the universal purpose of improving the wellbeing of mankind.

In making this suggestion I do not denigrate all that has been accomplished by the Housing Committee of E.C.E. What I firmly believe is that the whole process of exchange would be accelerated to the real benefit of E.C.E. and U.N.O. I shall not venture to suggest how I.B.A. should be financed. I know that other problems, for example, the preservation of design rights, could be encountered. These aspects are a challenge which should be taken up by the technical, financial, legal and administrative representatives of those nations interested in the activities of C.I.B. I trust those interested in this 3rd Congress, who pay heed to my views, will demonstrate how readily such problems can be overcome.

Conclusions. I have attempted to cover a very wide field for planning and design, in its widest sense is the concern of every one of us, administrative, professional or technical. I hope my remarks will provoke a desire to secure the exchange of information at international level, through the medium of a permanent, efficient, agency.

I trust I have demonstrated that trends in Britain's problems and requirements are similar to those of many other nations. What a splendid opportunity there appears to be for achieving international team working through the medium of an I.B.A. in order to speedily satisfy the important needs of mankind.

References

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Professor A. Ling, B.A., F.R.I.B.A., M.T.P.I.,
Head of Department of Architecture and Civic Planning,
University of Nottingham, England.
Dr. N. C. Sidwell, M.Sc., Ph. D., A.R.I.C.S., M. I. Struct. E., A.I.O.B.,
Head of Department of Building,
Heriot-Watt College,
Edinburgh, Scotland.
L. Hugh Wilson, O.B.E., F.R.I.B.A., Dist. T.P., M.T.P.I.,
(of Hugh Wilson and Lewis Womersley, London,
Manchester and Scotland),
Consultant Planner,
Cumbernauld Development Corporation.
D. F. Medhurst, D.F.C., M.A. (Manchester), A.R.I.B.A., S.P.Dip., A.M.T.P.I.,
Lecturer, Town and Country Planning,
University of Manchester, England.
D. W. Nunn, O.B.E., F.R.I.C.S.,
Chief Quantity Surveyor,
Ministry of Housing and Local Government, Whitehall,
London. S.W.I.
A. W. Cleeve Barr, F.R.I.B.A.,
Deputy Chairman and Chief Architect,
The National Building Agency,
London, England.
G. Oyler, B.Sc., (Eng.)., A.C.G.I., A.M.I.C.E.,
Chairman and Managing Director,
Concrete (Scotland) Ltd.
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B 4

U.I.A. group

Architects and the industrialisation of building

By J. Duret (Switzerland), M. Gout (The Netherlands), A. G. Héaume (France) and J. H. van den Broek (The Netherlands), members of the Union Internationale des Architectes

Influence of the spirit of industrialism on architecture

The industrialisation of building is an ineluctable phenomenon, springing from the evolution of the contemporary World. Building crafts have existed since ancient times; their technics were always amongst the most advanced, and their methods amongst the most skilful that can be invented when the hand of man is the only means and the only power employed. It was on this basis that architects in the past have always known how to define the ethics of their epoch clearly for future generations. There is no doubt that Architecture is acknowledged to be a basic reference whenever the study of any civilization is entered upon or knowledge of it sought.

It is therefore normal that an architecture of the industrial era should be an expression of this epoch, just as truly as earlier architectures expressed their epochs. Human progress, an essential factor of contemporary demographic expansion, necessarily entailed a simultaneous and continual development of industry, called upon to satisfy mens' needs, while the general raising of living standards resulted in the multiplication of these needs. For building, this led to a change in the scale of programmes which, at the outset, was a new element. It is an undoubted fact that, never in the past were so many great works achieved in so short a space of time. Reciprocally, industry has supplied the means of meeting this increased demand, by progressively replacing manual labour by mechanical processes in an evolutionary cycle, the final astonishing outcome of which it is not possible to foresee.

Today, scientific discoveries lead to the creation of new synthetic products with very wide possibilities for application. They open up new perspectives for the architect and, in this field, it would be rash to forecast any limits for the future. The field of architecture widens and finally becomes the orderly creation of the built environment; it begins with territorial development. In this respect, there has taken place in the last fifty years a revolutionary cycle which is only the starting point in the birth of an architecture for the industrial era.

Initial achievements must be thought of as experiments, tried out by men possessed by the idea of progress; more recent works already affirm, by the way they flourish, that the road chosen is the right one, but they do not yet constitute a final result. Moreover, it seems that, with the speed of progress of our age we shall never be able to imagine something final, and that the rule of the future will be continuous evolution. The architecture of the industrial era is, through its programmes, means, technics and social mission, full of promise. It is for architects to make this a reality.

The industrialisation of building

The industrialisation of building consists in the introduction into this field of great industrial methods and means. While resulting from a single leading idea, this can be carried out under various forms, adapted to the particular needs of the programme and of the moment. For it is not a question of creating a new industrial sector but of starting with existing structures in a field already formulated.

"A house" is, in essence, very different from "furniture" or from any other object. The first is part of a durable social framework which produces psychic emotions; the second only has value in use, is temporary and subject to rejection. Building industrialisation must take account of this peculiar characteristic and adapt itself to it. Several aspects can be distinguished:

The industrialisation of the building yard which consists in applying rational methods in the organization of the work and, without changing the place where operations are carried out, equipping them with the most highly developed mechanical means.

Prefabrication which consists in transferring to a stable factory the greater part of the operations previously carried out "in site". Here we must distinguish again between: a) the production of basic elements considered as utilizable objects for the construction of buildings; these elements can be produced in various specialized factories; b) direct production of complete buildings by repetition of typecells; this work is carried out in less numerous and integrated factories.

To be sure, this classification is far from being conclusive and, in the present state of affairs, the intermediate solutions are the most numerous.

The industrialised production of components is developing rapidly, and this is incontestably leading to an improvement in quality and a reduction in cost prices. Standardisation and modular coordination are the primary conditions of its expansion. It would appear advantageous to envisage preferential dimensions of measurements greater than those of the international module of 10 cm. For this purpose, sexagesimal dimensions would appear to offer special advantages, by reason of their divisability feature, these dimensions being, incidentally, nearer to the traditional foot measurements in the West and the Far East. The standardisation of building components should lead to their being utilized on the international plane and thus to the extension of the market. Architects should participate in work by organizations responsible for the definition of dimensional, qualitative and functional norms, in order to guarantee the adaptability of components to the purposes for which they are intended. The industrial production of type buildings is, at the present time, the most advanced form of building industrialisation. According to the degree of integration of the operating factory, it will be possible to envisage a specification peculiar to this factory, or to utilize more or less of the components produced outside the conditions indicated. This system necessitates large investments which impose the continuity of series, thus implying repetitions which run the risk of becoming inhuman.

In view of this, preference should be given to processes which permit different buildings to be realized on the same production chain with a minimum of additional costs.

We must not underestimate the experience of industry which shows us that variety can and must succeed uniformity, without the efficacity of mass production being thereby compromised. It seems that a perspective for the future should be opened up by the differentiation between structural and supporting elements and separation and equipment elements. At the outset macro-structures would place the edifice in the urban context and social complex; they would carry the stamp of durability. Functional cells incorporated afterwards would ensure the adaptation to individual programmes, would supply the advantage of flexibility in time and space and would open up possibilities for renewal, thus guaranteeing respect of the individual personality within the collective framework.

The position of the architect

Architecture is essential to society. Owing to urbanization, the framework of contemporary life is increasingly becoming an ordered and constructed framework which has a fundamental influence on the psychic behaviour of human beings. In order to carry out activities, meet material needs and satisfy spiritual and sensorial aspirations, the entire world needs architecture, whose permanent and unchanged role for thousands of years has been to satisfy the spirit by means of matter. This does not imply an idea of formal immobility; on the contrary, it implies permanent creation. Today this is not a question of simple evolution but of a veritable mutation, complete in all fields; there are grounds for thinking out anew the setting for the life of tomorrow's communities, under penalty of seeing civilization dissolve into chaos.

With this in view, architects must consider building industrialisation as a new and supplementary means which it is their duty to utilize. Industrialisation is not an end in itself but must be put at humanity's service, the contrary hypothesis being inconceivable. And it is, in particular, the duty of the architect to call the attention of the public and responsible authorities to this fundamental reality; for this purpose, he must preserve his independence of thought and liberty of expression. The spirit of architecture is of an order other than that of industry, and yet a combination of the two is an obvious necessity. This involves inevitable and close collaboration between the architect, initial composer and ultimate authority, and all those (engineers, consultants, constructors, etc...) who take part in the preparation and realization of a work achieved in common.

The assembling of men who have been trained in different fields and whose aspirations differ will enable ideas to be compared and complementary contributions to be synthesized.

The future status of the architect remains to be defined as regards the conditions of its application. Taking part in the working out of norms, in the study of basic elements and in the final preparation of prototypes, the architect as a "creative consultant" will be able to give industry the support of his experience as regards consumers' needs, the conditions which the article produced must fulfil, the essentials and the implementation of plans, while preserving the mastery of form and contributing to the whole his faculties of functional and plastic creation.

The architect should also regulate the composition of elements in order to integrate them in the urban context.

Two evolutionary possibilities result from the above various attitudes. It is probable that further aspects of the practice of the architect's profession will reveal themselves as time goes on and that this profession will have to submit to the prevailing rule of specialisation. In such a case, it will be of the utmost importance that this specialisation does not intervene before the acquisition and assimilation of very extensive general and professional culture. There would therefore be no question of its being the outcome of premature vocational guidance. While the integration of the architect within industry as an employee offers all the practical advantages of concentration, it presents the grave danger of a diminution in his authority to the detriment of his social mission. The essential problem is that of preserving his liberty of decision and preventing his being dominated hierarchically by men responsible to other disciplines. His authority must depend solely on the confidence he is given; it is for the public and the user to sanction the precision or inexactitude of his creations; this is not a matter for the civil servant or hierarchical superior. Some people think that, rediscovering an out-of-date tradition, the architect could once again become a producer himself. This is not inconceivable in certain special cases, but modern industrial conditions entail financial dependence and administrative obligations which are hardly compatible with the freedom of thought and action we have defined above as being absolutely necessary to the architect's position.

Those who venture along this path will surely risk coming into conflict with themselves. Without forbidding them to do so, it is best to put them on their guard.

Developing regions

Territories in process of development have by far the greatest needs; their means on the contrary vary considerably. In these countries, the industrialisation of building seems a tempting proposition, the potential of local traditional production being insufficient. However, this industrialisation of building is a function of industrialisation in general and cannot precede the latter. It depends on economic conditions (investment possibilities), geographical conditions (locality, importance, density of population groups) and industrial conditions (production of basic materials). Even if all idea of gain is put aside, a preliminary definition of the ruling market is absolutely necessary for the success of the operation.

The choice of methods and processes here is particularly delicate, for the following up of parallel and costly experiments, permissible in countries with a high economic potential, is not to be thought of in such cases. It is much more a question of adaptation than of innovation. The importation of type elements comes up against certain difficulties for, although there is a universal tendency towards unification of needs, we also note particularist reactions of public opinion which impose close adaptation of buildings to the deciderata peculiar to certain populations.

In these regions, more than anywhere else, the idea of rapid evolution is dominant. Here, the industrialisation of building offers the advantages of a rapid rise in the technical level and a promise of social promotion for those employed, by avoiding the slow cycle of evolution which results from apprenticeship to traditional crafts.

The mission of the already industrialised countries now goes beyond the stage of providing material means of equipment and of giving "technical assistance". If these methods still have to be continued for some time, the essential objective is that of training local specialized staff. They alone, after assimilating the experience passed on to them, will in their turn be capable of creating the means most likely to satisfy the original aspirations of the peoples for whom they will be responsible.

Confronted with the prospect of a world where economic planification is to guarantee a rise in the standard of living of each individual, it would be unthinkable if environmental living conditions, for which architecture in its widest sense is the sole surety and which the building industry alone can procure, were not also created for this same individual.

B 5

J. van Ettinger

Development cycle for low-cost housing

By J. van Ettinger (The Netherlands)

Mass-production in building is not in the first place—and decidedly not in developing countries—a question of the purchase and putting to use of expensive machinery for the production of large and small elements of buildings in ancillary industries or on the building site.

In order to industrialise building a number of conditions ought to be realised in the first place, for which it is necessary as a rule to alter the structure of society and the building world.

Necessary for mass-production are *continuity* in the production of large series of *identical products, specialisation and attuning, co-ordination* and the highest possible *mechanisation.*

Continuity in the building process can only be obtained if the central, regional and local authorities allot and clear the necessary building-areas in time and create, perhaps together with private investors, the financial possibilities of that timely acquisition of land, of site preparation and of building itself.

Long-term development planning is necessary, a realistic policy in the sphere of saving and investing (quality level!), physical planning to avoid waste in the use of the land, and a building policy aiming at continuity together with a corresponding financial policy.

Mass-production requires a *high specialisation* in both programming, designing, producing of ancillary parts and in assembly on the building site.

The result is a number of problems of *training* and *tooling*, of *attuning* and *co-ordination*, which make special demands on management in the building industry and the individual firm. A transformation process is needed for the building industry, which in some countries is already clearly in evidence.

Mass-production requires intensification of the thought that precedes the action and accompanies it. To this end the government and the industry ought to see to it that building research in all fields (function, technics, economy and organisation) receives sufficient attention. Then there are special measures to be taken for the completest possible integration of thought and action. The typical craft has less need of this integration because there thought and action occur almost simultaneously.

Now that, since World War II, we have gradually begun to realise the immense importance of building not only in times of reconstruction and as a means of providing employment, but first and foremost because the social and economic development of a given country are so highly dependent on it, we are becoming more aware of the utter complexity of the problem of building and especially of low-cost housing.

Striving after more and better building with the available means is a more urgent, more important and more difficult matter than we realised. Difficult questions can only be solved permanently by means of perfect methods.

In the last 15 years Bouwcentrum and Ratiobouw have been occupying themselves more and more with the evolution of a suitable method. This was done both in practice and on paper, both in Europe and in other continents, for both house building in affluent countries and very low-cost housing in developing countries. The method we developed was called the development cycle. It proceeds from the following starting points:

1. The combination of low building costs and relatively high quality presupposes *a large production of a very limited number of housing types, thoroughly studied and prepared for realisation.* To this end it will be necessary to form a combination of specialisms within a single organisational framework, in which all the essential aspects of townplanning, function, engineering, economics and management are represented.

2. Plans for mass-produced dwellings are only socially and economically justified if they are based on a *programme of requirements* which matches as closely as possible the prevailing and expected essential housing needs, while taking into account what the people these dwellings are meant for, can afford.

3. The *design* must not only be attuned to the programme, but also to production, i.e.

a. the plans for mass-production of housing must be brought to development by a synthesis of various technical aspects and production techniques;

b. like programming and production, designing must be done with an eye to costs down to the smallest detail.

4. Efficient *mass-production* of housing is only possible if allowance is made for the requirements of efficient organization of production even in the design stage of town-plans and also in each following preparation phase.

In order to achieve optimum results by fulfilling the above four conditions, it is necessary to ensure not only that the very extensive existing knowledge is put into practice wherever possible, but also that the large gaps in this essential knowledge are filled quickly. This requires teamwork of experts of the main disciplines with a background of an active, integrated, internationally orientated research, development, consulting and information institute. Necessary are also political interests, close co-operation with professional circles and with the different types of potential clients (central and local government and private investors) in order to be able to organise the demand side.

The work should be done so systematically that the knowledge is injected in the right place at the right time and that by integration of knowledge and practice and by feedback of experience, mass-production of dwellings of optimum quality is prepared, developed and realised step by step. The application of new knowledge and new experience cannot be left to chance here, but must be organised. This organisation, thus the form in which in mass-production the steadily improving relationship between quality and costs is realised, is the development cycle.

The most important phases are;

1. Research phase (function, technique, economics and organisation) including the choice of housing types and their programmes of requirements. (More types: higher production cost; fewer types: greater difficulty for the (unique) family to adapt itself to the (standardised) product).

2. Functional prototype, a specimen of the dwelling manufactured to full scale, but not yet in "actual" structural materials, to test the spatial quality of the dwelling.

3. Technical prototype, an improved functional prototype made of "actual" materials to test the technical quality of the dwelling.

4. Experimental series, improved technical prototypes manufactured with the aid of the "actual" production organisation, to test the production technique (assembly methods, assembly sequence, timing of operations, etc.) and the tools developed, and to train the labourers and their supervisors on the job.

5. Mass-production to realise planned quality and cost price.

6. Determination of use-value for the occupants of the mass-produced dwellings.

Phases 2, 3 and 4 are undertaken to enable all kinds of changes to be made before the fifth phase commences, because it is clear that once mass-production is under way any changes would be very costly and disturbing.

If optimum quality is to be achieved it will be necessary to make prototypes whenever the practical properties of the design cannot be adequately approached by theoretical means, thus on paper, and whenever there is a risk of serious damage if ultimate production takes place on the basis of untried designs. This situation is present when the product concerned is complicated, multi-dimensional and mass-produced.

Team work is an essential condition, after one complete cycle a new one starts on a higher quality level.

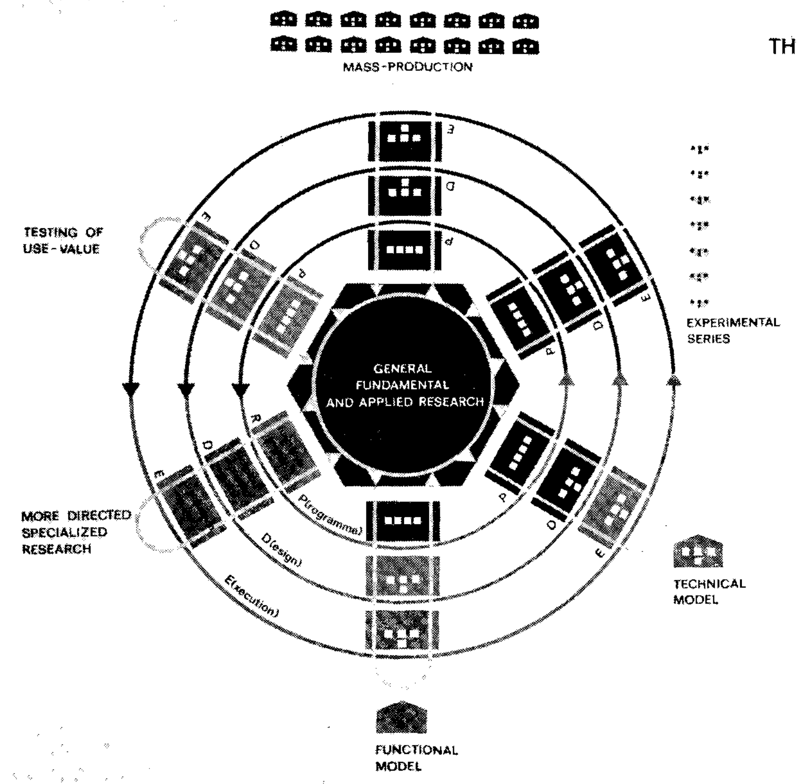
For the development cycle when being applied in poor countries, special attention must be given to the following points:

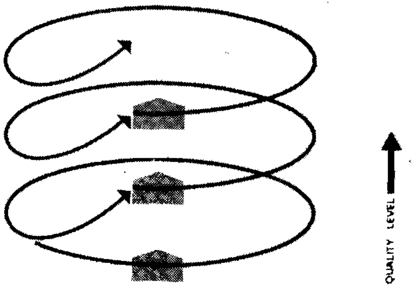
a. the quality level the people can afford.

b. the minimisation of the use of foreign currency (i.e. use of local materials).

c. the special measures to bridge the gap between need and buying power (more or less complete dwelling, application of various degrees of self-help and combinations).

THE DEVELOPMENT CYCLE





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B6

A. M. Gear

A private consortium

Method of working and results of collaboration between designers and a group of raw material producers, manufacturers and builders over the past twenty years

By A. M. Gear (U.K.)

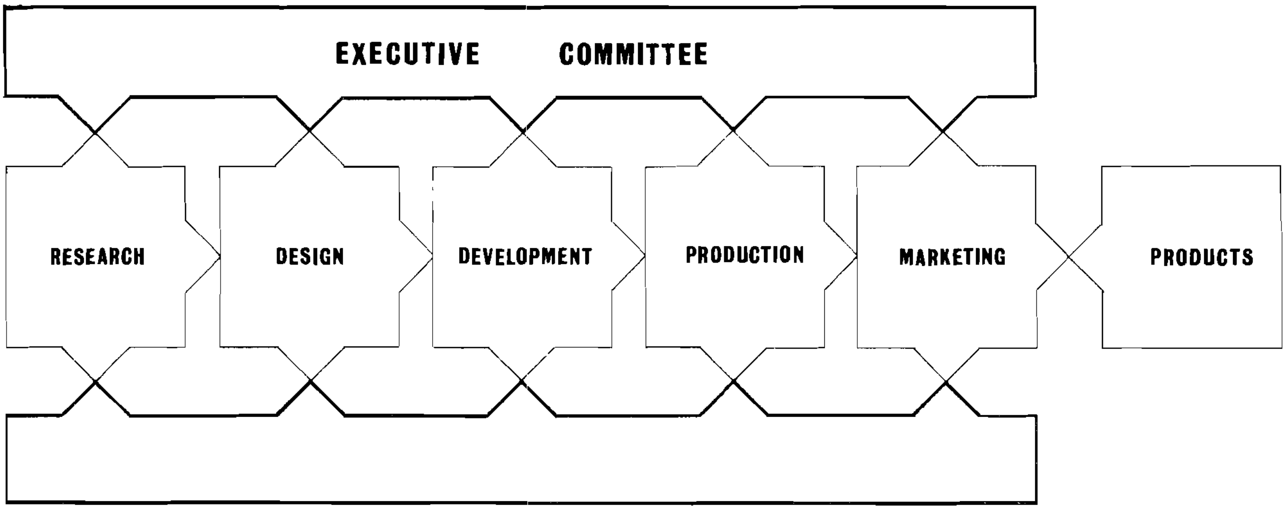


Fig. 1. Diagram of communications and flow of work.

In Great Britain over the past twenty years there have been considerable developments in the field of industrialised building, particularly so far as the factory production of "light and dry" building elements and components is concerned. This paper deals with one way in which this type of work has been tackled by a group of large companies who, through their Consultant Designers, collaborate together to carry out research and development work in the use of materials capable of being applied to the construction of buildings and upon techniques of building construction.

The present members of this Consortium cover the following, basic materials – ferrous and non-ferrous metals, cement, gypsum, plastics, asbestos, paints and general chemicals: they have the appropriate manufacturing facilities and selling organisations within the companies and a special Marketing Agent for the composite buildings resulting from the work.

The research, design and development work is co-ordinated by the Consultant Designers, who work with the technicians within the companies, with outside specialists, with appropriate Government and other research organisations, both in Great Britain and other parts of the world.

Since 1943 the basic work has been applied to the development of buildings and elements which have been used in over 100 countries, covering a wide range of climates, for a variety of purposes including factories, storage buildings, workshops, barracks, markets, schools, hospitals and housing.

Throughout the paper the word 'component' refers to items such as windows, doors etc., and 'element' to such items as walls, floors etc. As defined above, the scope of the paper will not include work on reinforced concrete.

Method of working

Before a project is started approval is given by the Executive Committee, composed of representatives of the various companies concerned and the Consultants, then on through the various steps shown in Fig. 1. Whilst some time is spent in obtaining basic information of general use to the companies individually and the Consultants, most of the Research and Design effort is directed to particular problems or projects. As the products resulting from the work are reproduced many times, considerable care and expense is devoted to these preliminary investigations which include such work as the preparation of performance specifications and cost targets, and the testing necessary to obtain information with which to design; these tests cover such widely different subjects as the behaviour of water in gutters and downpipes; the heat flow through different materials used for fixing external cladding in very cold climates; the physical properties of composite panels, and long term weathering tests.

Having prepared preliminary approaches to a design the Consultants collaborate with the various manufacturers concerned in order to determine the best materials and methods of manufacture for the project, at the same time contacting the Marketing Agents in order to take into account the problems likely to occur in transport or erection, and selling.

After making any necessary modifications, preliminary costs are prepared and compared with the target figures estimated at the start of the project, and if necessary mock-ups and handmade components are constructed to test out ideas – such as methods of jointing etc. In the case of the structural design the latest techniques are used – taking advantage of analogue or digital computers where appropriate. Where lack of structural design method makes it necessary, complete structures are tested to destruction taking into account the particular conditions for which the frame is designed – for example, high wind speeds. If it is agreed to continue the project, it then moves to the stage of Development, where final details are agreed, component drawings prepared for manufacture, tolerances agreed and general arrangement drawings are made showing how one component fits with another—or, in the case of a component development, how the technique will be applied to buildings generally. A prototype is erected – where possible from the first production run – to test the accuracy of the pieces and so that the methods of erection can be determined. In most cases this work is timed and filmed for purposes of record and where necessary used to pass on the information to the assembler.

As the buildings are exported to, and sometimes the components are fabricated in, various parts of the world, the details and erection literature must be available in the appropriate languages. Where possible, therefore, the illustrations should tell the story leaving the minimum to the written word.

All buildings or elements in production are under constant review; if modifications are necessary they are introduced into the range at a time agreed with all parties concerned. These modifications may be due to the following: – (1) changes in market requirements – there is a constant feedback of information from the Marketing Agent to the designers; (2) changes in manufacturing processes or policy; (3) modification in the materials being used, for example improvements in methods of making steel have resulted in an increase of the guaranteed yield stress; (4) modifications to the Codes of Practice or Building Regulations

Fig. 2. A roofing system developed for tropical countries, used as a market in Jos, Nigeria.

for which the building have been designed; (5) improvements in design based on further research work by the designers.

Outline of the work resulting from the collaboration

In the early days of the Consortium the main effort was concentrated on the design of building elements using new materials or established materials in a new way: it was found difficult, however, to design new building techniques in isolation—they had in some way to be related to a building project. Post-war housing was at the time very much on the minds of both the Consultants and members of the Consortium, so the techniques were developed around this theme.

As a result of the basic work which had already been carried out it was possible to design a house for the British Government's Temporary Housing Programme—some 41,000 units of this house being erected in various parts of the country between 1945 and 1948. This project provided vital experience in the problems of design, manufacturing, storage, transport, marketing and erection, and drew attention to the importance of long term research, if sufficient data is to be available for the development of a project.

Since 1948 a number of different types of buildings, elements and components have been developed for both tropical and temperate climates—industrial buildings, including a wide range of pitched and flat roofs with various systems of natural lighting; amenity buildings, single and multi-storey, for officies, schools etc., and a number of systems for housing, mostly in tropical countries. In some cases they have been designed to incorporate traditional in situ building methods where appropriate, others have been completely prefabricated. Over the past ten years the main research effort has been devoted to the development of interrelated building elements, and basic techniques of construction which can be used together, and with components or elements made outside the group of companies, on a variety of building types. The experience gained from this work is incorporated into the existing range of buildings, whilst new and more flexible systems are being developed. Latterly the methods of construction developed have been applied to special projects—in some cases specific building types—for example, textile mills where the designs have been evolved in collaboration with the equipment manufacturers.

To summarize, the results of the work have been (1) The design of a number of completely prefabricated buildings for special large housing projects. (2) The development of a range of buildings with limited flexibility—but the ability to incorporate traditional methods of building within the systems. (3) The design of a number of building elements and the development of techniques of construction with which to build. (4) The application of items (2) and (3) to the design of buildings for special uses. (5) Finally, and perhaps the most important for the future, the gradual evolution of methods of collaborative working between all the parties concerned in this complex but exciting exercise.

Conclusions. During the period under review the aim has been towards the development of factory-produced units for completely prefabricated buildings. There is no technical problem in designing or constructing such a building but the real test is economic, as there is no virtue in prefabrication for its own sake unless speed is of overriding importance or there is no other way to build.

At the moment the main work is related to 'industrialised building' which is understood to include prefabricated pieces in conjunction with improved in situ methods and better site plant and management. However, it is suggested that the trends in building methods are likely to be towards prefabrication coupled with better site organisation, rather than more in situ construction.

The immediate building problems, including the provision of low-cost housing, which is so important in many parts of the world, must be solved with the materials and techniques already developed, whether assembly is in the factory or on the site. There are many new and more sophisticated methods being evolved but it is suggested these should first be applied to industrial or amenity buildings—that is, factories, hospitals, schools etc.—and then gradually introduced into the vocabulary of parts for what is probably the most complex problem of all, the small house.

Whenever new methods are employed it is important to ensure that they should provide value for money at least equal to the available traditional methods they supersede, otherwise they will fall into disrepute and slow down the speed of development, a fate many new materials have suffered in other industries.

The research into or perhaps more accurately the development of these new building materials, components or elements must start from performance requirements and cost plans, and should not stem from the simple substitution of one material for another in similar form. This mistake has been made many times in the past as, for instance, in the introduction of aluminium window sections identical to those developed for steel.

There is a danger in carrying out comprehensive development based on only one material; by using the right material in the right place and in some cases a variety of materials in one composite element, the development of new techniques can be achieved more rapidly. Obviously these new materials or techniques can be more easily introduced on an economic basis when all their properties are used to the full. At the same time they must allow the maximum flexibility of building design and use if they are to interest the architect and the client, and also provide a reasonable production run for the manufacturer. It would seem likely that such flexibility will be increased as more sophisticated methods of manufacturing are developed.

The problems are urgent and the progress is slow; it is, however, suggested that the maximum speed in building innovation is achieved by slow steps and not in the brilliant conception of exotic forms. This is not to say that what we now consider as exotic will not one day be commonplace, but that which is successful say at the turn of the century will have been derived from slow steady steps rather than one big jump.

The speed and success depends not only upon the manufacturers and their designers but upon the ability of the architects and engineers to accept and work within the discipline imposed by the pieces; the building industry or assemblers to organise themselves to take advantage of the new techniques; the Building Regulations to be so written that they do not restrict the development; and the user to accept a new kind of building.

B 7

G. Hellsten, S. Jernström and Y. Palm

From town plan to moving in

By G. Hellsten, S. Jernström and Y. Palm (Sweden)

The process of building follows a complicated sequence and is affected by variables in numerous respects. No single body, public or private, controls alone the entire process. Rational reorganization is therefore difficult. To facilitate study of the problems involved the National Swedish Institute for Building Research has charted the sequence in 30 practical examples, equally representing redevelopment projects and new flat and small house schemes.

The Institute has carried out an investigation designed to tabulate the sequence of the building process through the study of 30 housing projects.

The choice of projects reflects the following considerations: fairly even distribution as between new blocks of flats, new small houses and urban renewal projects; situated in various parts of the country and in different types of community; and including large-scale projects (ten of them involve more than 100 housing units each), medium-scale and small (down to 12 units). An effort has also been made to include a representative selection of different types of client and methods of placing contracts.

No detailed analyses have been attempted, the report endeavouring only to give a broad view of the sequence and time required of events from town plan to occupation. Time required is taken here to mean the period during which those concerned have been engaged on the project. No report has been given of the amount of work done during that period. The information cannot therefore be used as a basis for capacity assessments.

The building process

The building process comprises normally the following principle stages:

- basic planning (regional and master plans)
- detailed planning (comprehensive development area plans, standing regulations and statutes)
- determination of site lines (surveying and site division)
- design of roads and services
- design of buildings (houses, flats, shops, schools, nurseries, spaces between buildings, etc.)
- construction of roads and services
- construction of buildings.

The process might seem rather simple. Difficulties of achieving a rationally planned process arise however mainly due to the fact that no single body – national, local or private – controls all stages and aspects of the process. Another serious obstacle towards an efficient building process is the lack of uniformity: there are a number of variables, as to, for instance:

- local administration
- availability of land and acquisition policy (freehold or leasehold)
- finance (with or without Government loan)
- client (public, co-operative or private)
- planning (urban rural, new development – renewal)
- responsible surveying officer
- site conditions (ground and slope)
- building type (multy-storey or terraced houses)
- design and technical specification (internal design department, design with help of one or more consultants)
- contracting (by means of own department, general contractor or several trade contractors)
- production volume (quantity of departments per object)
- building method (traditional or industrialised).

Major differences were therefore to be expected between the objects surveyed in the study.

The building process as a whole

The principal particulars of all the projects studied are presented in fig. 1. The diagram reveals wide variations as regards the time required for various phases in the building process and as well as to the chronological order of actions and results.

Town planning measures

The study reports on several projects where town planning took a long time because of *ill-defined premises*, necessitating modifications and the return of documents to lower levels of approval

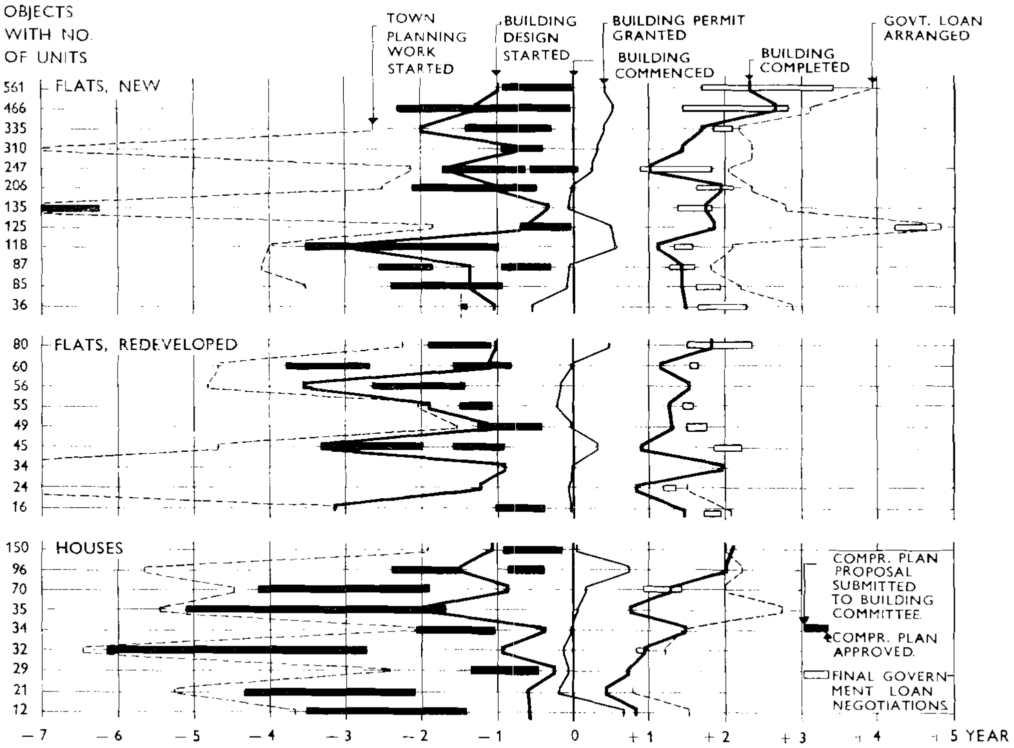
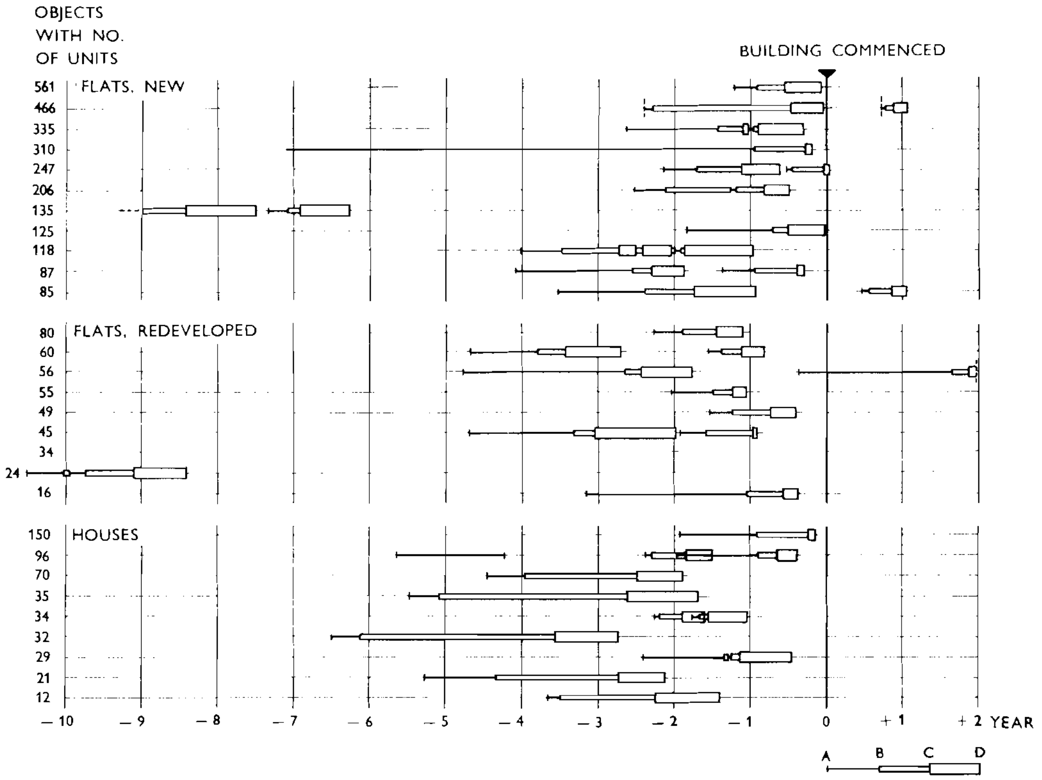


Fig. 1. General characteristics of thirty projects.



A Planning commenced.
B Proposal submitted to building committee.
C Proposal approved by town council.
D Proposal approved by country council or Government.

Fig. 2. Town planning measures related to time when building started.

– fig. 2. The great number of approving and commenting bodies involved in any town planning procedure often implies that a modification causes considerable delay. The delay may alter the premises on which the whole scheme was first based, with further delay as a result.

Other disturbances in the town planning phase stem from the fact that the superior approving body the national or county council – bases its decision on the same documents, and the *same degree of detail*, as the local authority; and gives its decision *after* the local authority. The broad principles are therefore dealt with *after* the details have been worked out and on the basis of the same documents. In several of the 30 cases this meant that matters had to be referred back to lower levels for modification and completion.

Not only the town planning stage of the building process suffers from this procedure. Costly interruptions, delays and redesigning may arise on the design of streets, services and buildings and the preparation for construction if these activities have been started on the basis of approval at lower levels. The awareness of this fact, on the other hand, may lead to pressure on the higher authorities not to tear up a plan approved at lower level, even though shortcomings are discovered.

Building design

Once the client has been passed the initiative in the building process, the designs of the various buildings (within the framework of the development plan) can be prepared, their translation into bricks and mortar planned, and the job carried out.

The decisions by the community – building permit, building licence and approval of State loan – are vital for the commencement of construction and are delivered immediately prior to the start of the building operations. In many of the projects it proved very difficult to obtain these decisions in time. Other pressures finance, housing shortage, labour employment considerations – urged as early a start as possible. This meant that it was often

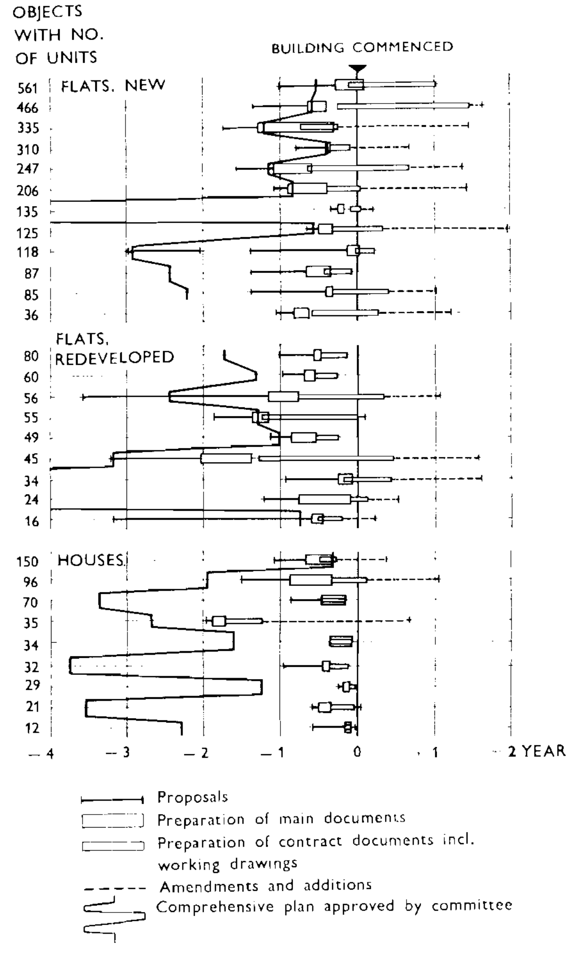


Fig. 3. Building design related to start of building. Architect's work.

necessary to make use of partial approvals—such as the approval of excavations to start or temporary exemptions from planning permission. In some instances the project was started without awaiting formal approval.

The period immediately preceding the planned start is notably rushed for the client and his consultants. This means that *many vital decisions have to be taken in a short period of time*. First, all the internal decisions regarding the design, which must precede submission to the authorities and advertising for tenders. Next, the official approvals mentioned above. Furthermore, before he can order a start the client must also secure the approval of the local authorities as regards services installations. Finally, he must compare the tenders received from firms willing to do the job.

The time spent awaiting a decision constitute a special problem. The 30 cases include examples where the pressure of work on authorities resulted in serious disparity between the time a document was actually under consideration and the total time to get it through. This can be explained in part by the widely different nature and extent of the various items to be approved. Unfortunately, the result can be that an entire project is stopped for a long time while a matter concerning a single aspect waits for its turn for consideration.

The report shows also the consequences to design of *changes in official regulations*. During interviews with those concerned on the 30 jobs criticism has been directed specially at changes in the rules for state loans. It should be noted that a change can cause dislocation, even when the change involves improved conditions. Replanning will be needed nonetheless. The complaints indicate that interim periods before new rules come into force do not always take account of the time required for the design work. It would be preferable if this could be carried right through on the basis of the rules in force when the work was started.

Major extra costs are caused by, above all, *modifications of drawings* after the start of building. Particularly remarkable are the commercial premises included in the renewal projects. Excessive delays in the early stages of the building process in some cases led to changes due to the original prospective tenants finding other accommodation, and their successors having different requirements. Changes after the start of building have also been caused by new types of machinery—refrigerators for restaurants, office machines, etc.—which are appearing on the market and implying alterations of electrical and piped services.

Construction

Poor co-ordination has been noted as between the execution of streets and services works and building construction. This is connected with the independent status of street and services matters, both in local administration and in design and construction. A building project of any size comprises buildings, roads and other works above ground, as well as service connections below ground. The scheduling, design, purchasing and carrying out of this entity are, however, grouped under different organisations. Furthermore, the organisations responsible for electricity, telecommunications and district heating work to a great degree independently.

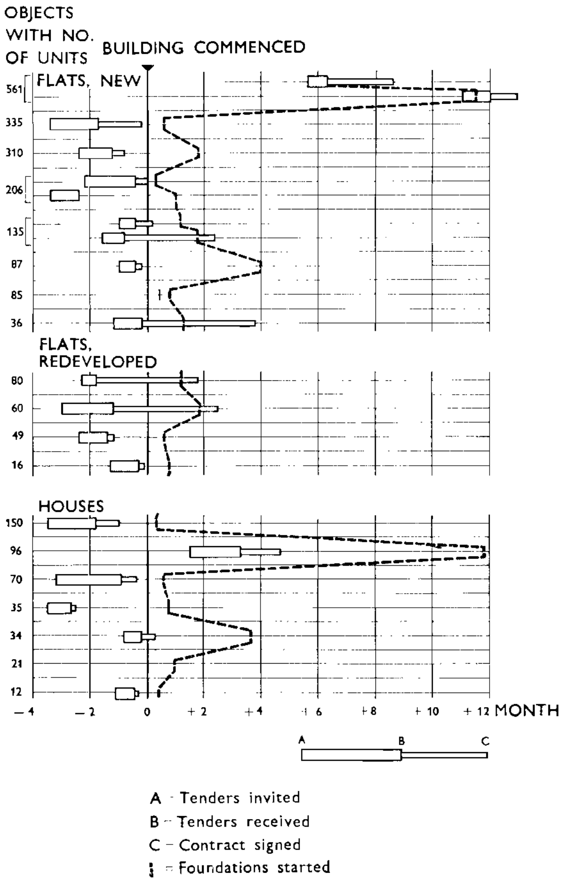


Fig. 4. Contract negotiations related to time when building started.

The problems facing the client due to concentration of decisions immediately before the start of building operations were discussed above. But this rush affects contractors more than anyone. In many of the 30 projects the contractors had but little time—only a few weeks—to submit tenders and contract documents, purchase materials, acquire labour, award sub-contracts and plan the entire operations. See fig. 4. The reason for this rush is the pressure on the employer “from above” to follow a certain housing schedule in order to keep labour fully employed and maintain new housing figures at a high level. But lack of knowledge about contractor’s problems has certainly been a contributory cause in some instances, with the result that *tendering times have been too short and the construction schedules impractical.*

Furthermore, it seems as if planning techniques, forms of purchases, checking and approval procedures, etc., have not yet become adapted to the development of new types of building components and building methods. The investigation gives examples of this, such as a case where design had already reached the stage of principal drawings when a decision was taken to switch from traditional to industrialized building methods, with the need to redesign as a result.

Experience from planning the use of steel formwork on building sites

By R. Hugsted and R. Wiig (Norway)

The introduction of new building methods is a time-consuming process. It starts when somebody gets an idea and ends when the new method has become generally accepted among labourers and builders and others engaged in the building process. There is very little coordination in this process of development, and consequently the whole process takes several years. This is to-day one of the greatest problems in the building industry and a problem which can be solved only through better communication and better management within the whole building team.

The Norwegian Building Research Institute—NBRI—works with practical problems in this field by solving development problems for contractors and consulting engineers. By doing this, we gain a practical orientation of the problems which we think is very valuable.

Problems encountered when introducing new building methods include the following: What kind of machines and methods of work should be used? What amount should be paid to the labourers? How should the costs be calculated? What sort of documentation should be used in introducing new methods? It is a fact that no set of routines exists within building firms to solve such problems.

In most cases it is up to the site manager and job supervisors to get information and to decide whether or not a new method should be used. Some contractors have given the job of handling development problems to some of the staff and this will enable them to solve the problems more systematically.

Background for work with wall panel shuttering

Wall panel shuttering demands the use of tower cranes on building sites. The ability of tower cranes for concrete work was early recognized by contractors, but as apartment blocks were mainly built with load-bearing brick walls, there were only concrete slabs to pour and the volume of concrete was not big enough to make full use of the crane's working capacity.

A comptetitive building technique for apartment blocks based on tower cranes depended on the use of the crane for other work than pouring concrete. Of course, a lot of materials, e.g. bricks, reinforcing steel etc., could be hoisted by crane. However, payment rates and work restrictions did not benefit the use of a crane.

For many reasons there was in the middle of the 1950's a change in construction methods for apartment blocks. A construction with concrete slabs on load bearing concrete walls from facade to facade came into use. This opened the way for the use of large formwork panels. However, continuous efforts to raise the efficiency of ordinary formwork methods were also being made. Gains were made both with regard to utilizing materials and raising labour productivity.

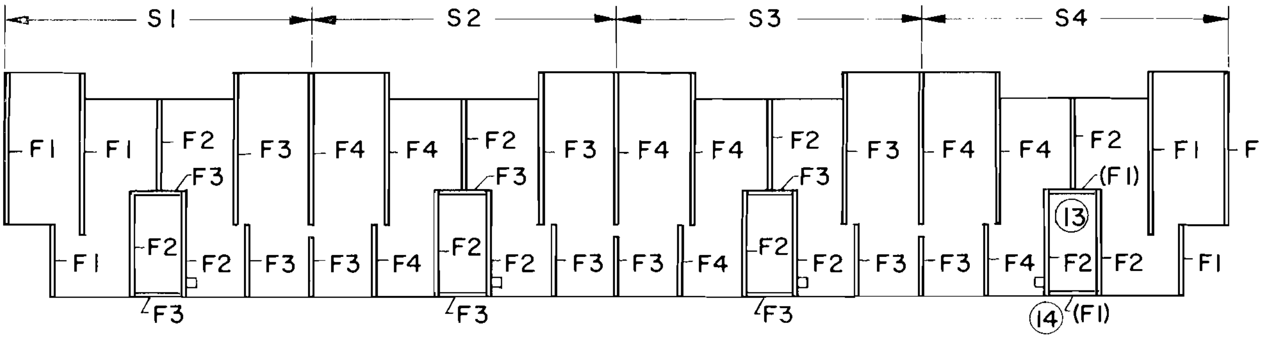
The contractors who build apartment blocks were much in doubt as to whether they should leave a technique which they knew quite well, which was competitive and for which only ordinary equipment such as concrete mixers and building hoists were needed.

In 1959, the NBRI was asked by a contractor to analyse whether he should take up the wall panel shuttering of steel or use the traditional methods which in this case were very effective. At this time wall panel shuttering had been tried but was not used by many contractors.

The contractor was to take up work on a building site of 240 apartments in four-storied blocks. An analysis should be made comparing the two methods and the contractor was to take his decision according to this analysis. It was also decided that plans should be worked out showing the co-ordination and timing of the work.

The first step was an analysis of the two methods. The two alternatives were described and cost calculations were made for alternative riggings, labour costs, shuttering and machinery. As a result of these calculations and the qualitative analysis of the two methods, the contractor decided to purchase cranes and wall panel shuttering of steel.

Later, the NBRI did similar work for other contractors, thereby gaining additional experience. Investment analyses have shown that tower cranes and steel shuttering are competitive.



SI - S4, sections for shuttering and concreting floor slabs in one storey

Set up sequences for one storey

Set up	F 1.	1 day				12 th day
Set up	F 2	2 day	5 day	8 day	11 day	
Set up	F 3	3 day	6 day	9 day		
Set up	F 4	4 day	7 day	10 day		

Wall no. 13 comes in addition on 12th day to set up F 1.
Wall no. 14 comes in addition on 1.st day to set up F 1.

Floor slab pouring sequences for one storey

Section S 1. 5th day
-"- S2 8th day
-"- S3 11th day
-"- S4 14th day

Fig. 1. Plan of load-bearing concrete walls for apartment block with 4 stories. Four different set-ups are used for wall panel elements F1–F4. The concrete slab is divided in four sections S1–S4 for performance of shuttering, placing reinforcement and pouring of concrete. 12 days are needed to pour all walls in one storey. Every third day a section of the floor slab is poured.

Calculated interests on the investment have been approx. 8–10%. Work time per sq.meter for the new method was originally anticipated to be 0.20 h/sq.m. Experience has shown this to be between 0.13–0.20 h/sq.m dependent on construction. Work time for ordinary wall shuttering would be approx. 0.45–0.55 h/sq.m. Prices offered by contractors for ordinary wall shuttering would be approx. 14–18 kr/sq.m. Later on the new method has forced the prices down. In 1963, prices between 10–12 kr/sq.m have been offered by contractors on competitive work. Contractors who volunteered the risk and took up the method early, thus enjoyed the advantages in regaining very quickly their investment and were able to advance further in this field.

Planning the use of wall panel shuttering

The panels most widely used have breadths of 100 cm and heights of 260 cm. These are standards but other breadths may also be obtained. The panels are put together into wall panel elements.

It must be decided how many standard panels should be available and how these panels are put together into wall panel elements. These elements are used every day and the day's work starts with taking out bolts and loosening the elements. Then the elements are hoisted and placed to form a new wall. If reinforcement and openings must be placed, just one side of the shuttering is mounted, then the necessary work is done and the closing side is mounted. These operations are planned by the following rules:

TABLE 1. Planning rules for the use of wall panel elements

1. The least possible number of panels should be used on a certain job.
2. The panels should be put together into a combination of elements which may be used to pour all walls on the project.
3. Standard panels should be preferred.
4. Large elements should be preferred but the lengths should not exceed 800 cm. The crane's capacity should be taken into consideration.
5. Each element should be used every day.
6. The sequence of the walls should be arranged in such a way that the concrete slab shuttering could follow up as soon as possible. If necessary, wall panel elements should be placed on the slab the day after the slab is poured.
7. The wall panel elements are usually demounted in the morning of the day following the pouring, the hardening time for concrete walls thus usually being from 12–20 hrs.

These descriptive rules are used to guide the planning towards an economic application of the method. Obviously, quite a lot of combinations of panels could be used and the aim of the planning is to fix one reasonable combination. First, the rate of progress of work must be decided. This is often fixed in the contract. With one crane and 3–5 men working with the elements and pouring the concrete, 50–100 sq.meters of walls may be produced every day. The corresponding rate of progress will be between 0.5–1.0 apartments per day. If greater rates are fixed, more than one crane and one set of wall panel elements must be used.

The work with the elements and other work connected with the bearing construction must be co-ordinated.

A close co-ordination must exist between the following operations:

TABLE 2. Operations connected with the concrete work

1. Work with wall panel elements.
2. Placing reinforcement in walls.
3. Pouring walls.
4. Work with concrete slab shuttering.
5. Placing reinforcement in slabs.
6. Pouring concrete slabs.

This work is traditionally divided between concrete labourers, shuttering labourers and labourers doing reinforcement work, all being a specialized branch but without the status of a handycraft trade.

In practice, the work organization is being discussed with the contractor. We usually recommend a specialized gang to do the operations 1, 3 and 6, mentioned above, another gang to do operations 2 and 5. But also other work organization may be used and this is often discussed on the background of "accord" (piece-work) payment and existing fixed prices for units of work.

Plan for moving wall panel elements

The plan is worked out on a lay-out plan of the building. Usually several combinations of elements are tried. One suitable combination is selected and a drawing is made showing the plan for one storey. Other drawings are made in scale 1:100, showing the set-up of the elements for each day.

Fig. 1 shows an example of one storey of a building with four staircases. It will take 12 days to produce the concrete walls for one storey. To do this, four different set-ups of wall panel elements are used. The first day the set-up F1 is used, the next day F2, then F3, F4, F2, F3 etc. Thus, it is possible to repeat the different set-ups a number of times for one storey, F1 is used two times, F2 four times etc. This is considered an advantage but is not, of course, always possible.

In this case the following wall panel elements are used:

One 8 m double, one 6 m double, one 5 m double, two 2 m double, one special element for the garbage shaft and two special wood elements for the staircase.

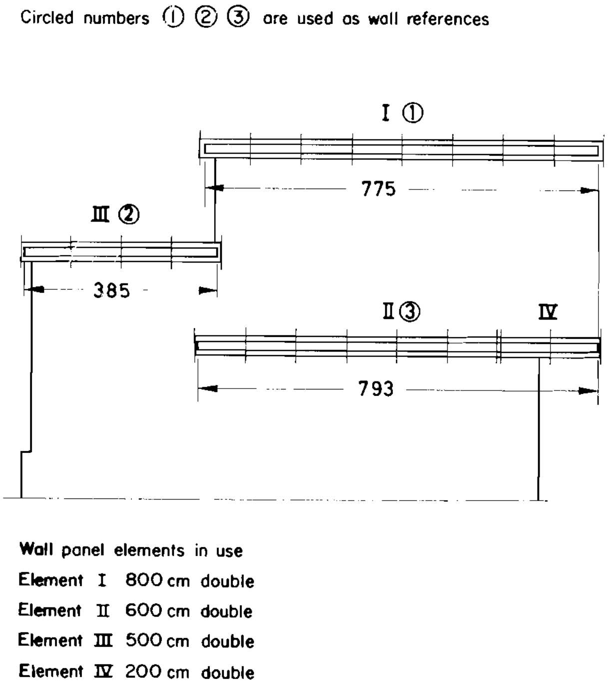


Fig. 2. Set-up plan F1 for wall panel elements. Circled numbers are for wall reference. Roman numerals denote wall panel elements.

One drawing is made for each of the set ups in scale 1:100. Fig. 2. shows the set-up for F1.

Detail drawings for the building site

Detail drawings are also made, showing end closings for walls and the use of special elements. Fig. 3 shows three different end closings and Fig. 4 shows special wood shuttering used on the staircase. This wood shuttering is used against wall blocks of light weight concrete with ordinary steel panel elements on the other side of the wall.

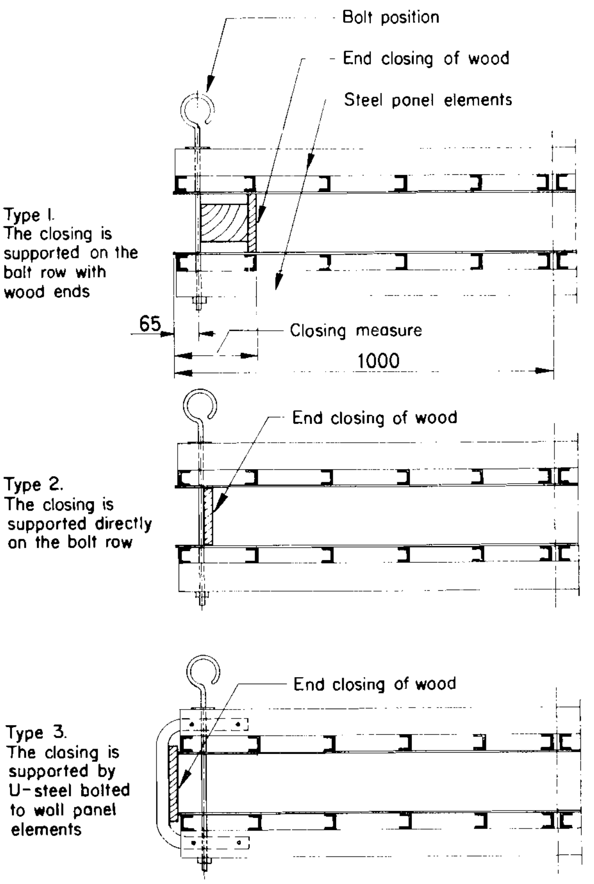


Fig. 3. Types of end closings for wall panel elements. A table is worked out in connection with set-up drawing giving information of what types of closings are used on every wall and in cases of type 1, what closing measures to use.

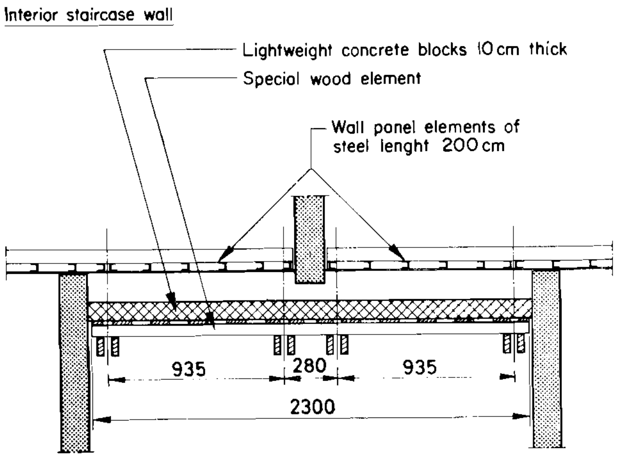


Fig. 4. A detailed set-up drawing showing the use of a wood panel element connected with steel panel elements on staircase wall. The wall has an insulation of 10 cm light-weight concrete which is piled against the wood panel element and fastened with nails. Holes are drilled for bolts through the light-weight concrete.

Drawings may also be made showing details connected with wall junctions and working joints as in Fig. 5.

The use of detail drawings need not go into every detail and when the labourers get used to the new method, they are able to do the work without such detail drawings. It must be judged how much information in the form of drawings and other instructions should be made available for the production on the building site. To-day we feel that too little information is used but one should avoid going to the other extreme using too much information.

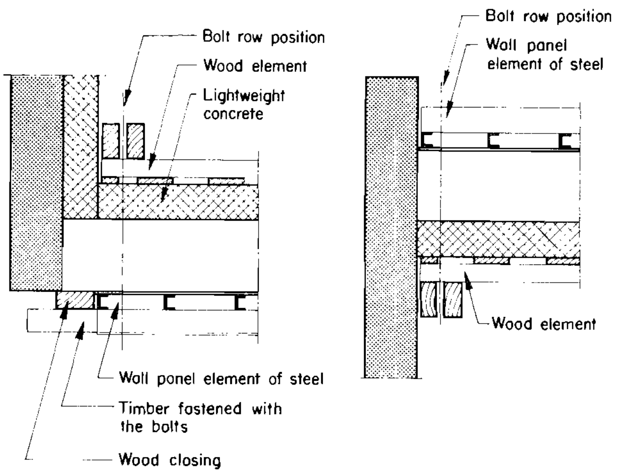


Fig. 5. Details of shuttering at wall junctions.

When the set-ups have been decided, an application with necessary specifications is made to deliverers of panel shuttering and, in due time, a delivery is ordered.

Planning the work

The planning of the work is usually made on the basis of standard time consumption rates for different operations and the plan shows the different gangs and co-ordination of work in time and place on the building or different buildings.

When dealing with wall panel shuttering, we have found a further detailing necessary and we, therefore, set up a detailed work plan showing the co-ordination of the operations mentioned in Table 2 for every day's work on one storey.

In this plan the work with the elements and the pouring of the concrete are considered to be the key operations which are used to steer the other operations.

In the example referred to previously, the gang working with panel elements and pouring concrete consisted of 4 men (gang 1), reinforcement work was done by two men (gang 2), and shuttering and scaffolding work was performed by 3 men (gang 3). Fig. 6 shows a part of the plan.

The references to the walls are made with respect to the plan for moving wall panel elements where each wall has a certain number. The work on the concrete slab is split up in four sections for one storey, S1 – S4, Fig. 2. The concrete slab is thus poured in four different days, each demanding 3½–4 hrs. As one storey takes 12 days, every third day is critical for gang 1 who does the concreting work. The other days the gang will usually have time free to do supplementary work.

Shuttering work on the concrete slabs is adjusted to the work on the walls. Gang 3 has continuous work on the block with scaffolding work as supplementary work. References are here made to sections S1–S4.

Reinforcing work is adjusted both to work done by gang 1 and gang 2, giving gang 1 priority and with the same references as mentioned above.

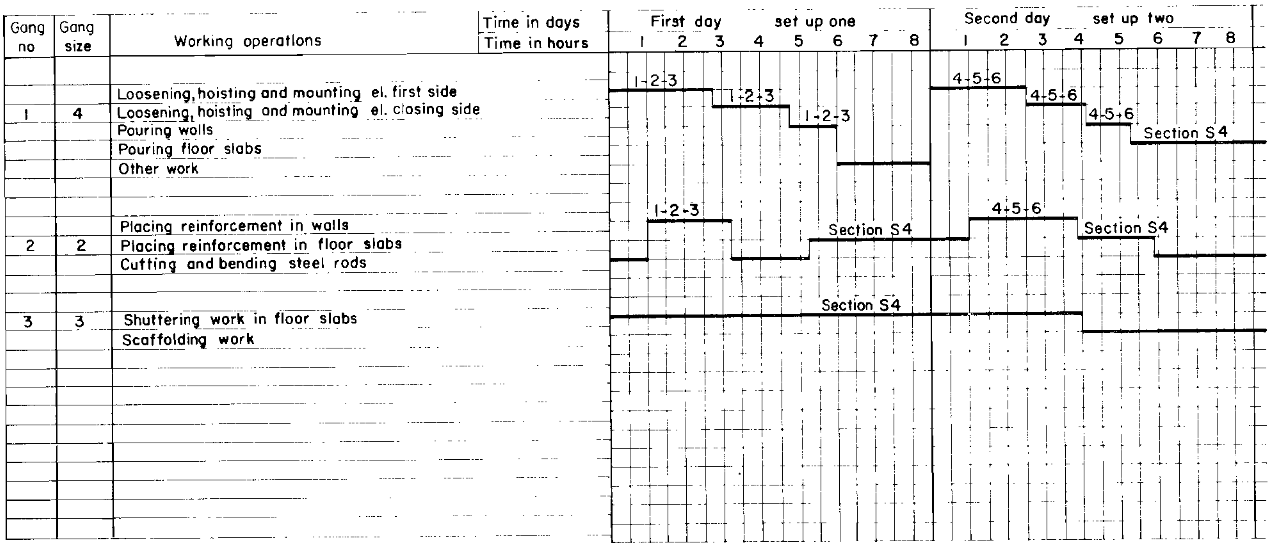
In order to plan the work, time consumptions must be computed for the different operations and sections of work.

Time consumptions for wall panel elements are computed on the basis of standard time consumptions in minutes for the following operations:

TABLE 3. List of operations for using wall panel elements

1. Measuring and preparatory work	One wall
2. Removing bolts	Per bolt
3. Removing and hoisting element	Per element
4. Mounting door closing	Per piece
5. Mounting end closing	Per piece
6. Mounting window closing	Per piece
7. Cleaning and oiling element	Per sq.meter
8. Mounting bolts	Per bolt.

R. Hugsted and R. Wiig



Gang no	Gang size	Working operations
1	4	Loosening, hoisting and mounting el. first side Loosening, hoisting and mounting el. closing side Pouring walls Pouring floor slabs Other work
2	2	Placing reinforcement in walls Placing reinforcement in floor slabs Cutting and bending steel rods
3	3	Shuttering work in floor slabs Scaffolding work

Fig. 6. Part of detailed work plan for shuttering, placing reinforcement and pouring concrete showing sequences of work for three gangs. Only gang one is wholly dependent of the crane but also gang two uses the crane when idle to hoist reinforcing steel. The shuttering materials for slabs is handled manually from one storey to the storey above.

There is another list of operations for the wooden elements. This enables us to compute the total time for each day (set-up of elements). Standard times are based on work measurements.

Time consumption for pouring concrete must be adjusted to the hoisting capacity of the crane, in this case 5 m^3/h was used for the walls and 5.5 m^3/h for the slab. These operations need 3 men in gang 1. Thus one man may be doing other work.

For the other operations, shuttering for slabs, laying steel rods etc., standard times estimated per sq.meter, ton etc., are used, partly based on experience and partly on work measurements. Quantities of work are computed for the different sections of work.

The result is a plan showing the complete work cycles every day for one storey. This is afterwards combined in a total plan—terminplan— covering all sorts of work from foundation to the finished building.

Use of the planning technique

The planning techniques described have been used on several occasions and have been particularly useful for introduction of the method when the contractor has no experience with wall panel shuttering. At the same time, this has meant an introduction of work planning techniques.

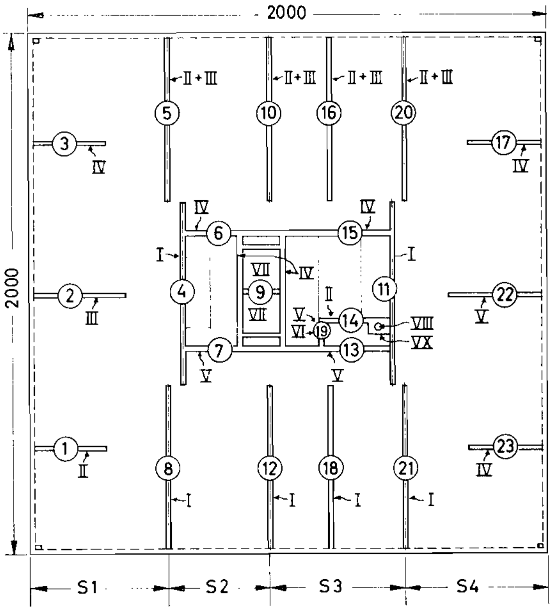
The method has been used both on ordinary apartment blocks with 3—4 stories and on tower blocks with 10—12 stories. Fig. 7 shows an apartment block of 10 stories with load bearing interior walls of in situ concrete. The walls and elevator shafts are all poured with wall panel shuttering. With reference to Fig. 7 the walls are concreted in the following sequence:

Set-up 1 wall number 1— 2— 3— 4
Set up 2 wall number 5— 6— 7— 8
Set up 3 wall number 9—10—11
Set up 4 wall number 12—13—14—15
Set up 5 wall number 16—17—18—19
Set up 6 wall number 20—21—22—23

It thus takes 6 days to concrete all walls in one storey. The concrete slab is shuttered and poured in four sections, section no. 1 the 5th day's set-up, section no. 2 the 6th day's set-up, section no. 3 when the first set-up is made on the storey above, section no. 4 when the second set-up is made.

To organize and co-ordinate the work for such a house is quite an intricate job because the different gangs must have continuous work, while the space is limited.

On this and other occasions one may ask the question what influence the wall panel shuttering has on the design of the building. Originally, the method was taken up by the contractors and they had to handle the problems with the consulting engineers on the site. Problems arising were where to allow working joints in walls and slabs, and how to arrange the reinforcement to fit



Floor is poured in 4 sections S1.-S4
○ Wall numbers are circled
Numbers I-IX have reference to panel elements

List of wall panel elements	
I	700 cm double
II	300 -"- -"-
III	400 -"- -"-
IV	400 -"- -"-
V	400 -"- -"-
VI	100 -"- -"-
VII	Two interior lift shaft elements
VIII	Interior garbage shaft elements
IX	Exterior garbage shaft elements

Set up	Walls to be poured
1	1 - 2 - 3 - 4
2	5 - 6 - 7 - 8
3	9 - 10 - 11 (9 includes both lift shafts)
4	12 - 13 - 14 - 15 (14 incl. garbage shaft)
5	16 - 17 - 18 - 19
6	20 - 21 - 22 - 23

Fig. 7. Set-up plan for wall panels elements on a 10 storey block. A working cycle must be set up which allows the different gangs to work continually without interruption. This is difficult because of limited space. Number of wall panel elements and sequences of work are shown in the plan. It is essential here that the core with lift shafts and staircase must be performed so that the whole work is not held up.

with the method. New details of reinforcement had to be arranged and connections with steel rods must be placed in the joints.

The consulting engineers had to collect information and gain experience bit by bit, which is a slow and time-consuming method. The NBRI has been asked for help and in some cases we have given advice on details to get the constructions adapted to the use of wall panel shuttering before the tendering procedure.

In one case the NBRI worked out a special document which was used as a tender document, advising the contractor how to perform the building with wall panel shuttering. The document described work, organization, set-ups for wall panel shuttering etc. with work plans and other documentation.

Details of reinforcement, working joints etc. were discussed, and drawings made by the consulting engineer who thus used the NBRI as a special consultant in production planning.

Of course, it is not possible to do such work on a broad scale but we hope to collect enough experience to write a manual or some sort of publication which may give general advice for the consulting engineers.

In this case, the tender prices were quite satisfactory for the client, being approx. N. kr. 10,— per sq. meter for shuttering of concrete walls. Although it is difficult to refer to and discuss single tender prices for units of work, we think that without the documentation and work done, the tender price for shuttering would have been approx. 50% higher.

Conclusion. The use of wall panel elements for shuttering is now a well known technique for contractors constructing office buildings and apartments. On several occasions the Norwegian Building Research Institute has been asked by contractors to help them introduce this method.

The different plans of work and details which have been worked out have greatly helped the contractors to avoid mistakes and get relevant information on a method of which they had no experience. We may now say that this method has been accepted by the contractors who also process equipment suited for the work.

A lack of communication exists between contractors and consulting engineers and architects. To-day, designers do not get relevant information on how to adjust their constructions to a certain production technique. Such adjustment is also prevented by the traditional methods of tendering which are done with no special reference to production methods. This has led to double-work for consulting engineers who, as in examples mentioned above, had to remake rod lists and details of reinforcement.

In future, we shall need manuals describing production methods to obtain relevant information on production techniques for the design offices. This will enable us to go on with the open tendering and with the open systems of building. The working technique described was, after the introduction phase, a cost-saving method and the prices of the units of work have been reduced from approx. 16–18 N. kr. per sq. meter to approx. 10–12 N. kr. per sq. meter for work where the method may be used.

Not many contractors do systematic development work for production methods mainly because of shortage of staff and resources. To introduce new methods, therefore, takes a long time, including the time from idea to the first successful application of a method. When a method has been successfully tried, it spreads quite rapidly but the lack of communication between designers and producers may continue to be an obstacle for a long time.

Much may be gained in time and costs from speeding up development processes through systematic work for introducing new methods on the building site. With respect to contractors this work has two phases. The first phase is to get the contractor's acceptance of the new method. Descriptions and analyses of the new and the old methods and cost comparisons are important in this stage. The second phase is to get the method introduced on the site. Site managers, foremen and workers must have relevant information on the organization of work and the methods which will be used.

When it is known that the new method can compete with traditional methods, information on the consequences and demands of the production techniques on the design must get through to design offices. When this has been done, the conditions for lowering prices or obtaining better quality have been fulfilled.

Typification as the basis of industrialised building

By S. Janicki (Poland)

Factors of typification

Typification in building gives the possibility of obtaining the greatest degree of repetition of all operations and products in design and production. Repetition is a factor that facilitates the industrialisation of production of building components in an effective way in large manufacturing works. It is an assumed condition for having a steady output from the point of view of quantity and quality of production in a reasonable time taking into consideration the technical and economic aim of mass production. Hence this factor of typification results in a gain in technical and economic profits. Typification reduces the number of types and sizes of building components needed in building, permits a specification of assembly groups acting on the building site, simplifies and decreases the variety of the equipment, which results in considerable economy in the building costs and accelerates the execution of the investments planned.

Reduction of number of types and sizes

Specialisation of production and the costs of production equipment exercise great influence on the design so as to constantly reduce the typical components needed for erection. In consequence it may be said that e.g. in Poland there is a great reduction of the number of typical components used in building in the large size panel system. Here two solutions may be distinguished. One comprises the architectural-structure solution of the buildings with identical number of stories, but having the full structure as to the number and kind of flats e.g. from one-room flats up to three-room flats. The other solution covers the full complex solution (architecture, construction and town planning) of a settlement or of a town-district. In this case it is expected that varying sizes of flats will be needed as well as buildings of varying heights from 5 to 11 stories. The respective number of typical components needed in the above mentioned cases of investment are shown in the table.

TABLE

	Average number of typical components in years	
	1958	1964
1. Buildings with one height of 5 stories with a full architectonic program	36	25
2. Buildings with different heights from 5 to 11 stories with a full architectonic and town planning program	60	44

Optimal period for production of component

Unfortunately, repetition is such a factor as is limited by technical progress. New requirements of designers and inhabitants as well as new methods of production and new materials make it impossible to maintain the stability of production quality over a long period of time. In consequence, a too long period of production of a component leads to the point in which the component is not modern from the technical point of view and not competitive as to its price.

All this applies both to building components and to the whole building.

Considering the question of the optimal period of production of typical components we use the function of interdependence of the costs of production of a component and the period of its course.

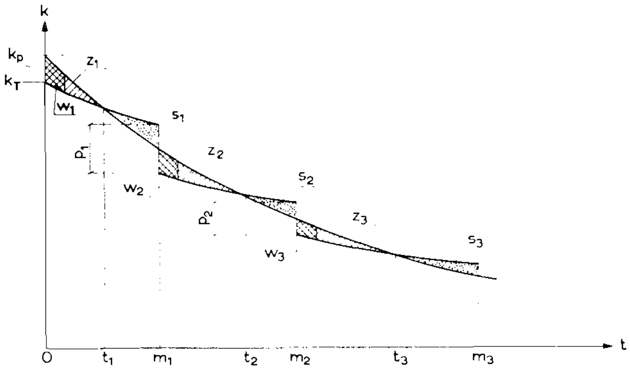


Fig. 1. The surfaces illustrating the losses and profits by the comparison of the production of typical and non-typical components.

In the figure there are shown two graphs, one as a continuous curve characterizing the production taking into consideration the technical progress, and a "salient curve" characterizing the periodical course of production stabilized by manufacturing of a typical component.

The starting points of the curves have ordinates k_P and k_T and give initial difference in the costs *k* to the advantage of the typical component.

For the sake of comparison we assume that the time of production for the typical and non-typical components is identical and equal to m_3. Stabilized periods of typical component 1, 2, and 3 refer to the division m_1, m_2 and m_3.

According to the general course of curves we obtain their intersections in each division t.

The area resulting from the intersection of curves, indicates the profit, the area *s*—the loss in production. The profit concerns the earlier period of production in each division in a case when the production of typical components gives an advantage, whereupon in the later period of each division the advantages turn into losses. It results from the possibility to apply technical progress in the production and to achieve a decrease of the costs in production. In order to achieve a suitable effect from the production in each period, the following inequalities must be satisfied:

$$z_1 \geqslant s_1$$
$$z_2 \geqslant s_2$$
$$z_3 \geqslant s_3$$

In order to obtain the same level of achievement in technical progress for typical components lost in the period 1, it is necessary to undertake investment assuring a sudden reduction of costs of production of typical components of the value p_1 for period 1 and of the value p_2 for period 2.

These areas are chequered in the figure. They are only a small part of the areas illustrating the profits in production. Hence the inequality must be completed by the expenses borne for investment indicated by w_1, w_2 and w_3. We get the inequality

$$z_1 - w_1 \geqslant s_1$$
$$z_2 - w_2 \geqslant s_2$$
$$z_3 - w_3 \geqslant s_3$$

adding these formulas by sides, we have

$$\sum_{i=1}^{n} z_i - \sum_{i=1}^{n} w_i \geqslant \sum_{i=1}^{n} S_i \quad \text{or} \quad \sum_{i=1}^{n} (z_i - w_i) \geqslant \sum_{i=1}^{n} S_i$$

The difference of the values of coordinates k_P and k_T is not important because we may take it that they are equal, that is, the production of the typical and non-typical component begins from the same cost level but it affects the results only in the first period of production.

Applying the mathematical analyses we can establish the period of time in which profits will be equal to losses. Outside this period, the production of typical components should be halted.

Systematic design methods and the building design process

By J. C. Jones (U.K.)

Several methods of making the design process more public and therefore better suited to the collaborative design of complicated products have been proposed in recent years. The term "systematic design methods" was used to identify such methods at the London Conference on Design Methods in 1962. Some of the techniques described at that meeting[1] and a few others of similar intent have been applied to the complex design problems of missile detection, guidance and control, to the design of such engineering novelties as the "Bluebird" speed record vehicles, to the determination of town plans intended to accomodate unknown technical innovations, to the exploration of man-machine links in equipment design, to the devising of advertising campaigns, to the cost-reduction of engineering components and to the teaching of architects, industrial designers and engineering designers.

Not all these attempts have been successful but enough has been done to suggest that systematic design methods, or developments of them, could be of considerable value in the design of buildings and their associated engineering systems. This paper is a brief review of some of these techniques and a suggestion for the re-organising of the building design process so that such methods could be more readily applied.

Divergence

Design methodologists seem to agree that the design process must begin by widening the field from which ideas are sought before deciding to concentrate on one favoured solution. This is called "divergence".

The advocates of creativity in design, of whom Osborne[2] has been perhaps the most influential, propose "brainstorming" meetings at which persons of very varied experience are asked to suggest any conceivable way of tackling a design problem. The inhibiting effects of criticism are avoided by a rule that no idea is to be evaluated until the meeting is over. There is evidence[3] that group brainstorming does not produce better ideas than does solitary thought but there is little doubt that it is an extremely quick way of extracting information from the memories of persons whose experience may be relevant to the problem.

Norris[1] shows how morphological charts can oblige a designer to think of several solutions for each of the major design requirements and how these solutions can be combined to form thousands and sometimes millions of alternative designs. Unfortunately neither brainstorming nor the morphological method include a reliable way of selecting a feasible or optimum design from the many alternatives that are generated.

Thornley[1] and Jones[1] propose a rather more controlled widening of the field of search at the start by the collecting of alternative ways of providing separately for each of many detailed design requirements, regardless of all the others. Unacceptable partial solutions are eliminated either by judgment or by matching against carefully worded performance specifications. Incompatibilities between the surviving partial solutions can be explored systematically using an interaction matrix before attempting to find feasible complete solutions. In this way the problem of having too many alternatives is reduced to more manageable proportions while considerable flexibility is retained.

Alexander[1,4] proposes a mathematical method of breaking down a set of design requirements into reasonably independent sub-sets. Physical components designed to match such sub-sets will not interfere with each other. This absence of conflict between different parts of the design is intended to increase the possibility of subsequent modification, adaptation and change. Such adaptability appears to be particularly desirable in the components of industrialised buildings.

Each of these systematic methods differs from conventional design procedures in one important respect: the design problem is divided into pieces each of which is solved on its own without reference to the overall design into which the pieces are afterwards combined. Step-by-step analysis of the relationships between the parts replaces visual insight as the means of combining them into a coherent whole. Intuition and experience are directed instead towards definition of boundaries within which a variety of acceptable designs are to be found.

Convergence

Page[1,5] discusses the strategy of starting the design process with models that are as rough as can be tolerated and changing to more refined models only after the major design problems have been solved. He suggests that design effort must not be squandered on detailed studies of designs that are later found to have major faults and that ideas must not be developed very far unless there is definite indication of convergence on an optimal solution. He does not show exactly how the convergent properties of a design may be decided before it has been explored in detail. Marples[6] has described how engineers direct their knowledge and experience to the avoidance of design decisions which are likely to create difficulties at later stages. The feasibility of avoiding blind alley decisions in the design of very novel products, of which nobody has sufficient experience to anticipate difficulties of manufacture, tolerance etc., is a vital point about which we seem to know very little.

Matchett[7] has developed the questioning methods of work study into what he calls "Fundamental Design Method". Engineering designers who have been persuaded to use this method have been able to reduce by about half the complexity and cost of engineering components without loss of performance. This method appears to throw some light on the difficult problem of convergence and seems well suited to the detailed design of building components that are to be made in large quantities. The method is intended to make it obvious when a product is unsuited to the resources of the organisation that is considering its marketing and manufacture; it may therefore be a useful technique to companies that are proposing to set up as makers of industrial buildings.

System engineering techniques

The most striking benefits of using systematic methods have been in the design of enormously complicated and yet very reliable systems for the detection and launching of missiles and space vehicles. These are cases in which the standard techniques of system engineering can be applied because the design is entirely composed of distinct components through which there is a flow of information, energy or materials, Gosling[1]. When the behaviour of the flow and of the components is well understood and is not too complicated, and when there is little or no direct interference between the components, it is possible to predict very accurately the performance of the system as a whole under various conditions. Even when the behaviour of each component is not understood, much can be done if the nature of the outputs and inputs to each component can be specified precisely. In such a case the matching of inputs to outputs throughout a flow diagram can ensure the detection of a large proportion of the operating faults of the system before the components have been connected together.

System engineering techniques seem to be very relevant to the design of the heating and ventilating services, and pedestrian circulation routes, in buildings. These methods may be equally applicable to the combining of the decision sequences of the many members of the building design team into a single logical process.

The application of systematic methods to the design of buildings

The conventional sequence of designing and constructing a building is of four stages; 1) Client's brief. 2) Sketch design. 3) Working drawings. 4) Construction, each of which is completed before the next begins. Systematic methods do not seem to be compatible with this serial design-strategy. The new methods

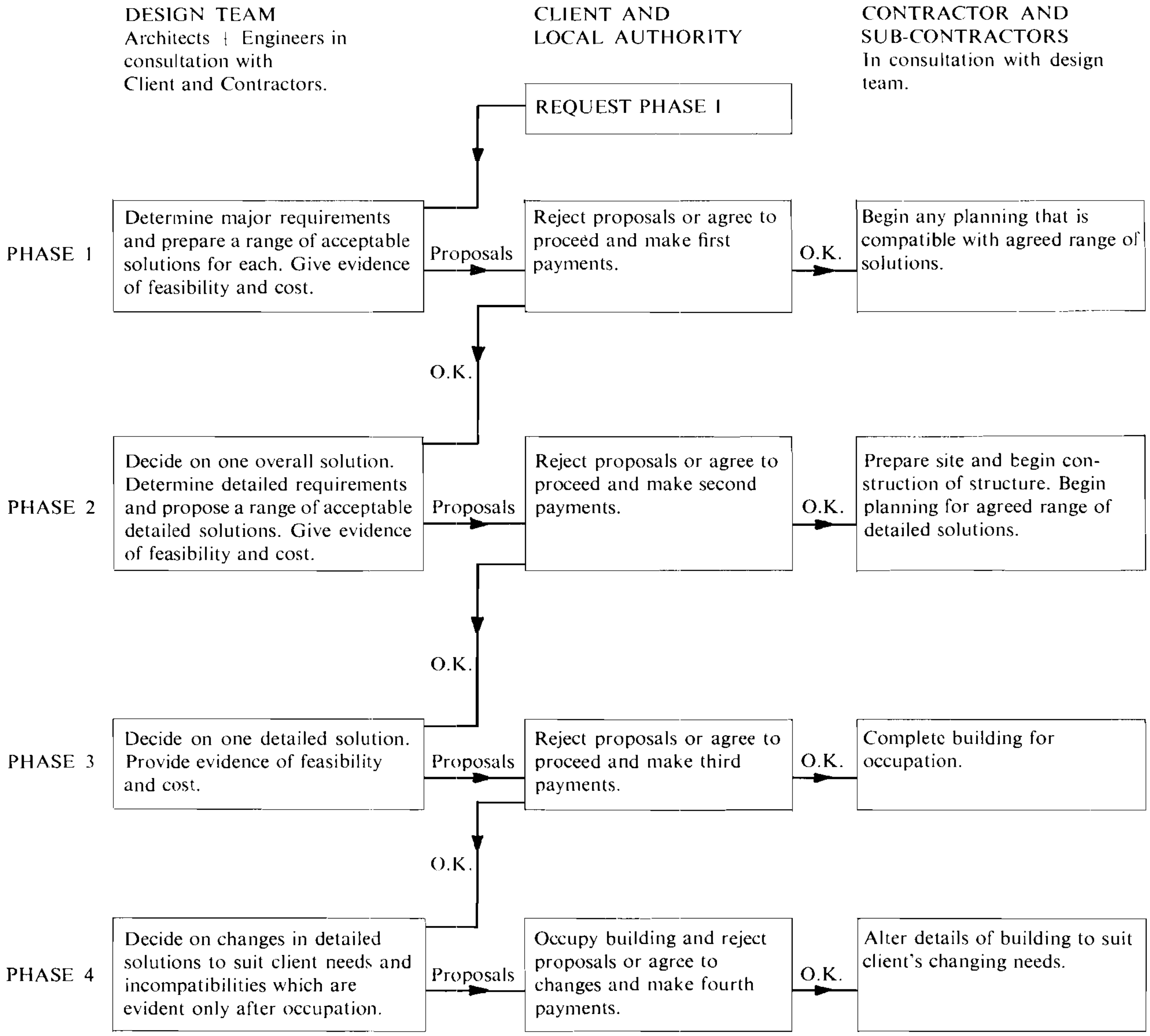


Fig. 1. Flow Diagram for the Systematic phasing of building design and construction allowing four opportunities for mutual adjustment of user requirements, structure, services, insulation, site and constructional problems before detailed design decisions are made.

pre-suppose detailed exploration of many more alternatives at the start and much greater opportunities to make changes in the overall design during slow convergence towards a detailed solution. There is not likely to be time for this protracted procedure in the design of an urgently wanted building and probably not enough money to spare for detailed analysis of many alternative designs and their many implications.

Is there an alternative strategy of building design that is quick and cheap and yet capable of sufficiently wide divergence and sufficiently slow convergence to permit the flexibility of a systematic method? As a first suggestion the writer proposes a scheme of design for building in four distinct phases—at each of which the client's needs are reassessed, Figs. 1 and 2. A controlled amount of divergence occurs in all phases and convergence of detailed design is deferred until the final phase when the client has been occupying the building for some time. It may be that this proposal would be feasible if there were few interactions between the major decisions and the detailed decisions. The avoidance of such interactions might well be a major objective in the design of components for industrialised building. Much research and development may be necessary before these suggestions can be expected to take a more practical form.

Conclusions. Systematic design methods are intended to make the design process more public so that a number of persons of differing experience can collaborate more readily in the design of complicated products.

The methods proposed so far are very different from each other but have in common the intention of widening the area of search so that a range of alternatives can be explored before converging on the final solution.

The feasibility of applying such methods to the design of buildings may depend on

(a) the development of components which are less likely to interact with each other. A systematic method of designing non-interacting components has been suggested by Alexander.

(b) altering the architectural design sequence so that many of the decisions at present made in the form of a sketch design are deferred until the user requirements, structure, services, insulation, site and constructional problems have been explored in stages and mutually adjusted.

It may be both necessary and feasible to begin construction before detailed analysis is complete and to continue analysis and redesign during the client's occupation of the building.

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	INTERNAL SPACES	EXTERNAL APPEARANCE	STRUCTURAL SYSTEM	SERVICES	INSULATION	SITE	ACCURACY OF QUANTITIES AND COSTS
PHASE 1	Numbers and kinds of rooms. Areas and volumes decided.	Alternative block plans.	An acceptable range of systems	Acceptable types of systems.	Acceptable range of types of cladding, roof, floor, windows, etc.	Range of alternatives agreed for access, foundations, etc.	± 20%
PHASE 2	Positions of walls and partitions.	One block plan and alternative elevations.	One type of structural system and foundations in outline.	One type of system chosen and ducts fixed.	One type of cladding, roofing, flooring, etc. chosen.	Access, services and foundations agreed.	± 5%
PHASE 3	Details of doors, windows, etc.	Final elevations.	Details of structural system.	Selection and detailing of components.	Selection and detailing of components.	Details of paving and landscape.	± 1%
PHASE 4	Alternative positions of partitions.	Changes to elevations.	Modified in detail.	Modified in detail.	Modified in detail.	Modified paving and landscape.	± 1%

Fig. 2. Decisions at each phase of the scheme for building design and construction proposed in Fig. 1.

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V. Jurík

The typification cycle and the experience gained in the course of its application in Czechoslovakia

By V. Jurík (Czechoslovakia)

Typification is a progressive method of work in the preparation of generally high quality mass construction. It expresses the degree of development of the social standard of mass construction, simultaneously creating prerequisites for the industrialisation of building.

In Czechoslovakia typification has contributed to a considerable extent to the ensuring of an ever increasing volume of all types of capital construction. It was one of the basic prerequisites for the development of the industrialisation of building, for the application of industrial forms of production of prefabricated components in large series, the application of progressive forms of organization of work as well as the reduction of costs of construction, an increase of productivity of labour and the improvement of other technical and economic indices in capital construction.

In the course of the first years of development of typification, generally the traditional production and material basis was used in Czechoslovakia, represented by brick masonry and in-situ reinforced concrete structures with a gradually increasing quota of reinforced concrete precast members (window and door lintels, floor beams, staircase units, roof structures, etc.).

The gradual increase of the degree of assemblability of buildings, and the application of new, progressive methods of construction characterized by the gradual concentration of prevailing volumes of production in permanent plants in which production has acquired an industrial character, have imposed new ever more exacting requirements also on the character of the typification cycle itself, which must respect in its full extent the complex character of changes occurring due to the transition to new standard typified designs (incorporating new prefabricated members and structures) and affecting also the material and production basis.

In the process of preparation of typified (standard) designs the following alternatives generally occur:

– a) on the basis of currently produced components, structures and technologies a new planning and volume scheme must be designed to satisfy new performance requirements and new requirements imposed on the standard of buildings;

– b) while maintaining the valid planning and volume schemes, a typified design must be prepared using new products, structures or a new technology of construction in accordance with the possibilities of the technical development of construction;

– c) a new planning and volume scheme must be prepared to satisfy the higher requirements imposed on the standard structures and technology of construction in accordance with the successful results of research, development and the conception of further technical development of building.

From the viewpoint of the speedy application of typified designs in mass construction the simplest prerequisites are given in alternative a) because the respective solution imposes practically no requirements on the new material and production basis.

Alternative b) represents the technical improvement of a certain existing typified design by replacing its less progressive structures and technologies of construction by more progressive structures and technologies in accordance with the possibilities of technical development.

The most exacting manner of preparation of new typified designs is represented by alternative c) which enables the typified designs to correspond to the highest social, technical and economic level, but involves vast preparations, the typification cycle consequently requiring a longer period.

Experience acquired hitherto has shown that in the preparation of typified designs as per alternative c) the following procedure must be adhered to:

1. On the basis of the results of social research in the field of capital construction, and research in the field of the material basis of construction, *preliminary studies (designs)* are prepared.
2. These preliminary studies are utilized for the preparation of *experimental designs* to be used in *experimental construction* in which the function of the building is verified from the viewpoint of performance as well as from that of the technical characteristics of its individual structures.
3. Evaluated experience from experimental designs and sites supplemented with an economic balance of the means of production, decisions pertaining to the components, structures and technologies to be used and the price limits is used for the specification of a *typification problem.*
4. On the basis of the approved typification problem *typified designs* are prepared. Simultaneously the *material and production basis* is built up so as to be completed at the time of approval of typified designs.
5. Approved typified designs are verified in the so-called *verification series* of buildings *built on the basis of the new typified designs.* The construction must be evaluated and the experience gained used for the improvement of typified designs.
6. Finally the mass construction of buildings based on the new typified designs is ensured.

Research, development and preliminary studies

Research work follows two trends, namely:

– a) research of useful characteristics of investments (planning, sociological problems, etc.)

– b) research of structural, technological, production and economic problems.

In Czechoslovakia problems ranging in group a) are solved by the Research Institute of Building and Architecture and by the Study and Typification Institute in Prague.

Research in the field of structures, the technology of production and construction as well as the economy of construction is carried out by the Research Institute of Building (housing, civil, industrial and agricultural construction), the Research Institute of Civil Engineering, the Research Institute of Building Materials and the Research Institute for Economy and Organization of Building.

Development is ensured by the development departments of investors and of the individual construction corporations.

Studies and preliminary designs whose purpose is to verify various alternatives stimulated by the results of research and development are prepared by research institutes, study institutes, and the design institutes of the individual ministeries and regional design institutes.

Experimental designs and experimental construction

Experimental designs are prepared on the basis of experimental studies or preliminary designs developing the latter in detail in order to create prerequisites for the construction of experimental buildings. They are prepared chiefly by study institutes, and the design institutes of the individual ministries and regional design institutes. On experimental sites all new structures, technological processes and performance relations are thoroughly tested and verified.

The problems to be solved on experimental sites are based on the problems solved in research institutes and development departments.

The technical and economic evaluation of experimental designs and experimental construction represent important data for application in the specification of the typification problem.

Typification problem

The specification of a typification problem is based on the experience gained on experimental sites, the results of competitions, perspective studies and typification studies. A typification problem incorporates the selection of structures, components and technology and the determination of the technical and economic indices for the new typified design. It contains also a time schedule of the individual phases of the preparation, discussion and approval of the typified design and the time schedule of the building-up of the required material and production basis. A typification problem is specified and approved by the central investor of the central organ of the supplier according to its character (design of a building, a structural system, a component).

Typified design

A typified design is usually prepared on the basis of an approved typification problem by the Study and Typification Institute, the design organization of the investor or if the typification concerns components and structures – design organization of the supplier.

In a typified design the designer specifies the compulsory parts and parts which can be altered. (In a typified design of a building the compulsory features include all dimensional parameters, the structural system and certain other parameters (technical standard, standards of area and volume, standard of technical equipment, etc.)

Verification series of buildings based on new typified designs

The purpose of the verification series is the complex introduction of the new typified design into the production, assembly and finishing procedures. On the basis of experience acquired in this phase final changes are made in the typified designs, technological processes are specified and technical and economic indices are specified with final precision. Evaluated experience gained in the process of construction of the verification series and their application to the typified design as well as to the material and production basis create important prerequisites for the successful development of subsequent mass construction.

Development of mass construction based on new typified designs

The fundamental prerequisites of the development of mass construction based on new typified designs are the material and production basis, which must be built up in good time and must be of an adequately high technical standard, and the definitively solved structural and technological problems.

The period of validity of a typified design depends on the pace of development of the general standard of construction (the typified design becomes morally obsolete) and on the life expectancy of the production equipment and the possibilities of its further improvement, generally varying between 5 and 10 years.

The described typification cycle has been used in Czechoslovakia in the preparation of new typified housing designs. On the basis of the state of research and development experimental designs were prepared in 1959. In 1960 they were realized on experimental sites and in 1961 the experimental buildings were evaluated from the technical and economic point of view, the evaluation being followed by the specification of a typification problem and the preparation of typified designs which were completed and approved in 1964. Simultaneously with the preparation of the typified design the material and production basis was also built (a plant for the production of vertical and horizontal load bearing structures, prefabricated plumbing cores, partitions, etc.). In 1963 and 1964 a verification series of buildings was built and the mass construction of residential buildings based on new typified designs was started.

Conclusion. The experience gained in Czechoslovakia has confirmed that this typification cycle is correct. It enables the preparation of new typified designs of a high social and technical standard. However, it is necessary to shorten the duration of the individual phases of the cycle and thus speed up the preparation of new typified designs. An important prerequisite in this respect is a timely decision pertaining to the selection of structures and components and the methods of their production and assembly. To ensure the fulfilment of this prerequisite requires that the prototypes of the production equipment must be evaluated as early as in the process of specification of the typification problem and their mass production ensured in a proportion corresponding to the development of construction, the respective decisions pertaining to the use of the respective lifting and transport mechanisms and the manner of their securing, etc.

The development of the industrialisation of building counts with the development of the processing industry in the near future. New materials and new technological processes will be used. This will stress even more the importance of the correct connection of the typification cycle with research and development and increase the requirements imposed on the preparation of the respective material and production basis.

B 12

K. Lachert, T. Persyński

Relationship between the process of design and industrial methods of organisation of large panel systems

By K. Lachert and T. Perzyński (Poland)

In our conditions today one of the basic problems of large-panel buildings consists in correlation of the following dependencies:

- the minimum number of the element types,
- the possibility of using them for at least 5 different residential structures,
- restricting to a minimum the use of concrete.

There exists a rule that the number of element types decreases as the size of elements decreases. Simultaneously the lesser number of types of elements creates more favourable conditions for the introduction of efficient production methods in the production plant. On the other hand the effectiveness of assembly requires that the elements are as large as the hoist can lift. Large sizes of elements also help to achieve a higher degree of readiness of the building on completion of assembly. These contradictions are clearly shown in the following table:

	Size of elements	
	large	small
Freedom of functional design	no	yes
Small number of type-sizes	no	yes
Conditions appropriate for effective methods of production of elements	yes	no
Effectiveness of assembly	yes	no
High rate of finish of building	yes	no

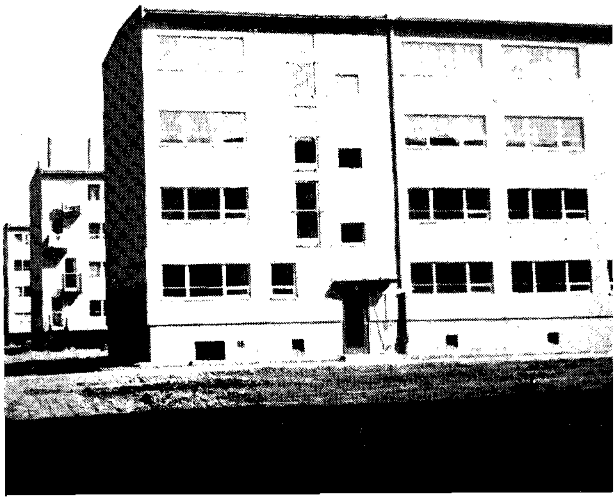
So, the basic problem for decision, on which design alternatives should be accepted, can be solved only through consideration of design-production dependencies and determination of their hierarchy in the given region. The tendency of using elements of fairly large surfaces leads usually, as far as floorings are concerned, to cross-reinforced systems, which make possible the largest surface at the cost of decreased thickness of floor with the required load-bearing capacity. Because of the best exploitation of their static state, the elements of this system have the shape of a rectangle with sides of similar length. The necessity of obtaining with this system, varied residential structures or different buildings leads to an exorbitant number of type-sizes which hinder the technical as well as economical effectiveness of this method. This in turn leads to the necessity of using too large production surfaces and primitive technology, as the highly efficient production methods can be applied only to long series of the same type of elements. The shortened series, appearing with the large numbers of type-sizes, gives rise to the tendency to start stand production, where the costs of forms are relatively low. It is, of course, connected with the amortisation of the costs of the forms. These contradictions can be settled – depending on local conditions – as follows:

a. production of large surface elements which, because of the necessity of erecting with them various apartments, and despite inefficient production methods, allows a quick assembly,

b. unification and reduction of the number of types of elements, shaping of floor and wall elements, so that they can be produced by the same technology resulting in a lengthening of serialisation and the introduction in these conditions of highly efficient production methods.

Of course, the first alternative makes possible the higher readiness of a building after assembly, the second often necessitates a longer time before occupation. In the conditions of the region of Warsaw in early years the large-panel building solutions based on the first alternative were used.

Large-panel buildings of the PBU-59 system erected on the cruciform lay-out gave a readiness after assembly of 72%. The size of designed elements "per room" amounted to 3.90 × 4.55 m and the number of types of elements to 95. Because of the large number of type-sizes the production of elements was carried out first of all by stand methods. The production area of the plant was, in the factory 2,160 m^2, in the yard – 1,578 m^2 – total 3,738 m^2, with a yearly production of 3,500 rooms. The exploitation of factory area amounted to 4.5 m^3/m^2 of usable area per year in 270 working days per year, and in the yard 2.4 m^3/m^2 of usuable area per year in 190 working days per year.



In these conditions the cost of production of elements amounted to 60% of overall costs of a building. It became clear that to reduce the costs of building the decisive factor is the introduction of highly efficient production methods, even at the cost – should that prove necessary – of certain reduction of size of elements or of lowering of assembly indices. The analysis of possibilities of improving production indices proved that radical improvement is possible only through consistently taking into consideration the precise requirements of production plant in the earliest stages of design.

These requirements tended to a reduction of the number of type-sizes and to such unification of elements that their essential share could be produced in efficient aggregates. To achieve that aim, the sizes of floors had to be unified for production in one aggregate, and the sizes of walls for production in another – or the sizes of floors and walls should be so calculated that their production could be carried in one common aggregate.

In order to obtain a permanent plant two types of battery aggregates were planned – one for floors and one for walls. For field plant one aggregate, common for floors and walls was planned. In the former case the sizes of floors and walls could be relatively independent, in the latter the size of floor elements had to tally with that of wall elements – therefore the apartment had to be planned in the shape of a square. Floor and wall elements had the shape of a rectangle with the proportion of sides 1 : 2. Both in the first and in the second case the condition of maximal unification of elements could be met only at the cost of giving up the cruciform lay-out of the building.

The requirements of the producer of elements could be fulfilled only by buildings with a lengthwise or transverse structural lay-out. In the first case the outer wall would have to be the load-bearing wall – in the second it could be only the panel wall. In Warsaw climatic conditions, the concrete outer wall structures can be erected only with the utmost care and that led to the acceptance of the transverse lay-out with the uniform panel wall.

The designs for buildings to be produced in the permanent plant (PBU-63), as well as in the yard plant, (OW-1700) are alike both as far as structural principles and the accepted technological methods are concerned. It testifies to the agreed conclusions from the experiences hitherto gained.

In result, the number of types of elements in the OW-1700 building was 25, readiness of building after assembly 60%, and the cost of building decreased by a similar standard.

The reduction of the number of the types of elements and the use of aggregate production renders possible the yearly production in the permanent PBU plant of 63,800 m^3 of concrete, which equals 10,000 rooms from the same production area which formerly, with the majority of stand production, yielded only 3,500 rooms. The exploitation of production area increases from 4.5 to 32.2 m^3/m^2 of usable area per year. The output of one worker per year reaches 709.1 m^3 concrete. Data for mobile yard plant are also satisfactory. One battery aggregate produces 73.5% of total cubature of prefabricated elements of the building. In the running production it amounts to 962 rooms yearly which equals 4,700 m^3 of concrete. The index of productivity of cubic meter of concrete from one square meter of production area per year amounted to over 40 m^3 per aggregate. The productivity of one worker per year – 675 cubic meters of concrete.

The favourable production and economical results confirmed the theses that only the consistent consideration of technological rules and of described design production dependencies at the stage of working out the spatial idea of a building, can give proper effects in large-panel building.

Z. Kleyff

Number of prefabricated element types, their average dimension, and flexibility in building

By Z. Kleyff (Poland)

The present work is concerned with investigation on correlation of three factors which come out in prefabricated construction.

Flexibility, owing to which it is possible to ensure to the executed object, the maximum of utility and beauty as well as the minimum of operating expenses;

Average dimension of prefabricated element, which the executor would like to have in, possibly, the largest dimension available in the range of lifting-capacity of transport facilities that are at his disposal, in order to gain a high degree of integration of works and to make the best use of transport equipment;

Number of prefabricated element types, which the producer would like to have in the smallest quantity on account of serial economics of their batch production.

As a result of investigations carried out it has been stated that interdependence on each other of the three above-mentioned factors is characterized by definite trends, as follows:

A. The tendency to a small quantity of types and to large average dimension of the elements, constrains flexibility.

B. the tendency to small number of types with simultaneous maintenance of flexibility decreases the average dimension of elements.

C. the tendency to a large average dimension of elements with simultaneous maintenance of flexibility increases the number of types.

Graphically, the afore-mentioned statements might be represented in the form of a table, in which the defined tendencies above (A, B and C) (vertical in columns) are bringing about, either the condition of accomplishment (+) or of non-accomplishment (—), referring to the three elements of correlation (in horizontal positions).

		TENDENCIES		
		A	B	C
ELEMENTS OF CORRELATION	Small Number of Types	+	+	—
	Large Average Dimension	+	—	+
	Flexibility	—	+	+

At present we are going to deal with a more accurate determination of the investigated correlations setting as a goal the presentation of their dependence on each other in the form of diagrams, and also — if it turns out to be possible — to formulate them numerically.

Study of correlation

With that end in view, it becomes necessary to establish indices for those three elements of correlation.

Index of flexibility — 'S'

In order to be able to define the degree of flexibility allowable by a given set of elements it is necessary to refer it to some maximum — the investigated flexibility being a fraction of that maximum.

The attempt to gain the comparable results, makes it necessary to denominate the above-mentioned maximum with a quantity number of all probable solutions, which might be designed under given conditions resulting from the accepted constructional system and the adopted dimensional devices.

The applied set of elements will permit to obtain all the solutions, or some of them, or none. The number of the gained solutions referred to the maximum number will determine the index of designing flexibility, conditioned by use of elements of a given set.

As a testing ground, a fragmentary of a building cubature was adopted, amounting to one flat floor space, one storey height.

In order that "maximum of flexibility" would not present an excessive number of variables, a range of restricting conditions was introduced for dimension of parting modulus, the average dimension of parting planes, their shape etc. owing to which the maximum of flexibility is expressed by an algebraic number of 44 parting solutions of the fragment under investigation.

The final result gained by means of a proposed set of various types of prefabricated elements of all those variants is determined as maximum degree of flexibility $\frac{44}{44} = 1.0$.

Attainment of a smaller number of variants — for instance "n" (where $n < 44$) — is determined as degree of flexibility $= \frac{n}{44}$.

We want it clearly understood that the above proposals are, of necessity, operating with considerable simplifications in adopting the restricting terms as a basis of established data. Therefore the obtained index of flexibility relates exclusively to the degree of *relative flexibility*, calculated in relation to the maximum of flexibility that might be attained by application of the given data; other different data will bring out another different set of conditions, with their own specific properties in which the degrees of flexibility cannot be compared with previously mentioned ones.

Index of element average dimension — 'W'

Here, the evaluation index adopted was the average surface of the walls (namely: a quotient of length expressed in modules multiplied by height) and the surface of floor elements (computed in square modules). It was obtained by dividing the global surface of all elements, contained in all the variants by the number of those elements.

Index of number of element types — 'T'

This index is expressed by the number of all varieties of elements applied to the solution of all variants occurring in one specific study.

Each set of these element types allows for the working out of one individual study based upon a schema of a testing ground (a fragment of a building), and the respective results of calculation are laid down in tables.

By applying as variable, kinds of element joints, the length of measuring (one or two modules), maximum dimension of element and its minimum dimension, then some 224 combinations are obtained, each of them representing one set of elements and thereby permitting to work out one individual study (example: a part of the study presented in fig. 1). Each individual study gives as a final result determined indices T, W and S (one for each — and corresponding to each other).

The analysis of interdependence of the three variable factors T, W, and S — may occur in theory in the spatial reference system of three co-ordinated axes corresponding to the three investigated variables (fig. 2) and their values gained in each individual study are symbolically denoted on those three axes.

However, since that system is inconvenient for graphic presentation it is replaced by a range of planar systems, each of them representing the correlation with each other of two variable factors referred to the third factor treated as a constant. (Diagram, (fig. 2) shows in an exemplary way the reference plane of the investigated correlation of T and S, where W is equal to constant = 'W_0').

Nevertheless, it has to be noticed that the indices gained from the 224 studies are scattered in a rather casual way on the co-ordinated axes (Compare: T_1, T_2, T_3, ..., W_1, W_2, W_3, ..., S_1, S_2, S_3, ..., fig. 2) and it is difficult to select the determinate values of any of them as a datum point designating the plane of investigation of the other two.

Therefore, the decision was taken to replace the single points

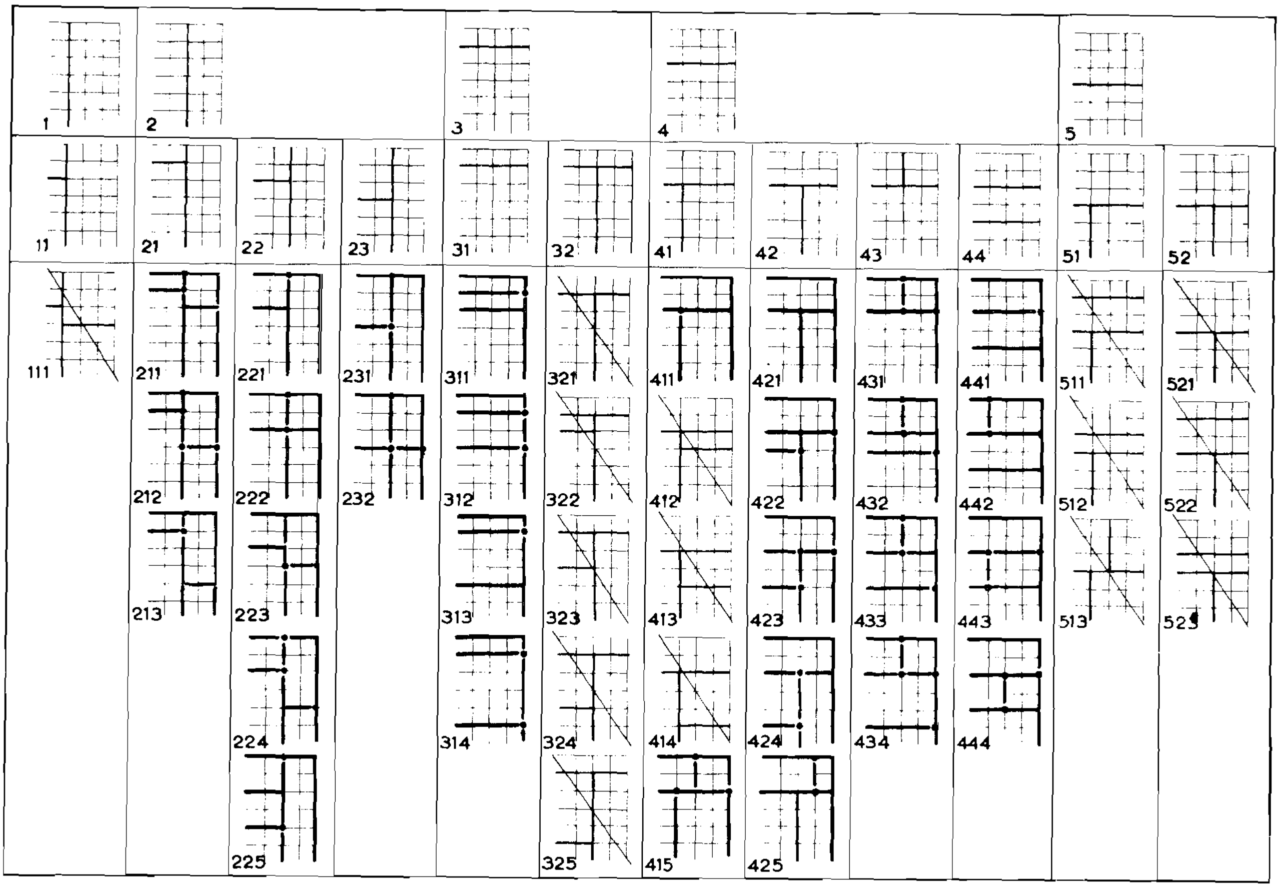


Fig. 1. Example of studies on series I—Walls. Filled-up drawing sheet for study No. 17.

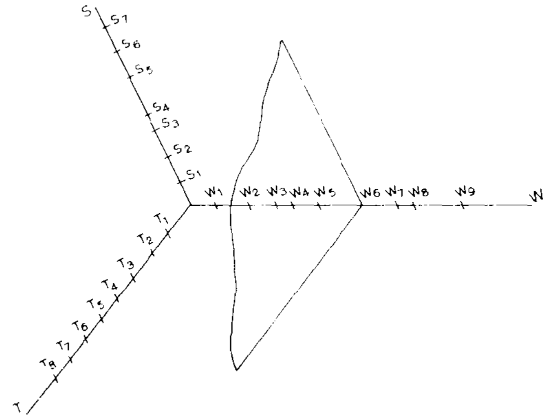


Fig. 2. Reference system to analysis of correlation T, W and S, with values obtained in studies marked on coordinates.

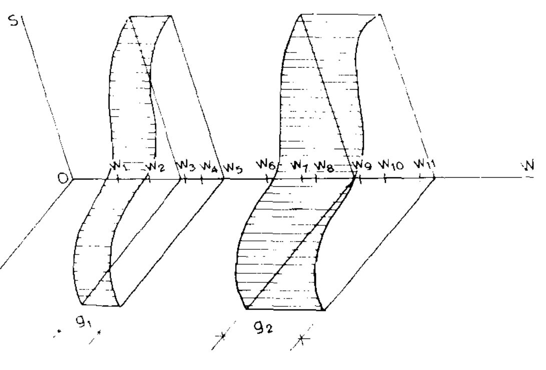


Fig. 3. "Reduced Planes" (substitute ranges) replacing geometric planes of analysis

on the co-ordinated axes, points which are to designate planes for analysis, by a group of points set within restricted ranges. All those ranges, however, are adequately narrow in order to make them pass for approximately homogenous "reduced planes", which can serve as suitable diagramatic plots for correlation charts (see fig. 3).

Those ranges ought not to be designated in a haphazard way—since it is essential that they should represent the corresponding degree of accuracy; that means their "thickness" should remain in constant ratio to the appropriate value on the coordinate axis (fig. 3 ratio $g_1/W_3 = g_2/W_9 =$ constant).

For that purpose series R_{10} of preferred numbers (Renard series) were used and correlated to them, on three separated tables, and ranged according to sequence values T, W, and S, which were gained as result of all our studies.

Constant ratio of "thickness" of ranges to the value of corresponding coordinates were obtained by determining the limits of those ranges with terms taken out of R_{10} series, by way of alternate "every second" order; the quotient of R_{40} series being known and equal to c. 1.06 a constant ratio of "thickness of ranges" to the value of coordinate equal c. 0.12, was obtained.

Each of the ranges obtained in that way, determines one reduced "reference plane" of the study. Expressing it in a different way: all the studies in which values T, W, or S are placed in one range are treated as if they were approximately equal to each other, and in that case, the two remaining coefficients may be pointed out on charts lying in the plane of investigation (as in fig. 2).

When the number of studies, with values T, W, and S, lying in one range, is adequately large, the lay-out of points of the remaining indices might permit to draw a line expressing the interdependence of those two indices, the third index being a constant.

In each particular range there is one corresponding curve. The compilation of curves for the whole series WS is shown in fig. 4, that for TS in fig. 5, and that for TW in fig. 6.

These images permit to draw, at least, some conclusions about the correlation with each other of the number of element types, its average dimension and flexibility in prefabricated building.

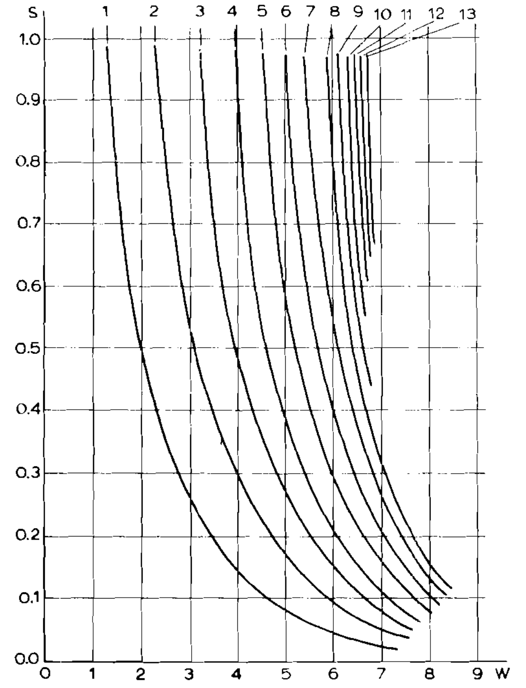


Fig. 4. Corrected collective diagram of data on correlation of average element dimension—W, and flexibility—S, by constant values of number of types T. (Ranges of reduced values—T marked with numbers).

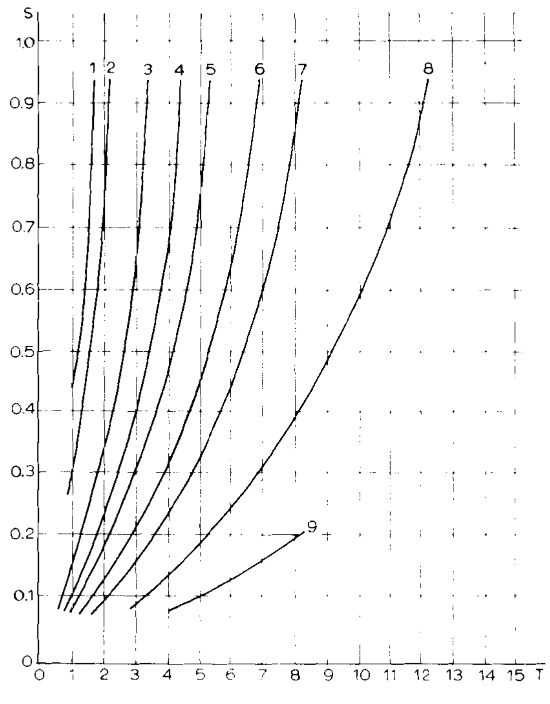


Fig. 5. Corrected collective diagram of data on correlation of number of element types—T, and flexibility—S, by constant values of average element dimension—W. (Ranges of reduced values—W marked with numbers).

Corollary

Analysis of the diagrams, which is intended to express the correlation of T, W, and S in the form of a formula:

$$f(T, W, S) = 0$$

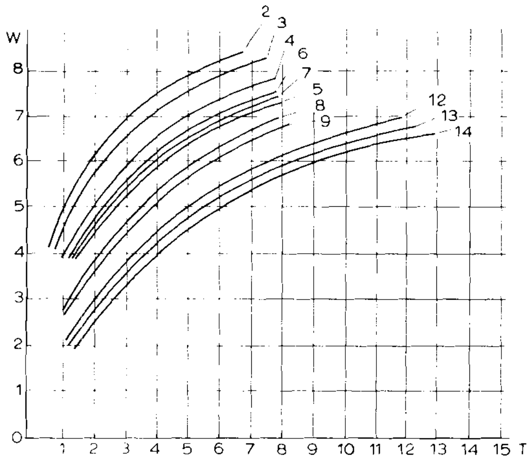


Fig. 6. Corrected collective diagram of data on correlation of number of element types T, and their average dimension—W, by constant values of flexibility—S. (Ranges of reduced values—S marked with numbers).

comes out ultimately as follows:

$$\frac{S\,W^{\delta}}{T^{\gamma}} = K; \quad \text{or else} \quad \frac{S\,W^{\delta}}{T^{\gamma}} - K = 0$$

where $1 < \gamma < \delta$

where K is a constant, invariable in the given conditions for the given series of studies (as e.g. in our elaboration), and dependent upon admitted structural and functional established data. In this particular case, that correlation might be, with adequate approximation, formulated as follows:

$$\frac{S\,W^{3}}{T^{3/2}} - 6.79 = 0$$

Considering it, for practical purposes, we may state that:

Correlation of WS (average dimension—flexibility) by number of types T = constant (fig. 4). Curves are hyperbolic.

These diagrams are illustrating quite well the fact, known in designing practice, that a change from small-dimension-element building (low value W) to the large-panel building (high value W) is followed by a violent decline of flexibility; whereas by further increment of the dimension of elements up to greater values of W (for instance by volume elements of dimensions in plan 3.0 m × 6.0—as represented in one of the latest Polish designs) flexibility is kept on a very low level.

Correlation TS (number of types—flexibility) by average dimension W = constant (fig. 5)

Curves are parabolic with the tangent to axis of abscissae where T = 0.

The increment of S is rising much quicker and exceeding in relative values the increment of T (for instance: the bending of the curve 8 shows that by increase of number of types T, from value 10 to value 11, means 10 per cent increment, the flexibility increases from c. 0.63 to c. 0.80 i.e. by 27 per cent).

Therefore, in practical conclusion, it is evident that at a given average dimension of elements W quite often it pays to increase even very slightly the number of element types, since in effect one can get a significant increase of flexibility, which in turn might bring, sometimes, great economic profits.

Correlation of TW (number of types—average dimension) flexibility S being = constant (fig. 6).

Curves are parabolic with tangent to axis of ordinates by W = 0.

In practice, it means that if the constant flexibility is to be conserved, the increased of average dimension of elements W, is followed by a disproportionately higher increase of the number of types T.

For instance, the curve 13 on the diagram shows that a hundred per cent increase of dimension W—from the value 3.0 to the value 6.0 is followed by an increase of the number of types – from the value 2.5 to the value 8.5 that is c. 240 per cent.

Hence, a conclusion of rather great importance for practical prefabricated building: the tendency to employ still bigger and bigger building cranes (for instance 85 and 120 ton-capacity instead of the smaller 45 and 60 ton-capacity), followed automatically by an increase of dimension of prefabricated elements allows for a higher degree of integration – and consequently for a better finishing. Nevertheless, due to the maintenance of functional and flexibility requirements on an invariable level, it results in an excessive increase of the number of element types. That increase of the number of types must be counted as a disadvantageous factor, while reckoning the positive economical effects, resulting from the increase of dimension of the elements and thereby the decrease of the scope of finishing works.

The exploitation of the obtained results does not consist of a detailed reckoning of what will happen to the variable ordinates in each case of variance of the abscissae, nor detailed reckoning of the accurate determination of numerical value of element types, their average dimension and flexibility. The eventual putting into use of the results of our studies means, above all, the undertaking of general decisions to be applied in carrying out and evaluating designs based on *perceived character* which determines the investigated, analysed correlations.

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W. J. van Nieuwkerk

Industrialisation of house-building in the Netherlands

By W. J. van Nieuwkerk (The Netherlands)

Due to the fact that the building capacity is as yet too small, distinct shortages of all kinds of buildings, particularly of dwellings, exist in the Netherlands. Besides doing away with existing shortages a considerable increase in the amount of building is also necessary in order to satisfy expanding future needs both as regards quantity and quality.

In view of the scarcity of labour a substantial increase of the amount of building can only be obtained through considerably raising the production per manhour. For this purposes a transition must be made in the building industry from manual to industrial methods of production, that is to say, mass-production of materials and components which are assembled in a series of identical end-products.

In the Netherlands, building materials and components are in general already mass-produced in accordance with modern industrial methods. The industrialisation of assembly, which takes place on the building site, is, however, in general still in an initial stage. An exception to this is house-building in which, to an increasing extent, a transition is being made from manual production of one or a few dwellings, to the industrial production of series of identical dwellings on the building site.

An important feature of this manner of production is the assignment of the workers to fixed specialised tasks, which can be performed uninterruptedly in a series of consecutive identical dwellings. In consequence, the number of manhours for each task decreases with each dwelling of the series, as also does the number of manhours needed to complete each individual house. Because of this decrease called serial effect, a considerable labour-saving is achieved. Moreover, the production of series of identical dwellings creates an economically justified possibility for the development and installation of labour-saving equipment (e.g. steel formwork), as a result of which further labour-saving is obtained. In figure 1 an example from actual practice is given of the decrease of the number of manhours per dwelling through serial production.

In the example given, the number of manhours per dwelling decreased from 2000 for the 1st to 730 for the 240th dwelling and an average of 880 manhours was spent on each dwelling. From the viewpoint of manhours consumption and building costs for this type, however, a serial size of a minimum of 400 dwellings is deemed necessary. Even if, after the 240th dwelling no further decrease would have occurred, not more than an average of 820 manhours per dwelling would have been needed for this serial size.

The production of series of identical dwellings furthermore creates the possibility of working out in advance, on paper, the most efficient way of putting labour and equipment into service. By doing so, a saving in building time and costs, besides a saving of labour, is obtained. Because of a saving of labour on the one hand and in building costs on the other hand, an opportunity is given to raise the quantity and quality of house-building and to combat increasing prices.

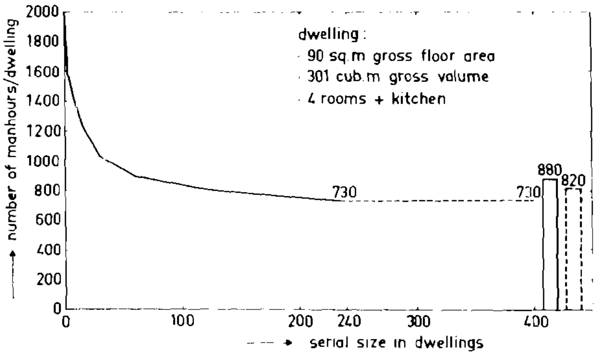

Fig. 1. Decrease of the number of manhours per dwelling through serial production of 240 identical staircase-entrance apartments.

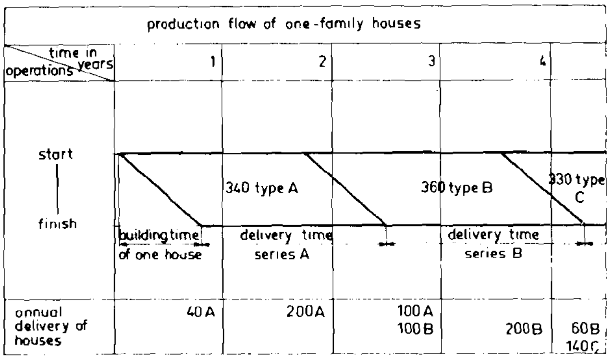

Fig. 2. Continuous serial production through a "production flow".

For bringing about organised serial production on the building site, series of at least 300–600 identical dwellings, dependent upon the construction method, are necessary. A fixed, specialised and continuous assignment of tasks for all workers is only possible, as has appeared from actual practice, if the building speed amounts to at least one dwelling per working day. In the Dutch climate, without the application of measures to combat unworkable hours, there are, on an average, 200 working days available annually. For continuous serial production, therefore, a production volume of a minimum of 200 dwellings per year is necessary per "production flow", as is illustrated in figure 2.

In order to be in a position to produce 300-600 identical dwellings on the building site, these dwellings will have to be projected in (extension) plans in the first instance. A certain differentiation in types of dwellings is necessary, from motives of need and for the prevention of monotony in town planning. This differentiation, however, will have to be restricted to the minimum, for example to 3 or 4 different types of dwellings. These requirements together can only be satisfied by taking as a starting point a large extension plan or a combination of smaller extension plans, together embracing at least 1000–2000 dwellings. As the drafting of extension plans falls under the responsibility of a municipality, this is a matter of municipal house-building policy.

In general the municipality merely acts partially as principals for house-building. To a large extent this task is also performed by housing corporations with regard to building under the Housing Act (financed by the Government) and by private investors in respect of government-subsidized ("premium") and unsubsidized house-building. For building assignments of 300–600 identical dwellings usually more than one principal is needed. It is, in such cases, a task for the municipality to bring about a co-operation among these principals in order to achieve an enlargement of assignments. Consequently the principals will have to translate their individual desires into one identically-worded demand.

Such a co-operation, a so-called "bundling" of the demand, has, in practice, already been brought about by several municipalities. Two different forms of co-operation can be distinguished, namely co-operation within the same form of financing (for example among housing corporations in respect of Housing Act dwellings) and co-operation among different forms of financing (for example among housing corporations and private investors in respect of both Housing Act and premium dwellings).

As has been already noted, for a continuous serial production per "production flow" a production volume of a minimum of 200 dwellings annually is necessary. In smaller municipalities such a production volume may exceed the annual need of dwellings. When it does a continuous serial production of dwellings can only be brought about by a regional co-operation among various municipalities. In several cases such regional co-operations already exist, where the number of participating municipalities varies from 2 to 13.

The projecting of series of identical dwellings and the bringing about of a co-operation among principals, however, are in themselves not adequate to attain a continuous serial production of

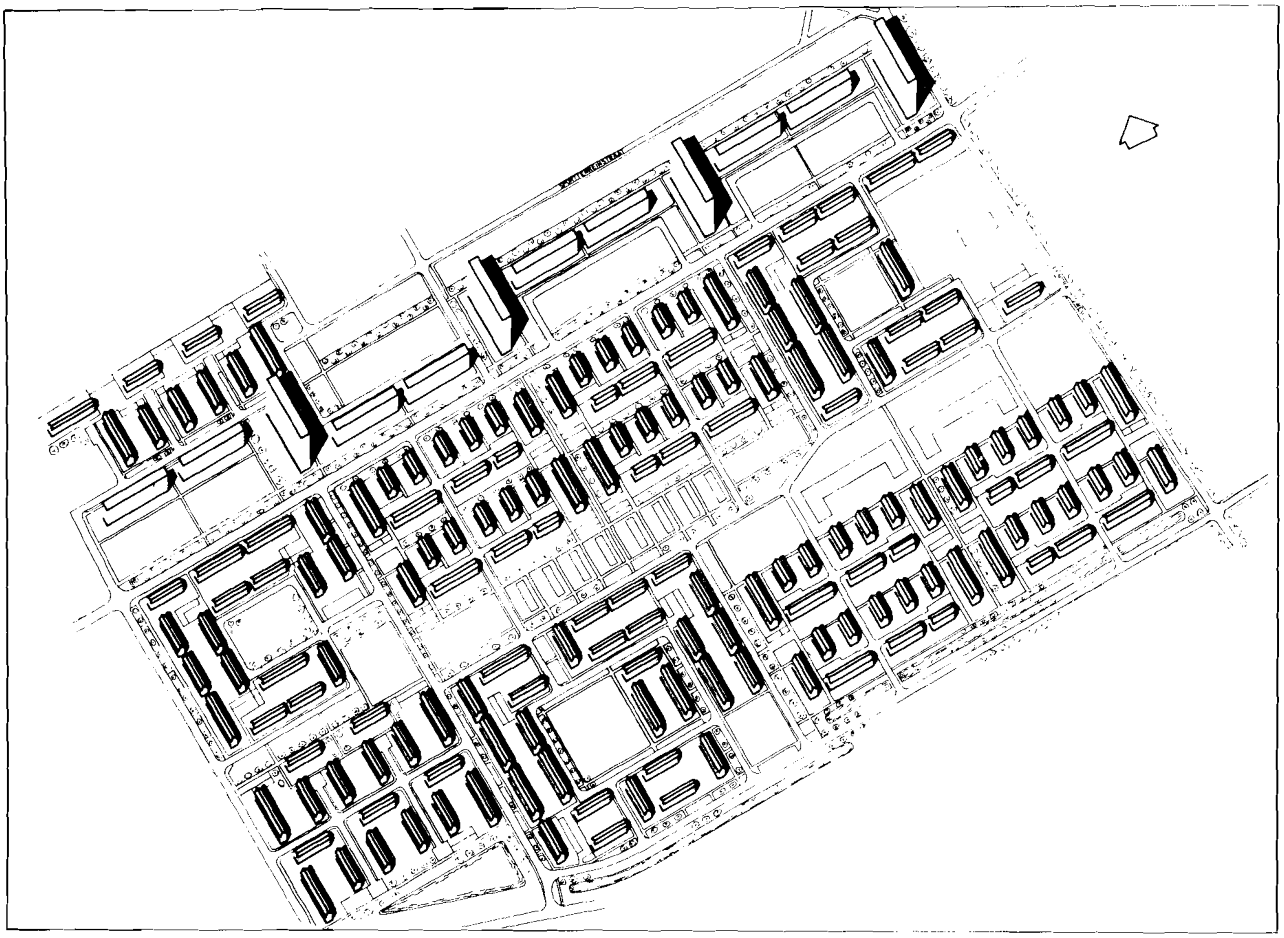

Fig. 3. Efficient extension plan.

dwellings on the building site. The fact is that dwellings, as distinct from motor-cars, radios, etc., are mostly connected with one another, e.g. apartment houses by definition in horizontal and vertical sense to form blocks, and one-family houses often in horizontal sense to form rows. The manner in which in the extension plan the dwellings of one series are connected with one another to form blocks or rows respectively, should fulfil certain requirements. If it does not, a fixed, specialised and continuous assignment of tasks to the workers is impossible, as actual practice has shown. Consequently when working out the extension plan, the town planner should also take these requirements into account.

An example of an efficient extension plan is given in figure 3. It shows a plan of a total of 1590 dwellings, divided among 4 series, namely 576 gallery-entrance apartments in 4 and 10 floors, 286 one-family houses of type A, 416 of type B and 312 of type C.

Besides the extension plan, certain demands must be met in the design of the dwellings. These demands are connected with the lay-out, construction method, construction details and finish. The design of the architect should strengthen the possibility of labour saving already existing in the design of the townplanner by avoiding solutions which demand a great amount of labour and by making possible the installation of labour-saving equipment. The townplanner's design and the architect's design together should create the maximum possibility of labour saving by rationalisation of both production method and product. In figure 4 an example is given of an efficient design of a one-family house.

In order fully to utilize this possibility of labour saving, the organisation of the execution of the work should be fully programmed on paper in advance and laid down in a detailed time schedule. In this way the use of the work force and the installation of equipment will be as efficient as possible. In figure 5 an example is given of a time schedule.

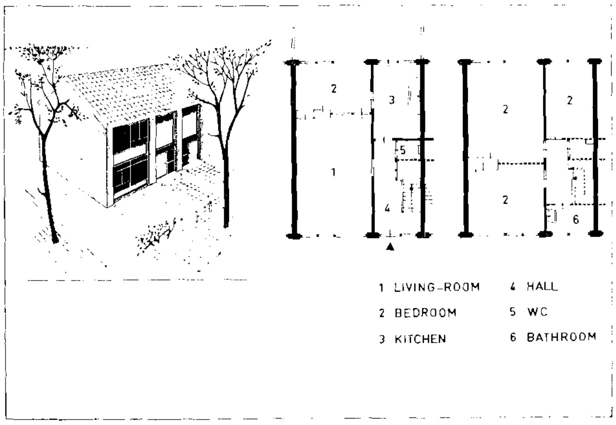

Fig. 4. Efficient design of the dwelling.

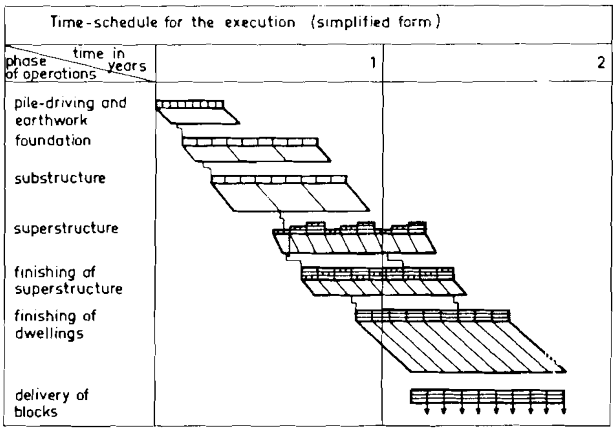

Fig. 5. Efficient organisation of the execution.

The building firm should possess sufficient capital and have an adequate capacity (workers, equipment and staff) in order to be able to attain a continuous serial production of at least 200 dwellings per year. This does not imply, however that only those firms which have already reached such a production volume should be used. It is possible also to consider approaching a number of smaller building firms which have formed themselves into a combination. In several municipalities such combinations of smaller local firms have already been formed.

In the foregoing it has been indicated that an efficient serial production depends upon the extension plan, the design of the dwelling and the organisation of the execution. With regard to a particular series, the number of manhours necessary for its completion will be more favourable in proportion to the efficiency of extension plan, dwelling design and organisation of work execution being higher.

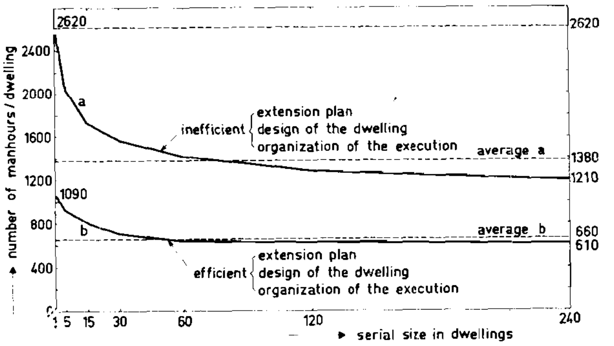

Fig. 6. Limits for the lines of decrease upon serial production of dwellings of a so-called traditional construction.

In figure 6 the limits have been indicated within which the line, representing the decrease of the number of manhours per dwelling for that series, will ultimately fall. These limits have been established on the strength of the results obtained in the building of 16 series of dwellings of a so-called traditional construction.

As appears from the figure given above, an average saving of 720 manhours per dwelling in a serial size of 240 dwellings is achieved by making the extension plan, the design of the dwelling and the organisation of the execution efficient.

The demands that, from the viewpoint of continuous serial production, are to be met by:

- house-building policy,
- extension plan,
- design of the dwelling,
- organisation of the execution,

all have a distinct influence on each other. The preparation of the plan, therefore, will have to take place with close co-operation among municipality, principals, town-planner, architect and contractor. This co-operation may well be obtained by formation of a building team which is charged with the complete preparation of the plan. Considering the important role of the municipal house-building policy, the setting up of such a team in practice mostly originates with a municipality or a group of co-operating municipalities. Conditions for the successful functioning of the team, are an efficient co-ordination of activities, and the willingness of the various members, while retaining their own tasks and responsibilities, to co-operate in frankness and mutual confidence.

In order to reach a proper decision with regard to the number of "production flows" to be brought about simultaneously, an insight into the locally or regionally available labour potential for house-building is necessary, besides an insight into the actual needs. Out of this potential a part, for example 15–20 per cent, will have to be reserved for the construction of dwellings which, because of their nature, are less suitable for serial production. Moreover, this opens the possibility of retaining the capacity of smaller firms to build small numbers of new houses. After having surveyed which part of the labour potential is, or will be, available for serial production of dwellings, it should be established how many simultaneous regional or local production flows can be set up. In this manner there is the best possibility of satisfying the already existing and future housing needs.

As has been already discussed, it is necessary to take as a starting point a large extension plan or a combination of smaller extension plans, together embracing at least 1000–2000 dwellings. After having established the number of possible production flows from the viewpoint of available labour potential, it should be ascertained what housing contingents will be necessary per year for the execution of the entire plan. In order to be able to meet these needs for contingents, the municipality or combination of municipalities will usually have to allocate the total annual contingent in the Housing Act and premium sector, and as large a portion of it as possible in the unsubsidized sector, to the plan.

Moreover, an addition of 25 per cent, on the municipal housing contingent has been given already, since 1961, by the Ministry of Housing and Building in the case of application of labour-saving building methods. The Minister stipulates for this addition a labour saving of 30 per cent in respect of almost comparable objects to be necessary. The following rough starting point has been accepted:

"That the construction of dwellings in a complex both of one-family houses and apartment houses may be considered sufficiently labour saving in cases where the labour requirements on a building site with a dwelling of a gross volume of approximately 300 cubic metres and provided with a 10-metre deep pile foundation, amount to no more than 900 manhours, not including the unworkable hours."

Besides the addition of 25 per cent, two other possibilities are given for increasing the municipal grant. In the first place, in order to promote the bringing about of production flows, it is permitted to anticipate the estimated contingents for the following years. In the second place the Minister is prepared, in order to retain the continuity of production flows already set up, to anticipate contingent possibilities of following years or to grant an extra addition.

In many cases, practice has already taught us that through organised serial production dwellings of an average of 300 cubic metres can be built for less than 900 manhours, a standard established by the Minister. According to the publication "Productie en Productiviteit op Woningbouwwerken" 1), however, the number of manhours per dwelling amounted to an average, over the whole country, of about 1650 in 1963 2). This means therefore, that by serial production a labour saving is possible of at least 1650 − 900 = 750 manhours per dwelling or of 750 : 1650 × 100% = 45 per cent in respect of the national average in 1963.

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1 Foundation Ratiobouw, "*Verzameling Bouwstudies*" No. 8.
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Address delivered at the symposium of the Union Internationale des Architectes, held in Delft, The Netherlands, on 6th-13th September 1964

By J. Prouvé (France)

It is surprising that in this industrialised age the question of industrialised building is still claiming our attention.

Two trends are noticeable to-day:

1) The scientific trend, productive of high quality achievements that stir up the imagination of the masses (aircraft, engines, rockets, rolling stock, household appliances);

2) the trend of human evolution, including town-planning and housing, which is over half a century behind the other trend.

People are not inspired by this second trend; it appeals in no way to most grown-ups and youngsters. What a failure!

In the mechanisation age, only building has had no part in the industrial miracle, which has constantly shown improved quality, jointly with lower prices. Another failure!

It is easy to note that in past production, proportionately speaking, architecture displayed, in some periods, a higher degree of industrialisation than to-day, based on very sound and marked techniques. There was at the time no fear of monotony.

That is the architecture we all go and admire and which gives us technical excitement. With rare exceptions such is not the case with our large residential towns. There is a breach of harmony between us and scientific achievements.

Why? Let us look closer at the building process: the builder in times past was a fully comprehensive being, who "undertook" in the most literal sense of the word. He was an architect, a thinker, an engineer and a practical man.

Inspired by the materials, he demanded that heed be taken of his ideas; he shouldered all responsibility; he lived on the building site.

What has become of this kind of architect? Let us confess that the architect's present position draws him away from technique and even more from building proper. He has turned into a lawyer, often a business man, who manages more than he designs.

Building work goes through a number of stages:

1) the customer,
2) the architect,
3) the technical designing office (the engineers),
4) the building contractors (other engineers).

All act individually with often divergent interests, usually detrimental to the job. An aircraft manufacturer declared that, if the building of planes were put in hand in such a way, these would not fly!

As a matter of fact, industry gathers together men in the same field; they share the same interests.

There lies the difference, when it is a question of industrialising residential building. A building is something to be constructed like anything else; only it is a larger thing and in these days it also stands for the greatest market.

Why not therefore look at it as something wholly designed, manufactured and sold by important industries? The essential point, to my mind, is that the heads of such new industries should be spirited people, gifted as architects, whether or not they have had their training. They should, just as motor manufacturers, make a point of producing the best dwelling at the cheapest price. That is the way industry prospers; the customer's judgment establishes the worth of production.

What is now taking place shows that if the architect does not unite with industry, industry will do without him; this is disturbing, as qualifications in respect of human problems are essential.

There can be no question of restricting the architect's function to that of a stylist. It is therefore necessary to form *a new type of architect*, simply a manufacturer. Why not? Personally I can see no other hope. An architect of that sort, an industrial leader, will be listened to, followed and not merely consulted. Eventually he will be all the happier for it. Of course, as all manufacturers, he will be assisted by engineers; it is very simple.

There is a French scheme to entrust directly a number of building component manufacturers with designing; the approved components would then be prescribed to architects for the purpose of mass production. What will happen about all this?

Machines are seldom built with parts selected from various sources; they are aggregately designed. I cannot, at the outset, accept the proposed system of open prefabrication. This will only become successful by selecting components among sets or for variation.

It is within the same industry that various models are put to use, having common components. Let us therefore start with closed prefabrication, the more acceptable in my opinion. It seems that the Order of French Architects was opposed to this scheme, when it could have grasped the opportunity to initiate negotiations.

Let us bear in mind that the major industrial groups have gone into this matter; no wonder. Who said that it is no use ignoring the tide? From time to time I got young architects to take an extensive part in the daily work in my shops. They became imbued with industrial requirements and discipline; they then found inspiration in the observation of shaping. They adopted technical propositions and produced very sound architectural designs, that would have been unthinkable in a bureau, working solely from a tracing. I recollect that they were quite happy about it.

The architect versus engineer antagonism, in itself absurd, is growing dim. It has unfortunately been detrimental to the necessary authority and prestige the true architect, who should of course be an engineer, must enjoy.

I must apologise for my strong views on this subject. They may appear biased; they are a firm belief. I need only mention two architects of great repute: A. Perret and L. Nervi, who were and are contractors; I believe they are men of great integrity.

I have noticed that many architects submit their work with a host of qualifications: ... "I would have liked to, but" ... A manufacturer knows his own mind; he acts as he thinks and takes pride in this. It is the customer who decides without compromise. A true building industry should be in a position to submit to the authorities, building designs which are operative, on a take-it-or-leave-it basis, beyond all question. The trying discussions with officials might then become less pronounced.

As a conclusion, let us take the example of schools. Huge sums were made available for industrialised techniques. Are such schools built for children? How did pedagogues and architects come into this? A regroupment of capacities would appear appropriate.

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H. Rettig

Development of construction and mounting of doors and windows in industrialised building of dwellings

By H. Rettig (East Germany)

Industrialisation of building construction, above all, endeavours to save man-power. The most important measure for achieving this aim is the transition from medieval building methods of adapting each structural element at the site to modern methods of industrialised production of prefabricated interchangeable units. In other words, each functional element or building should be divided up into its parts which in their turn should be exactly fixed in dimensions, manufactured under most favourable economic conditions and assembled without secondary treatment.

In order to achieve this, measures should be adopted as follows:

1. Application of synthetic building materials with exactly evaluated properties instead of natural-ones, the properties of which are widely different. Resulting from this, extremely large dimensions, inevitable for the sake of safety, could be reduced, thus economising on materials.

2. Application of new tooling methods: In the first instance cutting with devices guaranteeing high precision and automatic control. Increase of shaping with subsequent increase of output, but also higher expenditure for job-planning and installation; this, however, being compensated by far-reaching standardisation of manufactured elements with a subsequent increase of output and a drastic cut in expenditure. Transition to a unit composed system with application of elements employable in different ways. (Fig. 1).

3. Application of new working methods: elements in process of prefabrication being tested under site conditions. Strict observance of exactly fixed and permanently controlled tolerances permitting mounting without secondary treatment, the final aim being phase working in flow-line construction.

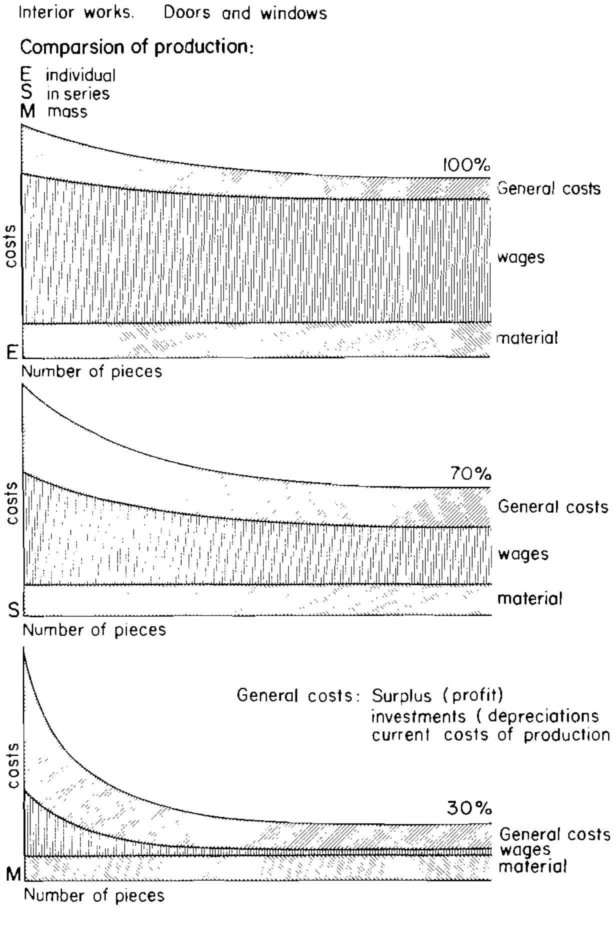

Fig. 1. Comparison of costs of different production methods of doors and windows.

4. Adaptation of structural designs to new building materials, together with new methods of treatment of materials and new working methods in manufacturing. Transition to light-weight structures preferably of the type of dissolved hollow profiles with three-dimensional co-operation of forces.

These measures have altered the technique of building entirely. Regarding windows and doors two groups of important problems should be considered in relation to each other.

Windows

Method of construction. In building dwellings protection against cold, damp and wind, as well as molestation through noise, are to be considered in the first instance.

Unfortunately there does not exist any material, combining all the advantageous properties of glass and transparent synthetic materials, otherwise window constructions could be solved in a very simple way and without frames (similar to doors made all of glass). Windowpanes require enclosure by frames, on which mountings can be fixed. Protection against cold can be obtained only through double glazing.

Single windows are only sufficient in districts with very mild climate. Recently the composite window with two, and in climatically unfavourable districts even with three, window sashes, each glazed with one pane, has been used. These sashes are either turning or balance sashes (or turning and balance sashes) and fastened in a firmly inserted frame (as blind or case).

Windows with a large surface are arranged so that they are movable and can be partially opened. The dimensions of fixed glazing are limited by the possibility of cleansing.

Double or even triple composite window panes are much in use. Costs, however, are still very high. One faces also considerable difficulties in replacing broken panes quickly. However, single sashes can be utilised, which should have a better sealing through the employment of plastic profiles. In dwelling construction these demands must be met for habitated rooms only. Windows in basements (cellars) and stairhalls can be designed in a simpler way, similar to those in industrial buildings. They will not be considered in this paper.

Apart from french windows for balconies, windows for living rooms, bedrooms and kitchens are distinguished from each other only by way of size. One could succeed in a comprehensive unification by introducing one fundamental type of fixed dimensions by floorheight, window lintel and sill, which would thus amount to 1.50 to 1.60 m. in height, the width being derived from the largest width of a turning sash with a maximum size of 0.80 m. These units could fulfill all requirements, when installed side by side, for instance one unit in the kitchen, two or three in bedrooms, three or more in the living rooms. One element would suffice in most cases and could be layed out as a turning sash, balance sash or turning and balance sash. This method would become of great significance if frames were no longer manufactured of wood but of plastic foil, possibly in one working process and by way of shaping. This aim, however, has not yet been reached. As a matter of fact, one manufacturer succeeded in manufacturing profile rods both of plastic foil and of metal. Concerning the junctions at the cornices, however, a satisfactory solution has not yet been found, and the manufacturing of frames in one piece in mass production has not yet succeeded.

The good properties of natural wood, particularly good heating insulation, have not been reached by any other building material. Therefore we shall not be able to dispense with it in the building of dwellings for the time being, especially with regard to low cost.

There might, however, be introduced a considerably improved method of manufacturing wooden units. Frames of laminated wood or plywood could be pressed in one manufacturing process with only little secondary treatment and the use of prefabricated profile rods as semi-product offers economic advantages.

Manufacturing. Practice has proved that the wooden window is still the best provided that the process of manufacture is improved. Up to now the procedure of manufacturing has been as follows:

Woodcut, cut-down milling, assembly of frames, fixing of mountings with their sparings. First coat of painting. Installation in prefab outer wall units either before vapourisation or on the site. Glazing and painting as a single process by hand. An improved working process could be as follows:

Manufacture of prefab profile rods, eliminating cracks by way of dovetailing.

Manufacture of frames. Each stud receives a slit and pivot so that the cut up milling may be performed without turning the sash. The water bar is replaced by a guard strip. As concerns mountings, sparings should be provided as far as possible. As a rule, set up mountings are used in preference.

Frames are immersed in liquid paint, dried, sanded, ground and finally sprayed with a coat of lacquer. Thus all rebates and recesses are protected. Painting in such a manner proves to be much more effective than execution on the site by hand. Finally stainless mountings should be fixed and the glazing of sashes effected by means of fixing ledges made of synthetic material. Thus the window is ready for installation and demands no secondary treatment.

Mounting. The wall opening is prepared for installation of the window sash. The most simple way of fitting it in would be to glue the frame in, thus obtaining a good sealing security as well. Security of sleeve screws, however, cannot be missed for the time being, as long as glazing materials have not proved their durability. Assembling (mounting) frames carried out in the usual manner, guarantee the fitting accuracy of openings, facilitate the fixing of frames and offer the possibility to replace window sashes by temporary weather protecting frames during the building period.

Doors (especially interior doors)

Way of construction. Doorleaf. Manufacturing of doors with plane and smooth surfaces is no longer a problem. Light weight construction is achieved by using various new materials. Outer doors consist mostly of glazed frames, normal wing doors are still much used and sliding doors are used in exceptional cases.

Doorlocks could be simplified by combining droplatch and bolt. Magnetic locking of internal doors could be considered in future, similar to those introduced already for cupboards.

Doorframes. It is the final aim to build in doorframes either at the site after assembling or in prefab wall units at the plant. Wood is not very fit for this purpose. Steel has been introduced although its disadvantages should not be overlooked. Steel may, therefore, be replaced in the future by fibre building materials (plastic foils or asbestos cement). It is imperative to assemble the doorleaf with the frame in such a way that they are interchangeable. In other words, after completion of the interior works it must be possible to put a door leaf on its hinges at any spot required. There it must fit so that the doorlocks work smoothly.

Manufacture. Doorleaf. Industrial mass production of doorleaves is already widely known on the international market and presents no problems.

Doorframes. A final solution has not yet been found. In the case of steel frames this problem will be solved easier than in the case of wooden ones. The latter demand a good deal of handicraft methods at the site in order to cope with the finishing of detail work. The exact snug fit of lock and hinge plate is a question of accuracy of manufacture or else of the possibility of employing hinge plates with adjustable hinge wires (pins).

Mounting. At structures erected in semi-traditional manner mounting means individual labour by hand while the building is in construction, while at prefab structures it means building in the frame element during the process of mounting and fixing the door in an upright or horizontal position.

One should examine whether the use of assembly frames such as those used for windows might be more economic. In this case a door unit consisting of frame and leaf would be inserted in the ready opening after completion of the interior works. Apart from minor additional labour an easier and simpler mounting would be secured.

Conclusion. Assembly of completely prefabricated windows and doors helps to save man-power. For this reason traditional constructions must be abandoned or greatly changed and improved. In this way not only man-power will be saved, but also construction time will be shortened and quality raised.

Rationalisation of traditional building methods in West Germany

By W. Triebel (West Germany)

Wherever building by means of prefabricated components is introduced, a distinction is made, in classifying building processes, between "traditional" and "industrialised" methods. But such classification is not comprehensive. In many European countries the true "traditional" methods are no longer or but seldom applied. Only the division of building work between factories and sites are still the same as in the traditional methods. Building materials—bricks, stone for ceilings, roof tiles, pipes, wall tiles etc.—are mass produced in factories in the same sizes, irrespective of the building job where they will be used. They are applied on the building site by manual operations.

However, methods have been developed to achieve automatic fabrication of building materials. Transport has been mechanised. Even site-work methods have been improved. In such developed traditional methods, use is made of many other means also applied in industrialised processes. On the whole, these methods have become much better organised.

There is consequently no clear demarcation line between organised traditional methods, on the one part, and industrialised methods, on the other part.

In most European countries organised traditional processes are used as well as industrialised processes. In the Federal Republic of Germany traditional building methods are improved and substantially rationalised. They are applied to a great part of the building work.

Gradual rationalisation of "traditional" building methods results fundamentally from the following causes:

- new building products and more efficient work methods;
- site-work mechanisation;
- application of prefabricated building components;
- typification, or partly, of buildings;
- current or repetitive building operations;
- rational site installation and organisation.

More rational building processes and materials

Thermic-improved bricks, of greater size and less specific weight, are applied to building outer walls. For using such bricks, large scale research has led to the most suitable methods and weights with regard to work techniques and psychology and the best way of using these bricks. At the present time these bricks are produced and used as dictated by research work. Transport methods have been rationalised. Thus the work of a mason for producing such wall surfaces has been cut down by 75%.

New and more appropriate processes have been introduced for the shuttering and reinforcement of concrete floors. Concrete is mixed and carried mechanically on practically all building sites. For formwork and dismantling auxiliary accessories, easy to operate, (frame-work bearing) have been developed. As a rule, floors are reinforced with steel netting which it is no longer necessary to cut, bend and trellis on the site. Under certain requisite conditions the production of one sq. m of a reinforced concrete floor, following the old methods, took 2 hours. With improved processes this is now done, under similar conditions, in 0.5 to 0.6 hour/sq.m.

Roof building and that of staircases, windows and other building component parts have likewise been rationalised.

Building work mechanisation

Whereas walls and other parts of the house are hand-built, by improved methods, it is still possible to carry out many other building operations by machine. This applies mostly to earthwork, concrete and mortar mixing, and transport of materials to and on the building site. Man has been freed at the same time of monotonous and tiring jobs.

On the top of this, a large number of interior finishing minor operations can now be carried out mechanically: plastering, boring holes, and long perforation, smoothing plastered layers etc.

Many building operations are machine-finished 50 to 75% cheaper than by hand. To obtain such good results it is of course assumed that the most efficient machines are used with optimum rating performance.

The mechanical building equipment in the Federal Republic of Germany has increased fourfold as a result of the rate of mechanisation of the entire above-ground and dwelling building work over the years 1950—52. The following mechanical equipment should particularly be mentioned:

Lifts	approx.	156%
Mixers	approx.	257%
Belt conveyors	approx.	300%
Cranes	approx.	3100%

Prefabricated components for interior finishing

In buildings, of which the walls are masoned following old methods, it is nevertheless possible to build the floors and to effect a good deal of the interior finishing work with the use of prefabricated components. The more complex and costly the hand-made details, the greater the saving in labour and money effected by prefabrication.

In this respect, typical finishing items are, e.g. stairs, piping, balcony slabs, railing etc. Quite a number of prefabricated components require some 40% less working hours than the corresponding hand-made elements, others even 50%.

The production of such kinds of prefabricated components and their application in aboveground building and housing, in the Federal Republic of Germany, is still on the increase. These prefabricated components in some buildings account for about 30% of the total construction value.

Standardised plans

Standardised planning is a prerequisite to the organised application of industrialised processes to buildings in a variety of places. In the same way building based on such plans is of considerable advantage also where improved "traditional" methods are used.

Design work is cut down. On the building site a saving on "running-in" is effected provided work has been prepared and organised on the basis of new planning. The most rational solutions to the production of the complex house components—kitchen, bathroom, stairs, balconies etc.—may be applied to quite a number of buildings by means of standardised plans.

However, in carrying out major construction schemes, buildings will have to be erected that vary in relation to growing families, ground and urbanised surroundings. Therefore, a variety of standardised plans is necessary.

That is the reason why, in the Federal Republic of Germany, house building component parts have been typified and standardised, so that they can be used in varied types of houses. Thus service installation equipment, kitchen and bathroom, and other parts of the house too have been standardised. Floor height has been standardised (and, ipso facto, that of stairs, windows and doors). In like manner the size of rooms is related to measurements fixed for furniture and free floor space.

Standardised elements—in this case, the sanitary installation—fitted up in houses of various types and sizes have provided a 30% saving as compared with others.

Current or repetitive work

When similar operations are repeated by the same gangs several times in succession, work efficiency is, as a rule, greatly increased. Such "current" or "repetitive" work was developed in Germany many years ago in building on "traditional" lines. Now, this method is applied not only to the abovementioned "traditional" process but also, and successfully, to building on industrialised lines. Work required on masoned outer walls has gone down by 25%, after a fivefold repetition. With a fivefold repetition too, work to complete reinforced concrete floors has decreased by 45%. By frequent repetition, a 17 to 30% saving was effected on total work required on building fairly large groups of residential flats.

Building site organisation

With a proper site installation a saving in labour, time and cost is achieved, in comparison with hasty and unsuitable installations. In the Federal Republic, rules have been worked out governing site installation and an organised sequence of building operations. Concrete cases are there to prove that a rational installation of building sites has resulted in a 20% work saving in relation to what was generally necessary on unsuitably installed building sites.

Building efficiency

The various measures taken to achieve better organisation in traditional building processes have resulted, in the course of years, in a substantial increase in building efficiency in the Federal Republic of Germany. Work expended on some definite types of residential flat building, not applying rational methods, has been estimated to be approximately 30 to 32% hrs/sq.m of habitable space. To produce buildings with rational methods following the abovementioned measures, work expended amounts to 21 to 22 hrs/sq.m only.

According to official statistics, the turnover per workhour in building, reckoning with price fluctuations, i.e. worked out on comparable prices, between 1950 and 1960, has practically doubled.

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S. Tyrén and H. Åkerblad

The rationalisation of drawings

By S. Tyrén and H. Åkerblad (Sweden)

Carrying on of rationalisation work

Organisation of work

Organisation.—The work should be carried out in work groups with representatives from architects, structural engineers, mechanical engineers for sanitary, heating, ventilation and electrical installations, interior designers and landscaping architects. Each of these groups performs its particular share of the planning and design work in close cooperation with the other groups. The different groups ought to make use of qualified research personnel. Work of this kind is time consuming and expensive.

Work theory.—For the production of drawings rules corresponding to those guiding the language must be developed out of a total picture in which simple and consistent systems are built up in order to achieve a survey of the individual parts, and to enable a study of them within their significant domains. The concept of rationalisation is deprived of its relative aspect and generally the common goal will be to achieve a minimum of drafting work, as simple as possible, combined with the easiest possible handling and interpretation of the drawings, which, must be fully correct and optimally complete. Within this total picture the different work tasks can be graded in order to make the best possible use of limited resources.

The work must be based on close studies of the working methods and the handling of drawings of the construction management, on the work site, and of other production areas, their requirements and qualifications for interpreting the drawings. For the planning and design work, itself a production factor, tests and sample drawings are made aiming at the production of drawings in a rationalised way—Rationalisation such as the elimination of repetition of information, especially on drawings made by different groups within the planning work means a gain both for the production and the planning. The basis for the rationalisation work must be the best work produced today.

Work method.—For the majority of work tasks common methods of surveying can be employed in: outlining of the work —investigations—preparation of proposals—tests—submission to committees—adjustments—publication. Redrawing of drawing sets of executed works provides a possibility for testing the cooperation of various sections within the entirety and to organize this entirety systematically.

Investigation work carried out parallel to the planning of a building and thereby making it possible to employ the rationalisation work directly on the actual design process and tested in full scale should, in the long run, probably be the most profitable method.

An active information work will have to be carried on in order to put the published results into common practice.

Primary aim of the rationalisation work

Production drawings.—The greatest possible gain in rationalisation is made in the work with production drawings, which are (drawing-) documents used for the tender process, for the work on the building site and for the production in factory.

Directions for uniform presentation standards.—The main purpose of the rationalisation work is to develop uniform presentation standards which can gain common practice. In order to reach this goal quickly a strong purposeful effort is required, working out from existing axis. Parallel to this a more long term development work could grow which could be studied in due time.

Limit of profitability.—The rationalisation measures must fall within the limits of profitability of the planning and design work, thus aiming at the highest efficiency in the utilization of the means available for this work. This requires due consideration from the very beginning of the existing common distribution of the means of production. A long term study would show what would really be an optimal planning effort in the total production.

Work task

Work on production drawings.—The tasks are of the following kind:

- those concerned with the entirety; the arranging and handling of a set of drawings, the correlation between different parts of the presentation, the requirements of the means of production upon the information given on the drawings etc.,
- those concerned with individual parts of the information given on the drawings, composition of drawings, drafting technique, dimensioning etc.,
- those concerned with the presentation of various types of objects; windows, stairs, reinforcement etc.

Other tasks.—Among the tasks considered important in an expanded activity should be mentioned the preparation of building programs, questions concerning legislation, planning methods, work planning as well as the use of new means of assistance (computing machines).

International work.—The work on rationalisation and standardisation on an international basis should form part of the activities in every country. For planners and designers working across the borders, and for tender work for building parts on an international market, the developing of internationally accepted standards is a requirement for rational preparation of drawings.

The set of drawings

Composition of the set

General starting points.—As the drawings collectively form a complicated unit, which demands a great work effort in design process, they must be systematized with regard to their own particular needs. As far as possible the following must be considered:

- greatest possible clarity of arrangement and ease of handling for everyone who will use the set;
- job management must have access to clearly arranged summaries;
- the erector (manufacturer) must have access to drawings for the execution of the work, made up with due regard to time, place and workman, i.e. a workman at a certain place who at a certain time shall execute a certain work must have available all information regarding this work collected on one drawing or on as few documents as possible bound in a set;
- particular information must always be found in a certain location within the drawing set;
- no information must be given more than once in the set;
- drawings made up by different planning units must be coordinated;
- drawings must be coordinated with the rest of the documents.

Basis of division.—The drawings for the building work must be divided into 1) drawings giving summary information of the building, and 2) drawings explaining the execution of the work for various building parts and components. Drawings of the latter group are further subdivided with regard to the character of the building part or material and work, with distinction between drawings for the work site and drawings for manufacture at and delivery from the factory.

Relationship between various parts of the drawing set.—In order to facilitate penetration into the drawing set, simple and consistent reference systems must be construed, with reference from drawing to drawing as well as from one drawn figure to another, on the same or different sheets. Each object or drawn figure must be located and identified by means of suitable indications in a clearly arranged relationship, which indications must be shown as headings in the detailing and specifications. The list of drawings is a collection document from which a want of information can be directed to a specific drawing answering the question.

Drawing categories

Summary drawings—The summary drawings, plans (elevations, sections) and room drawings fulfil the functions of composition, of reference and of dimensioning. Of this, the function of composition is primarily fulfilled by a special set of plans. In an elaborate presentation the other functions are fulfilled by one or more sets of plans for the frame and its complementary parts, and by drawings for rooms and interior details. Special summaries account for limited operations etc., which are typical in the structure (for instance reinforcement).

Drawings for building parts and components. — A first category of drawings gives a complete presentation of various details e.g. roof eaves, walls under windows, and of composite units e.g. entrances, stairs, a general information of the design of the building and its structure, and information of manufacture and erection at the work site. A second, third and fourth category account for parts of the frame, parts complementary to the frame and interior parts broken out of their places in the overall picture and shown as separate units of production.

The presentation can be systematized down to a few types of drawings with the starting point whether an object should be made in a special way, made in accordance with a common standard ("Swedish standard"), as per manufacturer's standard or chosen from catalogue. Special and complicated ways of execution require presentation in plans, elevations, sections and details. In other cases the information can be given by simplified, schematic drawings, while for objects chosen from manufacturer's catalogue written specifications will suffice.

By developing a strictly systematized discipline for the presentation of various types of building components the gain will be, apart from functional drawings for manufacture and delivery, a rationalisation which will influence the production. As the planner-designer, by the pattern of presentation, can more clearly survey his material the number of variants (e.g. windows and doors), can more easily be limited to the minimum required by the function or by aesthetics.

Detail drawings. — Design details are shown on separate drawings kept together with the groups of drawings showing building parts or components to which the details belong. The details information offers a starting point for the part of the rationalising work which consists of judging between small scale outline figures and complementary details in bigger scale.

Special questions

Relationship between drawings and other documents. — Specifications and descriptive Bills of Quantities account for the information concerning material and workmanship in systematic order (the SfB-system). In the latter each item may be given a code indication. Provisions exist to employ this same code indication directly on the drawings in connection with each drawn figure. It is also possible to transfer considerable parts of the information given in the specifications to special areas on the drawings.

Completion of planning. — Against the influence of the tender procedure upon the presentation on the drawings stands the requirement that the planning shall be completed before the start of the tender procedure (or before start of construction if the drawings are made by the producer). When building with prefabricated parts the information on drawings concerning such parts must be ready for a purchase procedure at an earlier stage, which will have special bearing on the planning work.

In cases where production methods or the purchasing of special prefabricated parts cannot be determined during the process of planning, the design and quality requirements must be laid down without making unnecessary drafting work.

Volume, type and production method of building. — The system for the preparation of a set of drawings must produce a result which is easy to read and to handle, whether the planning work is big or small. The type of the planning work or its production form should not influence the principle of the system but only cause variations of "loaded sections". These requirements are best met by a system having a limited number of fixed main sections, with subsections flexible to a certain degree.

The drawing

Composition of drawing sheets

The form. — A standardisation work is necessary for the drawing form and its special requirements. This is valid for the sheet size, the choice of sheet size for drawings for a special work, location and composition of the title block, orientation indicator, space for revision information etc.

Drawn figures and lettered information. — Similar general composition questions are also applicable on the showing of drawn figures and lettering. From a formal point of view this is valid with respect to the choice, location and interrelation of the drawn information and for the placing of headings and other lettered information. Further developed, it denotes that the means at the planner-designer's disposal be arranged with due consideration to the psychological factor influencing the interpretation of the drawing.

Production and handling of the drawing. — To safeguard the requirements for the final content and arrangement of the drawing, the continuous progress of the drawing based on simple work routines must be watched in the process of rationalisation. For the handling of the drawing the development of safe routines in connection with revisions will directly effect the efficiency and cost of the product.

Drafting technique

Lines. — The use of lines of varying thickness and types for different purposes must be clearly defined. A line technique should be pursued which enables the use of lines alone as the only means of expression, thereby avoiding crosshatching etc. of section areas and other complementary methods which are time consuming and generally do not give the intended result of improved clarity. The simplification of the drafting technique can be carried far, especially for summary information.

Symbols. — Drawing symbols for various building parts must in general be avoided. To cover the much-varied needs, symbols would be too numerous and difficult to handle. Exact information by means of lettering and code indications in connection with the simplest form of marking (a cross, a square etc.) will in principle be more correct.

Drawing of figures. — Drawing of figures is generally based on parallel projection for which a general way of looking at the matter is aimed at. It has, however, proven a practical advantage to employ a special projection method (mirrored parallel projection) for showing walls and floor framing simultaneously, for the use at formwork and reinforcement. The commonly used methods for placing of figures (European and American projection methods) can be abandoned and replaced by considerably reduced rules, which can give no cause for misinterpretation.

Dimensioning (and measurements)

Setting of dimensions. — The setting of dimensions is a complement to the drawing of figures and is guided by special rules of drafting technique, which are to serve the function of dimensioning while at the same time the need for adaptation to the drawn figure is given due consideration. Conventional and modular dimensioning must both follow the same rules.

Dimensioning methods. — The system for dimensioning which has proved to be the simplest to apply and to give safest results works from base lines located longitudinally and transversally through the building, duly fixed in plan by determining the coordinates for the intersection of the lines. From those base lines dimensions are set to structural walls and columns, and from those are set secondary dimensions to complementary parts and for indication of measurements and sizes.

For buildings with repeated identical units the base lines are located along the structural system of the building (system lines). They form a suitable starting point for modular dimensioning.

Dimension tolerances. — Increased necessity for greater accuracy in the planning and construction in connection with prefabricated parts asks for a dimensioning with given tolerances. The theoretical foundation for such dimensioning is already in existence but a more general use thereof in the production is a condition for improved planning in this field.

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U.I.A.

The architect and the industrialisation of building

Themes and conclusions of a colloquium held in the framework of the Union Internationale des Architectes (U.I.A.) in September 1964 at the Technological University of Delft, the Netherlands

As a result of the invitation of CIB to the Union Internationale des Architectes (U.I.A.) to propose contributions for the 3rd CIB Congress in 1965, a restricted colloquium was held at the Technical University of Delft, the Netherlands in September 1964 with a view to discussing those aspects of the industrialisation of building of consequence to production, architecture, and the position of the architect.

Participation

The organisation of the colloquium was arranged by Professor J. H. van den Broek (the Netherlands), liaison officer between the U.I.A. and CIB. The chairman was Mr. Gontran Goulden (U.K.) and the secretary Professor M. Gout (the Netherlands). Those taking part included architects and scientific and technical experts in the field, some of whom were themselves architects. Architects attending were: G. van Bogaert (Switzerland), A. G. Héaume (France), J. Katona (Hungary), Z. Kleyff (Poland), M. Macura (Yugoslavia), V. Prochazka (Checho-Slovakia), H. Schmidt (East Germany), M. de Sola-Morales de Roselló (Spain); experts attending were: Ph. Arctander (Denmark), R. Camus (France), L. M. Giertz (Ethiopia), J. P. Mazure (the Netherlands), J. Prouvé (France), R. Sarger (France) and W. Triebel (West Germany). J. Duret (Switzerland) attended as observer and made a record of the proceedings.

General theme of the colloquium

With a view to objective and exact consideration the term "architecture" was considered to embrace the whole concept of design, construction and architectural form, in order to relate to those interests of the U.I.A. which had been discussed at the last meeting of the U.I.A. Commission "Research Industrialisation" in Moscow 1962, together with the approach described in the provisional programme of the Congress issued by CIB, and which concerned itself more with 'building' properly so-called, (notably groups B, E, F, G and J of the provisional programme; Integration of design and production, Modular standardisation, Production Methods, Materials Development, and Developing Areas).

Subdivision of the themes of the colloquium

The colloquium considered the following specific themes:

1. Technical developments: (industrialisation of traditional methods, new construction systems based on different principles; elements of different size, use of different materials, etc., with emphasis on the effects of industrialisation on production, quality, durability, objective and subjective architectural appreciation, and dimensioning and composition of elements).

2. The aims of industrialisation in the construction of dwellings, schools, industrial buildings etc. (with emphasis on type plans, variations, economy of production in factory and on site, cost aspects, amortization and financing).

3. Relation between architect, engineer, builder and manufacturer: (emphasis on needs for research responsibilities of architects, industrialists and clients, construction teams, the private architect applying industrialised methods).

4. Influence of industrialisation on architecture: design—execution—architectural form (emphasis on standardisation and modular coordination both in large and small individual projects, application of industrialised techniques by architects, modern architecture).

5. Industrialisation of building in developing countries: (emphasis on use of local materials, possibilities for industrial production or import of elements of construction).

Conclusions. As a result of discussions of the specific themes listed above, the colloquium came to the following conclusions.

1. Contemporary architecture cannot fail to be influenced by its own era. The era being an industrial one, it is to be expected that architecture will interpret the characteristic aspects of it. This fact is all the more evident when architecture demands that industry furnish it with the *means* of realisation, and expression of its ideas.

2. There are, at the present time, two methods of industrialised building. The *first* consists of producing standardised building elements in specialized factories. These elements are used in the construction of individual buildings the design of which is done by architects.

The *second* consists of producing complete buildings, by repetition of type plans.

3. Standardisation and modular co-ordination are the basic conditions for the industrialised production of elements. It is desirable that PREFERRED DIMENSIONS are used, larger than the present standard international module (10 cm, or 4 inches). In this sense, a multiplication unit of 6 seems to be of particular interest because of its characteristic of divisibility. Standardisation of building elements must lead to their increased use on an international scale, with a corresponding increase in mass production and improvement of quality. Architects must take part in the work of responsible organisations on the definition of dimensional, qualitative and functional standards, so as to guarantee demand for them. This method of industrialised building has the advantage of allowing varied design of buildings, under different programmes, and of assuring a stricter adaptation of the work to the needs of the programme. To a certain extent it will also serve to prevent monotony due to the repetition of identical buildings.

4. Industrialised production of standard plan buildings is, at the moment, the most advanced form of industrialised building. With this method there may exist modulation and standardisation in the factory, but it is equally possible to use those elements which have been produced according to the method described in 3 above, as far as the particular system in the factory observes the rules of modular co-ordination. It is necessary to limit *series* of similar buildings to avoid "inhumane" repetition. In this sense, preference ought to be given to processes which, on condition additional costs are kept to a minimum, will allow the production of different types of buildings from the same production chain. Experience shows that reduction of prime cost becomes less important once a certain figure has been reached.

5. A solution must be found in the future to the differentiation between structural and load-bearing elements on the one hand, and the insulating and servicing elements on the other hand. It would have the advantage of allowing *flexibility* (open plan) in space and time, and of offering man the chance of expressing his personality within the community.

6. Architecture is necessary for society. Architects must regard the industrialisation of building as a new way to satisfy the natural and spiritual aspirations of mankind. The spirit of architecture being of a different order to that of industry, it is important that the architect preserves his *independence of thought*. This does not prevent close and necessary collaboration with all those (consulting engineers, contractors, etc.) who participate in the elaboration and achievement of the common task. It is in this sense that the role of the architect will be defined, if necessary in several aspects, on condition that the status of his profession will not become stiffened.

7. Although the absorption of the architect as a paid employee, within industry, offers practical advantages of concentration, it also presents the grave danger of diminishing his *authority*, to the detriment of this social mission. It is not unthinkable that the architect should be an *industrialist*, but if he is, he will risk finding himself in intimate conflict with himself.

8. Industrialisation of building in developing countries is bound up with the level of industrialisation in those countries generally. It depends on such factors as the economic situation possibilities of investment), the geographical position (ethnic

groupings), and the development of industry (production of raw materials). The choice of methods and processes to be used needs great care, since, in these areas, it is not possible to undertake costly experiments.

If there is a universal trend towards *unification of requirements*, one can also observe specific reactions necessitating strict adaptation of buildings to the needs of these people.

Industrialisation has the advantage of raising the technical level of personnel, while avoiding the slow cycle of development resulting from professional training in traditional skills.

It is necessary not only to make available to developing countries equipment and technical aid, but also to ensure as quick as possible that local groups of professional leaders, having assimilated the experience of advanced countries, will in their own turn create the means whereby the basic hopes of these populations will be best realized.

Concrete elements for the construction of offices, public buildings and hospitals

By F. Walley (U.K.)

It has been estimated that in Great Britain a 50% increase in production will be required in the next 10 years and this must be achieved with little or no increase in the labour force. The building and civil engineering industry has been and is likely to remain in the near future essentially a craft industry so that increases in production of the order envisaged are unlikely to be achieved without a radical reappraisal of available methods of construction.

The problem may be considered as analogous to the car industry where the means of production are constantly being considered when the design of a new car is developed. Similarly, a building in this age should not be conceived as a finished creation without considerable thought being devoted to the means of its creation. Because of the nature of traditional building there is probably quite a low limit to the amount of mechanised equipment which can be mobilised on a site in terms of hire-purchase per person or £/per person and this in itself militates against a sharp rise in production. The problem therefore is posed as to whether it is possible to achieve a system of construction which can be largely mechanised and transferred from site to a factory.

It should be made clear at this point that this paper is not concerned with "system" building as applied say to multi-storey flat construction. The latter with its large panels and small rooms is a totally different problem from those which arise in the type of building being considered. It also does not deal with the contribution which precast cladding units, used alone, can make both to productivity and the aesthetics of buildings.

Mechanisation, however, is economically achieved only if reasonably long runs of production are ensured. These runs need not be of identical units but the type of unit should be similar. Any move towards mechanisation must be reviewed in an economic context and standardisation of types of construction and repetition of standard details must lead to a lowering of cost both in precasting and subsequent site erection. At the present time the precast product is likely to be dearer than in situ work. This is, no doubt, because factory overheads are so much higher than site overheads where rates are not paid and where heating, lighting and canteen facilities are often rudimentary. A widespread move towards standardisation should, however, eliminate these differences in cost and produce comparable buildings with a reduced labour force. It has been said that reasonably long runs of production are required but this needs qualification since moulds have a finite life and it would appear more important to standardise on "types" and methods of construction rather than on the specific shape of any particular unit. In this way it should be eventually possible to obtain realistic prices for such work as familiarity with the methods grow.

Even a brief survey of this field in Great Britain shows a tremendous variety in methods of construction from virtually wholly precast with bolted joints to largely in situ work with isolated precast units. In an attempt to highlight the reasons for this diversity and to point a way forward a survey has been made among a number of engineers, contractors and precast concrete manufacturers to seek their views on design, manufacture and erection.

Buildings may be divided into five main components:

1. columns – internal or exposed external
2. beams – which may be visually absent particularly in flush slab construction
3. floors – which may be solid, hollow or T-section
4. stairs – which may be sudivided into flights and landings
5. stability walls – which may be independent or form part of lift or staircase walls.

Although these are the main components "the sum of them is greater than the whole" since together they provide not only the means to carry the superimposed floor loads but also for the stability of the whole structure. In this respect it cannot be overemphasized that in the design stage more provision should be made than is "theoretically" necessary to provide for both local and overall stability.

Particular care should always be exercised in detailing connections. It is normally at these points that trouble, if it is going to occur[2], will arise. Firstly, consideration should be given to welding reinforcement together at critical points to ensure it cannot be displaced during casting; secondly, the necessity for cover to the ends of bars which will eventually be adjacent to in-situ work should be examined; thirdly, the practicality of placing the unit, any additional reinforcement and in-situ concrete should be investigated with mock-ups if necessary. The latter should take into account all the normal tolerances which exist in the trade and which will be discussed later.

A few years ago the "frame" of a building was designed to carry the whole of the disturbing forces. With increased knowledge obtained from loading tests it has been realised that the real stability of a frame depends to a very large extent on the presence of internal walls. It is therefore possible to isolate the vertical components of loading from the racking forces and to provide for the latter by using internal walls required for other purposes. The problem of precasting and erection becomes simpler since full continuity need not be sought and all connections can be fundamentally pin-ended. This is, of course, an overstatement since a measure of continuity is always desirable to take care of the unknown stresses caused by creep, shrinkage and temperature.

It is now proposed to examine the five parts of a building in more detail.

1. Columns. These may be in single or multi-storey height. In the former case, two contradictory conditions have to be reconciled – a simple pin-ended connection is all that is finally required, but for erection purposes temporary stability and means of quick adjustment in line and level are necessary to allow a speedy release of cranes. Here a more sophisticated and relatively costly device, such as a bolted connection, has often been introduced. (Fig. 1a). Although temporary stability across a building can easily be achieved, stability of external columns along a façade is not so simple and this has given rise to multiple or "goal-post" units. These, however, are heavier and dictate the size of the crane, although on the asset side there is one lift and not several. Costing has shown that they are always more expensive than simple units. The whole approach to a pin-ended connection for columns has been revolutionised by work[3] on "end-blocks" for prestressed concrete. This has shown that it is possible to transmit pure compression using high contact pressures, provided adequate precautions are taken to withstand the high bursting stresses. If this is done a simple grouted dowel connection is all that is required (Fig. 1b). This has the additional merit that washers may be incorporated to correct for level at each floor level should it be necessary. This would appear to be the way forward and is being used for a 20 storey Government office building.

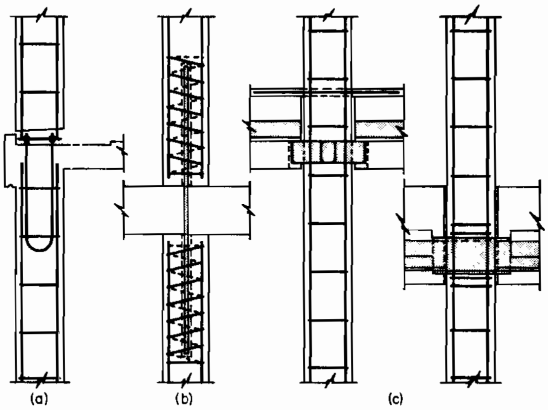

Fig. 1. Steel connections.

In multi-storey columns the junction of beam to column can be made by leaving a protusion (such as a steel member) from the column at each floor level (Fig. 1c). In such cases, columns of 8 in. square can be erected up to 50 ft. long.

2. *Beams.* Here the problems are not the same as for columns. There are two – the major one, the connection of beam to column; the minor one, the connection of floor to beam. In the first the problem can be different for external and internal columns. In exposed columns where the transome forms part of the precast unit or even when it is separated from it the joint can be a dead bearing and the only problem lies in joining the ends of the beams or transomes. With close centres of columns the joint may be made midway between columns, merely cantilevering out each beam end from the column face. No structural connection is required, but care must be taken to weather the joint. This type of joint (Fig. 2a) assumes that adequate tying is introduced between floor and beam. It has the added advantage that temperature and humidity movements which are largest on the façade of a building can take place relatively easily. Where large external column centres are required the problem becomes more difficult but the same principle may be adopted (Fig. 2b). In exposed beams, this solution is sometimes unacceptable because of joint lines in the elevation. This has given rise to a solution where the column spacing alternates between long and short (Fig. 2c). In cases where ends of beams must rest on columns many solutions have been tried and probably a cheap and satisfactory answer has yet to be found. In some cases it may be possible to provide concrete haunches to obtain an adequate seating but this is hardly possible in the type of building being considered. In other cases a steel to steel seating connection can be made (Fig. 3), a measure of continuity being introduced using a bar in an in-situ screed or by welding (Fig. 4). In other cases beams have been designed to rest vertically on the edge of columns using a temporary seating cleat or scaffolding. In these cases adequate provision must be made to carry the whole of the shear through an in situ R. C. connection. There have been many cases, even with apparent bearing, where vertical cracks have developed either in the end of the beam or in the support caused by high principal stresses arising from the combination of vertical and horizontal forces. Such cracks arise from shrinkage and creep and occur more frequently where prestressed beams are used because of the larger creep movements. This has been experimentally investigated by the P.C.A.[1] (U.S.A.) and recommendations to overcome it have been made.

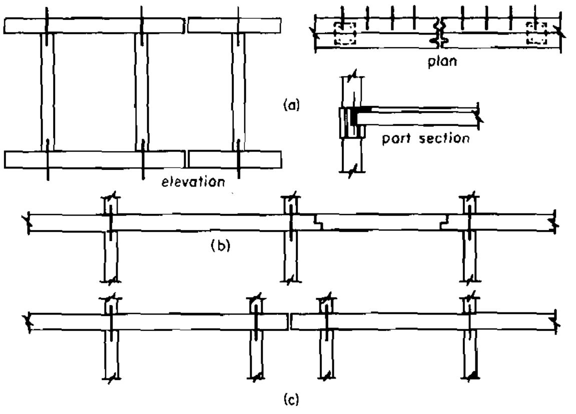

Fig. 2. Breakdown of steel connections.

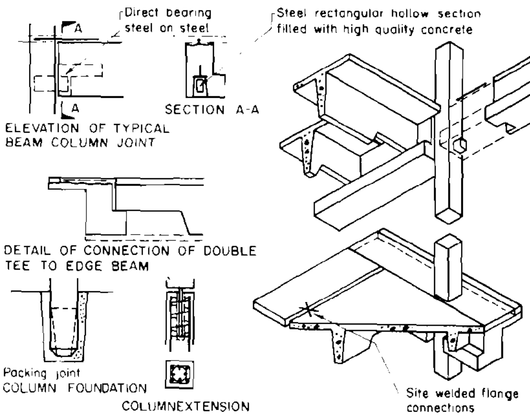

Fig. 3. Details of standard building frame B.C.C.F. (Gifford).

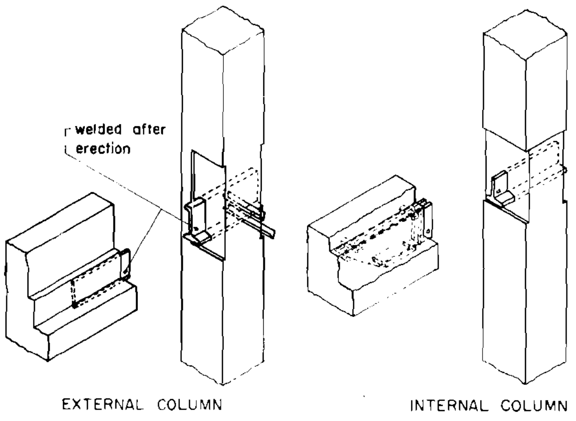

Fig. 4. Standard building frame (Concrete Ltd.).

The floor-beam connection is normally simple. Where it is possible to rest floor units directly on a precast beam care is needed to ensure a measure of continuity between the beam and the floor. This can be done by having projecting bars from the beam turned into a screed whether the latter is structural or not. This must be done in any case to ensure that the floor acts as a horizontal diaphragm to transfer the wind loads back to the stabilising walls.

In modern office construction, however, it may well be that internal downstand beams are not desirable. In these cases they may often be incorporated in the depth of the slab provided temporary propping is acceptable.

3. *Floors.* There are innumerable precast floors available in Great Britain and millions of square yards are laid each year. They may be divided into four types:

1. hollow box or solid units giving flush soffits and top surfaces – generally they are not propped.
2. beam units with hollow pot infills. The units can be full depth in which case propping need not be used or they can be part full depth when in general propping is necessary.
3. precast soffit units on which structural screed is placed – these always need propping.
4. T-units or inverted U-units with or without the provision of a false ceiling – these usually do not require propping.

1 and 4 will normally require a finishing screed to provide an acceptable finish for floor coverings. 2 and 3 are provided with a structural screed in which can be buried any conduit for lighting or telephone circuits. This screed can also be finished to receive floor covering. In this case a distinct cost advantage can be gained both in the cost of the floor and in the supporting structure because of the reduction in weight.

For larger span floors T- or double-T units and for two-way spanning floors large inverted precast units can be used in conjunction with in situ ribs.

In Great Britain there appear to be developing two schools of thought among contractors when erecting multi-storey buildings – that which dispenses as much as possible with shuttering and propping and that which for safety and convenience will deck out a floor completely unless it is type 1 or 4 even if no soffit shuttering is required. This latter school considers an in-situ floor to be preferable.

From the cost point of view two items obscure the differences in the basic cost of a floor, the first is the cost of plastering (or battening with plaster board) and the second and more important the cost of the screed. Ideally, therefore, unless a plaster or false ceiling is required, a precast floor should have a finished soffit and an in situ structural screed finished to receive a floor covering. For medium spans this may be achieved using prestressed planks side by side with a structural topping. Such planks are usually 2-2½ in. thick and have to be propped at 5 ft. centres. For longer spans it is more economic to use a hollow type of floor even if a false or plaster ceiling has to be used.

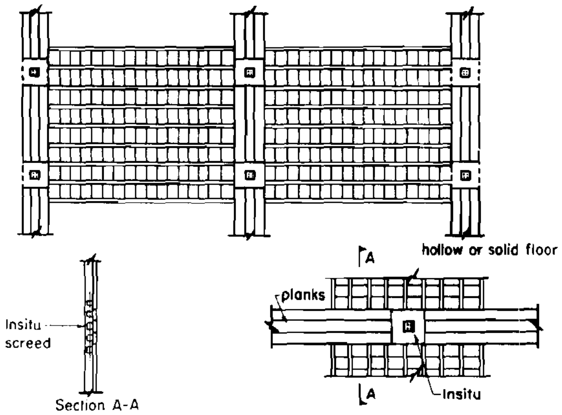

Fig. 5. Typical lay-out of precast beamless floor.

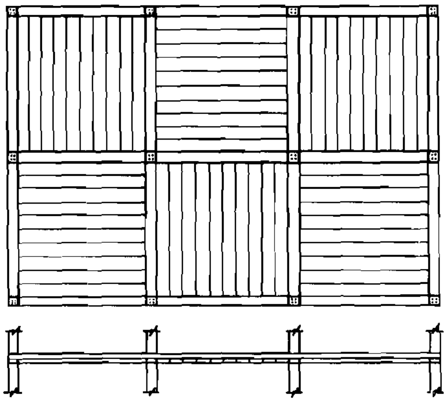

Fig. 6. Alternative lay-out of precast beamless floor.

Both types of construction may be satisfactorily used to form flush slab floors. In these cases, virtual beams in the depth of the slab may be created by reversing the line of the plank and adding reinforcement where necessary in the in-situ screed (Fig. 5). Such a technique does not require one set of planks to be supported by another and is particularly useful when the spans across a building are appreciably greater than along the building. Where approximately equal grids are possible, the alternate bays may be turned through 90° (Fig. 6).

All this assumes a screed is necessary. It is possible in certain circumstances to use wholly precast panels if the joints between them can be masked either by internal walls or wide in situ strips to even out irregularities between units. Such a floor, however, is usually more suitable for garages or industrial accommodation.

4. *Precast stairs.* These are a familiar sight and have proved attractive to the contractor. Very often, unless large precast fascia panels are also used, they would be the heaviest units on site and though few in number could dictate the size of the crane. In these cases, it is probably best to precast the flights alone with or without steel protruding from each end to be incorporated in an in situ screed at each landing. These must be detailed to rest on the lower landing.

5. *Stability walls:* It has been assumed that the overall stability depends on the presence of vertical walls somewhere in the building. Usually such walls are built in in-situ concrete (or brick). Site experience shows that these are time-consuming operations. Work is proceeding on the efficacy of part precasting of these walls. Sufficient work[5] has been done to show that a simple infilled frame is excellent in resisting lateral forces. This infilling might well be precast using vertical units similar to floor units. Model testing is proceeding to prove this assumption.

So far the problems and certain solutions to them have been outlined. These have proved acceptable on site and cost wise. The way forward would appear to lie in the adoption of partial prefabrication with some in situ work to ensure the continuity and hence the integrity of the building when subjected to the day to day movements which occur because the material is "alive". However, there are two other problems which must be mentioned, moulds and secondly tolerances.

Moulds. The provision of these is one of the more costly items in precast work. Accuracy of casting depends entirely on the stability of the mould over its life. A large order, provided there is a reasonable delivery time, will justify the provision of steel moulds. A small order will only justify timber moulds unless the client is prepared to pay extra.

There is no doubt that a greater variety and better finish with closer tolerances can be achieved with precast as compared with in-situ work, and for this reason alone it is often chosen. It should be ensured that the finish required is compatible with the structural system. The use of glass fibre moulds has increased in recent years and where a high quality smooth finish is required they are almost a necessity.

Tolerances. Some variation in accuracy of form is inevitable between mass produced units. With timber moulds the final dimensions of a finished product are disturbed by the swelling and distortion of the timber in contact with wet concrete. In prestressed work in particular additional distortion is caused by volume changes in the matured unit. Even when steel moulds are used, distortion can often take place if the moulds are handled carelessly. The standard of fitment and finish of the work can have a decisive influence on the development of efficient connections between members of the frame and any supported cladding. In multi-storey framed construction the precision must be such as to ensure the safety of the structures, allow for ease of erection and show an alignment between the parts which is acceptable for exposed concrete or as a bed to receive a finishing membrane. The permitted deviation should not be so exacting as to require exceptional measures of manufacture with correspondingly high costs, nor so gross as to condone a low standard of workmanship. It is not economic to demand a precision in manufacture beyond that which can be achieved by standard procedure. The details must be arranged so as to absorb satisfactorily the expected variations in dimensions. A realistic table of tolerances is given below for units normally used in the type of structures being discussed.

	Tolerance	
Position	Rate of deviation (in./10 ft.)	Limit (in.)
Length Bow Twist	⅛	¼
Cross section		⅛
Position of fixings and fittings		⅛

It should be borne in mind that inaccuracies are often introduced after demoulding by bad stacking and curing while the concrete is green.

Standardisation. Only general principles have been discussed in this paper. These can be applied to any standard module or standard dimensions of units. In Great Britain a system of preferred dimensions[6] is being adopted for different types of buildings and with widespread use will reduce the number of beam and column sizes. The frame for a public building or office will be different from that for schools or hospitals. The former usually require open areas which can be subdivided at will, in the latter provision has to be made for a large numbes of services. Considerable space has to be allocated between floors to accommodate them.

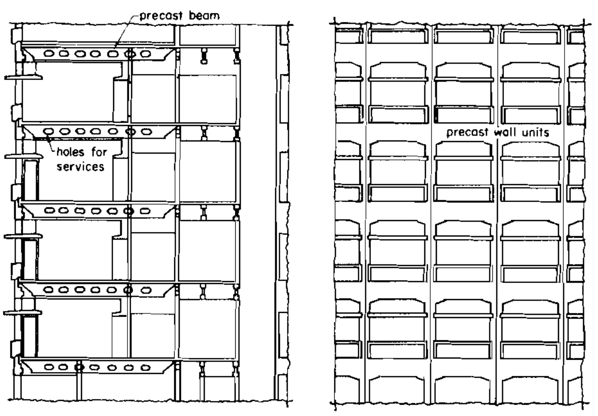

Fig. 7. Section and elevation of precast hospital (Intergrid).

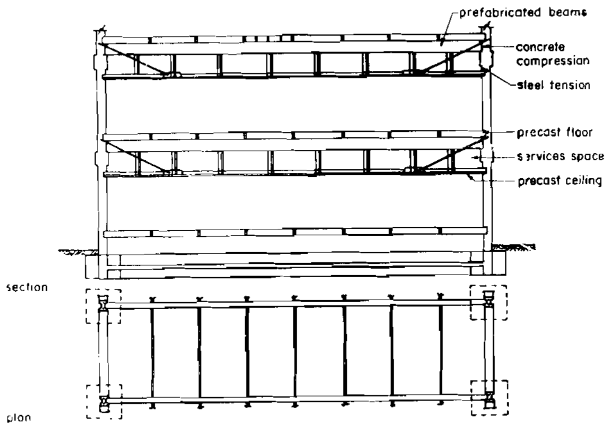

Fig. 8. Section and plan of prototype hospital. (C. Weiss).

It has proved impossible to get an adequate picture of the whole field in which precasting has been applied. It is being used for the construction of many new hospitals Figs. 7 and 8 illustrate two of these. It has been used in the construction of many new universities or colleges. It is being used extensively in government buildings for offices and laboratories. A large number of schools have been and are being built.

There is no doubt that there will be a growing demand for this method of construction as skilled labour gravitates towards the factories where mechanisation can be more easily introduced. It is to be hoped that rational methods of design together with the increasing use of preferred dimensions will lead not only to an economic solution of the problems posed by precasting but also to an upsurge in productivity in this vital industry.

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Group C
Planning of Operations

Final report from the group rapporteur J. B. Dick, Building Research Station, United Kingdom.

In the move towards industrialised building, the development and application of industrial methods of planning and control have an important role. As was clear from the various subjects dealt with in the individual papers and in the discussion at the Congress session, a variety of methods is being developed and these are being applied in many fields of planning. In reviewing these applications, it is convenient to proceed by considering first the problems involved in site construction for the one-off project and to follow this by examining the corresponding overall building process. This will then be followed by considering multiple projects as carried out by individual enterprises, and finally the problems of planning construction on a regional or national scale. But before reviewing the applications, it is as well to preface the discussions with some comments on the developments of techniques which have been taking place in the last ten years.

Techniques

There is little doubt that the most important development in the last ten years has been that of network analysis in which a process is seen as an inter-related sequence of events and activities. The initial form adopted in the Programme Evaluation and Review Technique (PERT) took account of the inherent uncertainty in predicting progress, in that optimistic and pessimistic estimates of durations of individual operations were introduced into the calculations of the estimated progress. The application in the building industry has usually been rather less sophisticated with only one estimate for the duration of each operation, and on this basis the critical path has been calculated and estimates made of manpower and material requirements. The representation of the process has usually been in terms of an arrow diagram in which the arrow heads represent the events and the shafts represent the activities. An interesting paper for discussion at the session was the comparison between the block planning network ('Potentiels Tâches') and the arrow diagram (Coiffard and Deloro, France, C5). They suggested that in Europe where a considerable amount of updating is at present required, the 'Potentiels Tâches' method is preferable, in that it provides the flexibility required. This suggestion received considerable support during the discussion and it was perhaps rather surprising that there was so much agreement on this particular point. But it did appear that those concerned in the industry found the block or circle-and-link diagram simpler to understand and easier to manipulate when, for instance, updating or dealing with overlap. It may be that some of the technical difficulties experienced have arisen from inadequate use in the arrow diagram of dummies to represent the constraints in the process: if these have been omitted, difficulties can arise when introducing modifications. But clearly there are other practical advantages in the use of block diagrams, and as computer programmes can be readily modified, we may well see an increasing use of this method.

Perhaps the most outstanding problem area in the network analysis of building processes is that of resource scheduling. Ordinary network analysis does not explicitly allow for the limitations in resources of labour, plant, etc., which are met in practice in most projects, although from the analysis it is possible to obtain graphs of the resources of each type required each day, if every activity is to start at its earliest time. The resource requirements obtained by network analysis are often very irregular and it will usually be desirable to smooth the curves and perhaps to limit them to certain defined maxima, either for a single project or for several projects together. Various methods have been used to tackle this problem, either by hand or with computers, but none of them can be guaranteed to give the best possible schedule, or even a near approach to it, under any particular circumstances. These methods are still being developed, and at the present time it is difficult to decide which methods are best suited to various types of situation.

There is no doubt that the tool of network analysis has brought to the construction field a discipline of logic which enables processes to be more clearly understood in terms of the sequence and inter-relationship of the individual operations in the process. But what was clear from many of the papers and from the discussion at the session was that existing knowledge of the characteristics of individual operations such as labour expenditure and duration was barely adequate. This subject is of prime importance in developing the application of modern methods of planning and control in the industry and is discussed at various stages in this report.

However, even if more reliable estimates are obtained in the future, a certain residual variability will remain. Present methods of programming can accommodate this uncertainty by accepting that although the programme is produced in deterministic form, updating will be necessary as the job proceeds. This updating involves recalculating at regular intervals the programme for the work which still remains to be done and also introducing, between these full updatings, some minor modifications in the day-to-day programme. These site decisions can be assisted by the use of flexible planning boards, but it does appear that more detailed guidance in the form of decision rules could be developed. Some preliminary study of decision rules for controlling repetition construction has been made in the United Kingdom and it may be that this subject merits further development.

Planning and control of individual site projects

The general principles of the application of critical path programming to construction are outlined in the paper (C3) by Guanerio and Carnemolla (Italy) on time and cost control in modern programming techniques. They give an example of how at different stages control can be exercised either by reallocation within the original plan or by taking additional measures not previously envisaged. Gore (Australia, C7) gives a practical example of the application of critical path programming to the construction of the Sydney Opera House. Of particular interest here is the development of job costing, which enabled the costs incurred in the early stages of repeated operations, such as the placing of in-situ concrete, to be fed back into the control calculations; the consequences of cost trends on the final costs could thus be estimated and remedial action taken where necessary. This breakdown of work into a series of repeated operations can be applied in many large scale projects. Examples are given by Slipchenko (U.S.S.R., C20) who outlines the application of flow-line production methods to civil engineering projects such as canals and underground railways, and reports on the economies achieved.

Where a contractor is involved in a limited range of operations in different jobs, he can also develop his own feedback systems of information from the site. Gabrielsson (Sweden, C6) outlines detailed time and motion studies on heating and plumbing installations which form a basis for synthetic time standards for operations. A similar approach is possible where the concern is one of design development, and the paper by Johnson (U.S.A., C10) dealing with research in home building productivity shows how detailed work study analysis together with design development can make a real contribution to productivity.

But in general, the construction of one-off projects must be programmed on much more limited information. How this information can be improved appears to be a problem in many countries. In this context, Bishop (U.K., C2) discusses the problems of defining the operational elements: unique descriptions for operations differing only insignificantly in content must be avoided as this would make it difficult, if not impossible, to transfer the experience obtained on one job to another. Ritter (Switzerland, C19) discusses the same problem for traditional building, and emphasises the need for a 'standardised description of productivity', in which all the usual building jobs are arranged in a systematic sequence of items and in which a specific job is always classified under the same number and worded in the same way. He reports that Switzerland is preparing a standardised description of productivity for the building trade.

Ugander (Sweden, C23) describes in detail systems of integrated data processing which have been applied in Sweden by builders and contractors primarily engaged in the construction of apartment houses. This provides for regular feedback of information from site so that cost control can be exercised and if deviations from the original schedule are large this can lead to revision of the network diagram. Information on production rates is also stored for use in future projects.

The methods by which improved data could be obtained were discussed by several contributors at the session. One essential was that the collection of data must not be expensive, and the most promising method was to adapt existing routines for payrolls and invoices to provide the data required. Ugander stressed these points and also suggested the need to be selective in deciding which data should be collected. For each project there were certain operations which were of special interest; other less important operations could well be grouped under one item.

Plannng and control of repetitive construction

The economies which are achieved with repetitive construction have been clearly established in recent years. Palm (E.C.E., C16) summarises the effect on operational time as being due to the increased work tempo achieved by training, and the successive improvements of work method and arrangements in the immediate environment of the actual operation. Planning of repetitive construction has to take into account the probable improvement curves which will be realised, and Hugsted (Norway, C9) reports the development of a planning model in which allowance is made for the longer durations of operations when work is first started and for the time delay before the basic or final rate is achieved. Palm (E.C.E., C16) points out that where flow-line methods of production are adopted, it is rather difficult to allow for the gradual improvement of labour productivity as work proceeds, and instead some adaptation of the general work rhythm is introduced from time to time. An alternative, particularly where shorter series of repetitions are involved, is to leave more flexibility in the initial programme so that advantage may be taken of improvement as it occurs. In these circumstances there appears to be scope for the application of some form of decision rule.

With repetitive construction the recording and monitoring of progress data is much simpler, so that there can be a useful feedback to improve control generally. This experience is not necessarily restricted to one site: a firm specialising in one type of construction can develop its approach in its whole building programme. Murphy (Australia, C13) reports on the controls developed in the Housing Department of Tasmania in large scale single unit housing. He mentions the establishment of standards for materials, labour and overheads; his approach on allowing for improvement in productivity is similar to that suggested by Hugsted in that 'estimated' time standards are progressively reduced as work proceeds with the eventual goal of the time study standard.

Planning and control of the building process

So far we have been mainly concerned with the problems of planning and controlling site construction but now we must consider the other activities which are involved in the building process. The paper by Ugander (Sweden, C23) besides dealing with the site planning and cost control, also covers the estimating procedure required by the builder. A system called DATAKALKYL is used for quantity surveying and cost estimating, and this makes provision by classification and coding to provide a breakdown in terms of elements and in terms of operations. The latter can then be used for network planning by computer, and can also be linked with a cost control and cost analysis. Taken together, these systems provide a closed loop through the whole process so that correction by feedback is ensured. As Ugander remarks, however, the building process starts long before the contractor comes into the picture and further development is required to include the earlier activities, in particular those of the architect.

It is at this stage that some overlap must occur between the discussions of this session and those of Group B, concerned with the integration of design and production. Both groups have an interest in the characteristics of the overall process, and one of the requirements for efficient planning and control systems must be to provide adequate feedback from production to design. The paper by Bindslev (Denmark, C1) outlines his work on the development of his coding system of Co-ordinated Building Communication (CBC). This is aimed at providing a system suitable for the application of EDP techniques at the various stages of the building process. The starting point is a central specification which is described by Nielsen (Denmark, C14); this, in effect, is a library of descriptive terms stored on a computer which covers 'all common and recommendable structures, methods of construction, finishes, etc., used in ordinary building jobs'. The information in this central store, which includes data on materials and labour, is available to the architect designing the individual building, and his specification can be printed out by the computer on the basis of the central specification tapes. This basic system is also intended for use in assessment, planning and control throughout the building process; as Bindslev concludes, the system provides the possibility of creating an administrative tool for the whole of the building industry.

There are no doubt a considerable number of technical problems to be solved in the development of such all-embracing systems, but it is clear that in many countries work is developing in these areas. One approach, exemplified by Bindslev's work, stems from the design side of the process; others, such as Bishop (U.K., C2) start from the production side and consider how site data may be obtained and then communicated via an operational bill.

Considerable support for the development of a more rational system was apparent during the discussion, and the question was raised whether we had not now reached the stage where international action was needed as regards the nomenclature and coding system which might be adopted. This was particularly important with the growing use of computers and could lead in the end to a co-ordinated system of communication.

However well these developments go in the future, there will remain problems of planning and controlling the early stages in the building process. No papers have been submitted which deal in detail with the work of the designer in these terms. Staniszkis (Poland, C21) does however outline general rules for the programming and planning of the process of building. The investment process described runs from the initial considerations, through the design process, to the preparation of the site and the completion of erection. Staniszkis stresses the importance of adapting the organisation of the team of participants to the tasks apparent from the operational breakdown of the process.

A notable contribution concerned with the early stages in the building process was made by Grafton (United Kingdom) during the discussion. He dealt with the use of cost planning throughout the design stages – a process which could assist in ensuring that cost consequences of alternative design decisions were taken into account and that the final cost was within agreed limits.

Planning and control of multiple projects

We must turn now from the problems of planning and controlling individual or repetitive projects to consider management methods which can deal simultaneously with a number of projects. The projects may for instance be those undertaken within a firm or corporation which deals with a variety of work; or they may be similar projects to be carried out by a specialist firm; or they may also be the projects to be undertaken in a region.

Stradal (Czechoslovakia, C22) discusses the use of linear programming to determine the optimum balance for the activities of a building corporation, taking into account the limits imposed by the types of labour, materials and equipment which are available. He reports that in Czechoslovakia, linear programming experiments of this type have been carried out for several building corporations, also for several of their subordinate units and finally for a whole building trust employing some 10,000 people. These experiments showed the advantage of this form of production programming for the planning of building production.

The extension of management control to cover all large projects in an economic region is discussed by Ribalski (U.S.S.R. C18); data from each construction site is fed back to a single computation centre, where analysis for each site is carried out and information on requirements for plant and materials is addressed to the appropriate organisation. Ribalski also deals with the development of long term planning models for optimising the construction programme in a region. This involves organising a set of the required flow-lines and establishing the optimum priority and time of construction for various enterprises. The computer calculations involved are of particular interest in that they essentially explore the effects of changes in the assumed values of certain variables in order to seek an optimum solution. The technique appears to be a powerful one which could well have other application at different stages in building.

The applications of P.E.R.T. and C.P.M. to town planning are discussed by Misuraca (Italy, C12) who outlines the method used for an overall plan for a large residential district in a town in South Italy. This general programme incorporates a number of more detailed P.E.R.T. programmes for groups of activities. Of particular interest in this paper is the discussion of the application of network analysis to include not only the building process but also the administrative procedure prior to obtaining official permission to build. This was necessary because of the great number of people and private and public corporations which were, in some way or other, involved in the procedure. Misuraca reports that following this examination it was possible, by taking various steps including changes in legal requirements, to reduce the time for this stage from more than two years to about one year. Clearly, industrialisation of the building process itself must be accompanied by a streamlining of the preparatory procedure.

Some of the basic problems in town planning are discussed by Guiducci (Italy, C8) who is concerned with the effect of the size of new towns on the overall costs. His work suggests that there is no optimum size but that there is a series of maxima and minima as size increases. There is clearly scope for development of such studies so that costs can be minimised by efficient design as well as by efficient programming and control of the subsequent building operations.

General discussion

The papers presented to the Congress and the discussion at the meeting showed how modern techniques are being applied for planning and control. The techniques outlined ranged from simple planning methods which could be used by those with little training in mathematics to the most sophisticated methods which used computers with vast stores of information. It was more difficult to ascertain the extent to which the techniques were being used in the different countries. There had been little systematic study of this aspect, though Burgess (U.K.) did report the results of a small survey; this showed that of a sample of contractors who were known to be using network analysis, less than 25 per cent applied it as a site control, and of these only15 per cent were in fact using it on site.

But it was not only a question of finding out what happened in practice, for different views were expressed by contributors about which methods were most appropriate; for example, differences in opinions were voiced about whether computers had to be used in critical path programming and control. This apparent disagreement seemed to arise not so much from basic differences about the value of the techniques, but more from differences in judgements about the best method for a particular situation. The argument was reminiscent of the discussion in the session on the developing areas where the problem was to match the characteristics of the construction programme to the available resources of manpower, materials and capital equipment. In the same way the introduction of more advanced methods of planning and control must be related to the circumstances. Industrialisation of planning does not necessarily mean that computers should be used for all problems, and it may well be that the introduction of simpler methods is more appropriate in some circumstances. We have to consider not only the higher cost of more advanced methods of planning and control but also the people who have to use the methods and the limitations imposed by the difficulties of obtaining comprehensive data about the process.

The lack of data about the building process was certainly one of the main obstacles to the introduction of better methods of planning, and as mentioned earlier in the report, this point was discussed in some detail at the Congress. In spite of the difficulties of obtaining comprehensive data, several people are working on the problem of developing a co-ordinated data system for use in the building process; this would be used for both the design and production. On the design side the main emphasis is on building elements, whereas on the production side the emphasis is on operations. This difference in requirements might have proved a stumbling block some years ago, but the development of computers does mean that data in one form can eventually be translated to the other as required.

What then are the main research problems in planning building operations? There are clearly a number of technical problems, such as the development of improved methods of resource allocation and the exploration of decision rules for use in control, but perhaps the outstanding impression from the papers and the discussion is the need to obtain a better knowledge of the building process, not only of its constituent parts but also of the process as a whole. A better understanding of the characteristics of the process would enable a closer integration of the parties concerned and open up further possibilities in the development of planning and control to obtain higher efficiency.

Data processing as a key to overall communication and feed-back

EDP-coding of drawings, specifications, bills of quantities, CPM-networks etc.

By B. Bindslev (Denmark)

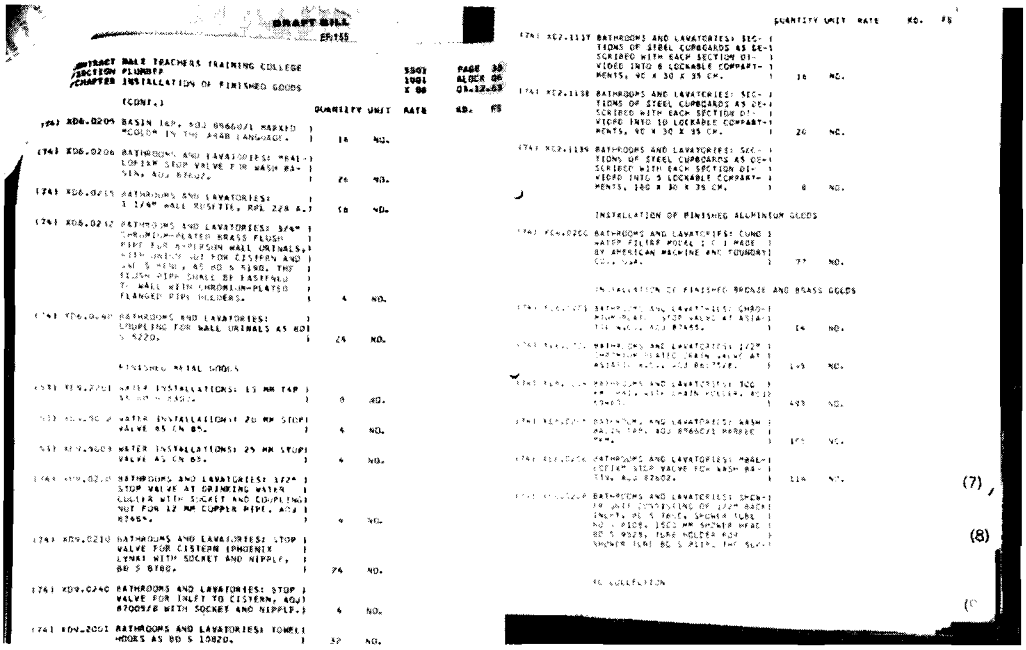

Fig. 1. Two bill sortations of the same catalogue items. The bill page on left is sorted on the second facet, while that on right is on the first facet. The top item on left is repeated third from bottom on right. The differing quantities are due to the left-hand bill having been prepared for one block of the contract only, while the right-hand bill covers several blocks on the same contract.

Drawings, specifications, bills of quantities and CPM-networks are the means of communication within the building industry and their chief object is the co-ordination of the differing production processes. The increased specialization is already beginning to highlight the inadequacy of our present methods of communication.

If building shall solve its problems in connection with planning and administration and become a real industry abreast of technical development in other fields, communication on the basis of the EDP techniques seems indispensable. This is particularly the case when preparing operational and cost control for larger typified repeat projects where the total number of identifiable operations on each block of flats may easily amount to 30–50,000 items. Only EDP-administration would seem to be able to utilize the repeat factor in contract documentation and costing procedures for such projects.

This paper deals with a coding system known as Co-ordinated Building Communication (CBC) which has been developed in Denmark in 1963 on *the Sydjyllandsplanen* (a housing scheme comprising 1800 dwellings in 3-storey blocks of flats spread over 6 towns in the South of Jutland), and which since then has been applied on other projects in and outside Denmark.

Theory of central specification

Any list of descriptions, bills of quantities or similar documents are first and foremost *a specification* or list of works and materials. It is on this document that the contractors carry out all calculating, pricing, purchasing, and planning of work. It is obviously of primary importance at all stages that this information can be easily read and understood.

Coding has an important part to play particularly in providing *cross-reference* between the specification, the bills of quantities and working drawings. Examples from other industries, e.g. the automobile industry, have shown that codes only should be used on the drawings whereas the code and the full text should be given in the specification or bills of quantities. It will be obvious that if the code itself is constructed logically and has a meaning, it can be used as a means of separating information into clearly defined groups irrespective of the type of document concerned. In practice this is of particular importance as a logical coding structure can form the basis of a coherent system for the preparation of drawings. A Central Specification consisting of EDP-coded items could in this way be used mutually by the architect in the annotation of drawings and by the quantity surveyor in the printout of fully texted items which literally comprise the "building-stones" in the bill of quantities or the calculation by the contractor.

The Central Specification is not basically differing from a normal manufacturer's catalogue in which all products have been numbered with reference numbers for the use in ordering either in specifications or in the annotation of drawings. The Central Specification should, however, contain a list of *all* labours and materials which may possibly enter into a specific job or development plan. The Central Specification may in its widest sense comprise a national or even an international building industry (e.g. European market co-operation), if it is suitably combined with a limitation in the differentiation of products or if it is equally combined with national or international standardization.

Codes and additional codes

A full notation according to the SfB-system, which has been the basis of CBC would be as follows:

(21) Fg2

Where (21) means *external walls* and Fg2 means *bricks or blocks of heavy burnt clay*. The combination of (21) and Fg2, thus

$$\begin{tikzcd} \text{(21)} & \text{Fg2} \arrow[l, "\text{\textit{Operation}}"'] \end{tikzcd}$$

Element *Product*

symbolises the placing of bricks or blocks in external walls, in other words: *a building operation*.

By means of the SfB-system it is possible to code all relevant building operations in a logical and scientific way. Furthermore, it is possible within the system to code any conceivable item down to the smallest secondary labour. It can be used for preparing drawings, specifications, bills of quantities, cost analyses, cost plans. It can form the basis for operational analyses and will give identification of any individual operation or activity irrespective of whether this is described graphically or in writing. Because of the facet nature of the SfB-system it is possible to arrange the individually coded items in different groups or sequences to suit the many differing requirements. In practice it is necessary to supplement the full SfB-code with additional codes (examples: 1. Job number, 2. Block number, and 3. Trade).

Use of coding system for EDP

Experience has shown that the SfB-system with necessary amendments can be used for coding input material for electronic data processing. In this way it is possible to use the Central Specification as a basis from which bills of quantities can be prepared for individual projects. Furthermore it is possible within the same system of working to prepare priced copies of bills, cost analyses, cost plans, lists of drawings etc. and to present this information in a number of alternative sortations for any particular purpose.

In the technique described here the full SfB-code is always used: (21) Fg2.1234. The four-digit number appearing after the full stop takes the form of a sequential number, and it has significance only in item identification. Experience has shown that in practice it is necessary to apply a system of coding capable not only of coding any specific building operation but also *any arbitrary combination of operations*. This has been made possible through a technique known as "over-coding", and at its highest level it is possible to print out bills of quantities for complete projects by means of only a small number of instructions (over-codes).

This principle of over-coding makes it possible to carry out detailed analyses on the basis of any predetermined vertical or horizontal division of the building into sections, storeys or blocks, and it will be apparent that this forms the basis for integrating items in bills of quantities with CPM-activities which may be overcoded and automatically priced according to the system. The principle of overcoding is of particular importance in quantity surveying where there is a high degree of repetition.

Experience from actual projects

All programs for projects so far prepared have been written for use with IBM computers 1401, 7070 and 7074 on the I/S Datacentralen, Copenhagen.

In the preparation of the Central Specification the following procedure has been adopted:

1) Programming and planning of the EDP procedure.
2) Formulation and coding of the individual descriptive items.
3) Writing out of the descriptive items for punching.
4) Punching and control punching of the descriptive items.
5) Transfer of the descriptive items from punched cards to magnetic tape.
6) Sorting and subsequent printing out of the items in form of a catalogue or library of descriptions.

Bills of quantities have been prepared according to the following general principles:

1) The full SfB-code, which refers to a specific item, is written down together with the relevant job-, block- and trade-code and to this information is added the relevant dimensions of the item.

All this information is entered into a taking-off sheet specially designed for this method of working.

2) The taking-off or factor sheets are checked and proof-read.
3) The information is punched and control punched.
4) Data is then transferred to magnetic tape.
5) The information is sorted, the calculations carried out, and the relevant items are selected from the Central Specification tape.
6) A control print-out of the final bill of quantities is taken for checking and subsequently the final bill of quantities is printed out.

On most projects all drawings have been coded as documents and separate lists of drawings have been printed out. Lists of drawings are normally printed out either in the order of sequential numbers or in a sortation according to building elements with trade-reference.

Future development

Architects, other consultants and technicians must be prepared for the transition to EDP in the fields of production planning, and building, and building administration, which will involve demands for the observation of new rules in the layout of drawings and specifications. This will mean a higher discipline, but at the same time easier working will result from the advantages offered by the EDP-technique. Transition to EDP-administration in the methods described means full co-ordination between planning and production in a way that makes economic management, calculation and costing possible at a higher level than has ever been practicable.

The step forward, from the existing product-catalogue-confusion with a casual and un-co-ordinated coding of products, to national or international fully coded building *catalogues* with texts that have been entered on national or international magnetic tapes and which may be directly employed in contract documentation by the user is not a big one.

The text employed in the product catalogue for description of the individual product may, via the magnetic tape, be directly employed in the architect's work.

Behind the concept of the Central Specification there lies, in the widest sense, the idea of direct co-operation between manufacturers and the other parties to building with the possibility of creating an administrative tool for the whole of the building industry.

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Communication of cost information

By D. Bishop (U.K.)

The building industry in the United Kingdom is served by a system of communications which evolved at a time when the work in the industry was based on craft processes. In these the tasks of handling, fabrication and assembly are often combined in a single operation undertaken by gangs working independently of other operatives, and assisted only to a small extent by mechanical plant. But many new constructional methods entail considerable mechanisation and the integration of the building process from design to completion. In these circumstances there is need to examine some aspects of the system of communications employed and its compatibility with the ends served.

In the United Kingdom building work may be commissioned in several different ways. Some contractors offer a 'packaged deal', by which the contractor undertakes to design and to construct a building to satisfy the requirements of a building owner. In the majority of cases, however, a building owner (the employer) engages, on a fee basis, a professional designer (usually an architect) who, with the assistance of specialists (structural engineers, heating and ventilating engineers, for example) designs the building and supervises its construction by an independent contractor. Selection of the contractor may be by open competitive tender or as a result of negotiation between a specific contractor and the employer's professional advisors: these procedures are, of course, encountered in several modified forms. The contractor, however selected, usually undertakes the work for a lump sum contract. The conventional view of the relationship between an employer and a contractor is that the contractor undertakes, for a consideration, to provide a complete building in accordance with the drawings and specifications issued by the employer's professional advisors, and that the methods of construction and the solution of any physical problems encountered are the sole responsibility of the contractor. In this way contractual obligations are clearly established.

Except in the case of minor projects, the employer usually appoints a quantity surveyor, again on a fee basis, who advises the architect on the probable cost of the design during its development, thus ensuring, as far as is possible, that the employer's budget is not exceeded by the final cost of the contract. Also, when the design is sufficiently advanced, the quantity surveyor prepares bills of quantities in which the building is described in terms of the materials of construction, as embodied in the building, thus reflecting the obligation of the contractor to provide a complete building.

Bills of quantities normally devote a separate bill to each trade, excavator, bricklayer, carpenter, for example, and there is always one bill dealing with general matters, called preliminary items—insurances, site clearance and other site works, observance of by-laws and safety regulations. Within each trade bill the work to be done is described by the materials involved, as x cubic ft. concrete in columns, or y cubic ft. timber in floor joists, for example. In preliminary bills and in site works bills, however, an attempt is made to describe the physical circumstances surrounding the contract so that the attention of a contractor is drawn to the hazards that are likely to be met on site.

If the contractor is to be appointed by negotiation the bills of quantities, when priced by the contractor, form a basis of negotiation because the employer's quantity surveyor can compare the rates entered by the contractor with rates for similar work. If, and this is the more usual case, the contractor is appointed on the result of a competitive tender (or bid) each contractor competing for the contract is provided with a set of unpriced bills of quantities which, when supported by drawings and specifications, ensure that every competing contractor has a common basis for tendering. Each contractor then prices the bills of quantities by entering rates or prices against each item; the totalled value of the bills is then adjusted to take account of the contractor's overheads and the state of the market when the bid is made. Although the tenders are essentially lump sum tenders, the successful contractor is required to submit, before appointment, a priced bill which is checked by the quantity surveyor for internal consistence of the rates. During the currency of the contract this priced bill provides an acceptable method of adjusting the amount of money due to a contractor on account of authorised variations between the building constructed and that tendered for.

It will be noticed that bills of quantities act as the channel for cost information in an industry in which the design and production functions are separated. Quantity surveyors who, during the design stage, have to predict the probable cost of the design when submitted for tender, use priced bills of quantities or analyses of priced bills of quantities as their source of information. Contractors who must estimate, at speed and under pressure of events, both the likely cost of construction and the state of the market when the bid is made, also have their information structured by the character of the information contained in priced bills. On the one hand contractors' estimators must gather information in a way to enable them to set rates against the items in bills of quantities, on the other the money entered in a bill for an item, or group of items, is often used to set target outputs on site. Hence the bonus earned on site, which relates the output actually achieved to the target set, can provide a feedback of information to estimators. Similarly the level of prices received in the course of a series of tenders indicate to quantity surveyors the consequences of a design in terms of cost. This feedback of cost information is clearly an important function in an industry where design and production are divorced and the character of the cost information received as a feedback from production to planning, from planning to estimating, from estimating to design is likely to become increasingly important as building processes become more sophisticated and details of design affect more directly production methods.

The quality of the feedback provided by priced bills of quantities will be discussed in the remainder of the paper and an alternative to conventional bills of quantities will be introduced. This in no way questions the utility of bills of quantities to an industry in which individual contracts are obtained by open competitive tenders: this would fly in the face of experience because bills of quantities are used to obtain tenders for roughly £800m of new building construction each year; and, possibly because of the use of bills of quantities, there is relatively little litigation in the building industry. No attempt is made to examine the whole communication system in the building industry, for such a task could not be accomplished in the space available.

Bills of quantities and feedback

Two conditions have to be satisfied if bills of quantities are to provide effective feedback of cost information between construction, estimating and design. First is that the information presented in unpriced bills of quantities should identify the implications of a design from the standpoint of construction. If this is so buildings that are difficult to construct will attract the high prices they warrant and designers will be alerted to the cost of persisting with that type of design. If bills do not reflect the difficulties inherent in constructing a building, contractors may not be able to differentiate between buildings that are cheap to construct and those that are not, and there will be little encouragement for designers to develop building types that are easy to build. The second condition, a corollary of the first, is that it should be feasible, that is both practicable and not too costly, to allocate site costs to individual items in bills of quantities. If this is so the experience obtained on successive jobs can be generalised and used to predict future performance; that is estimates can be based on historical evidence, records of past performance on similar jobs. If this is not possible the rates entered in tenders will have to be based on bidding procedures which may or may not reliably estimate the cost of any given building, and will probably estimate the cost of an 'average' building, weighted by the state of the market at the time the bid is made. That is, the bids received will not respond sensitively to changes in design, particularly changes in design which affect progress on site.

In order to determine whether unpriced bills of quantities necessarily display the implications of a design from the standpoint of construction some of the factors which influence performance and cost on site must be considered. Fortunately some factors can be ignored; for example, factors common to all jobs, the level of wages paid, the ability of site supervisors, the relationship between management and operatives. Other factors, which may enhance or reduce productivity, and thereby affect costs, are, however, related to the design of the building; these are:

(i) Sequencing and interdependence of operations. In craft processes a man or a gang of men tend to work on stages of construction, independently of other operatives. This independence is ensured in the majority of trade gangs by the inclusion of non-tradesmen who prepare materials and handle materials from store to the workplace. However, each stage of construction is bounded by other stages, the responsibility of other trades or gangs: for example in conventional house construction carpenters first visit a house to set the ground floor joists, return to set the first floor joists, return to set the ceiling joists above the first floor and to pitch the main roof timbers, and return to complete the roof, each task being interrupted whilst bricklayers continue their work. Therefore, although trade gangs apparently work independently at their own best rate, their actual rate of work is determined in part by the availability of workplaces which are made ready by other gangs. That is the sequence and pattern of operations, determined by the arrangement, the size and the design of the building, has an important effect on the organisation of work, on the number of gangs employed and, hence, productivity.

(ii) Constructional methods. The productivity achieved in tasks that do not involve craft work is determined mainly by the method actually employed, for example the type of shuttering for in-situ concrete work, or the method of jointing and assembly in precast concrete construction. Here, clearly, much depends on the compatibility of the design, the method selected and the resulting tolerances on size, form and surface finish. Also, as the degree of mechanisation increases, the work on site tends to become more closely integrated so that the tempo of work is determined by one or two key operations which dictate the progress made and the productivity achieved on site as a whole. In multi-storey concrete construction, for example, the time required to shutter the stairwell and lift-well may determine the tempo of work for the remainder of construction, and also the productivity since the size of gangs on other tasks may be fixed by practical considerations as well as by the amount of work that is available for them to do.

(iii) Improvement through repetition. Finally the organisation of work and the level of productivity achieved is improved when an agent, the foreman and operatives have continuous experience in a limited range of work. The repeated encounter with the same problems enables the operatives to master the difficulties met and gives an opportunity for the organisation of work to be successively referred. Because of this contractors have a strong incentive to man sites with a large number of small gangs, each responsible for a specialised task; but this can be done only when the work in a building repeats and the building is of sufficient size. Long-term improvement can be substantial: for example, one contractor engaged over a period of years on a series of large housing contracts on a new town development was able to retain the service of agents and operatives and to gradually reduce labour requirements from more than 2000 to less than 1200 manhours per dwelling, although there was little change in the design of the buildings or in the constructional methods employed.

Thus it will be seen that progress on site is made by men or gangs of men tackling stages of construction in sequence, the extent of each stage and its relation to other stages being determined by the physical requirements of the building. The principal factors affecting productivity include the design in its technical aspects, repetition within and between stages of work and the interdependence of the many operations of construction. But these are issues difficult to display in conventional bills of quantities in which, it will be remembered, buildings are generally described in terms of the materials of construction in situ and the units of measurements are not those which describe site activities, which are necessarily measured in units of time; man-days, machine-days or days hire of capital invested in plant. Hence conventional bills of quantities do not clearly display the interaction of design with production.

The previous discussion has shown that the analysis of a building into the materials of construction, in-situ, does not display the effect of the design on costs. Similarly this analysis made makes it difficult to relate the way money is spent on site to the items listed in the bills of quantities, except arbitrarily. On site money is expended in time, as man days of work, as machine-days of plant costs, whilst the items in the bills of quantities are in number, units of measurement or weight. Also there is no necessary correspondence between the extent of the items listed in bills of quantities and the boundaries of the work of various gangs. Even when the allocation can be made, the cost of gathering the data is prohibitively high. This is because the wide range of variability in operation times – a 3 : 1 range for the same operation is frequently encountered – necessitates many observations before an average operation time can be estimated with sufficient accuracy. Also the cost of determining average operation times, and the factors affecting them, is increased when a task is analysed into small elements, as is the case with conventional bills of quantities. Hence, on the grounds of incompatability of the method of analysis and the events observed on the one hand, and the expense of collecting the data on the other, it is not feasible to attribute a process cost to many of the items in bills of quantities. That is, it is not feasible to directly relate the rates entered by an estimator to the costs incurred on site.

In practice, of course, the level of pricing responds to some extent to the relative complexity of a design. Experienced estimators recognise designs that are difficult to build and may learn to associate high site costs with certain designers. In particular, expensive materials attract high prices because the cost of these may be estimated fairly precisely. But the fact that feedback of cost information is, at the best, expensive and, at the worst, impossible must make estimating insensitive to changes in design. Bills of quantities stated in operational terms are more directly related to site processes and may provide the possibility of feedback of information from site to designer. Two of my colleagues, Mr. W. S. Forbes and Mr. E. S. Skoyles are investigating this possibility, by a study of bills of quantities in which the building is described in operational terms.

Operational bills

In an operational bill the work to be done is described as a series of operations, each operation representing work by a man or by a gang uninterrupted by the work of other men or gangs. The operations are also selected to satisfy the physical constraints defined by the building; for example foundations must be excavated before concreting takes place and floor joists set before flooring is fixed. Analysis of a building commences with a schedule of operations which satisfy both requirements given above. This, it is emphasised, does not assume the resources that will be available when the work on site commences, for these can be decided only by the successful contractor. In brick construction, for example, one bricklayers' operation would be "construct brickwork from foundations to ground floor level", at which stage concrete is placed to form the ground floor; another bricklayers' operation would be "construct brickwork from ground floor to first floor level" at which stage work is interrupted whilst carpenters place the first floor joists. The operations and the relationship between them are shown conveniently on a precedence diagram (figure 1) and the operations described in the bills (figure 2) are those set out on the precedence diagram and follow the order of it.

For each operation description, the work to be done and the materials to be incorporated are described separately. The work to be done is shown on operational drawings, each drawing identifying the scope, content and boundaries of an operation

D. Bishop

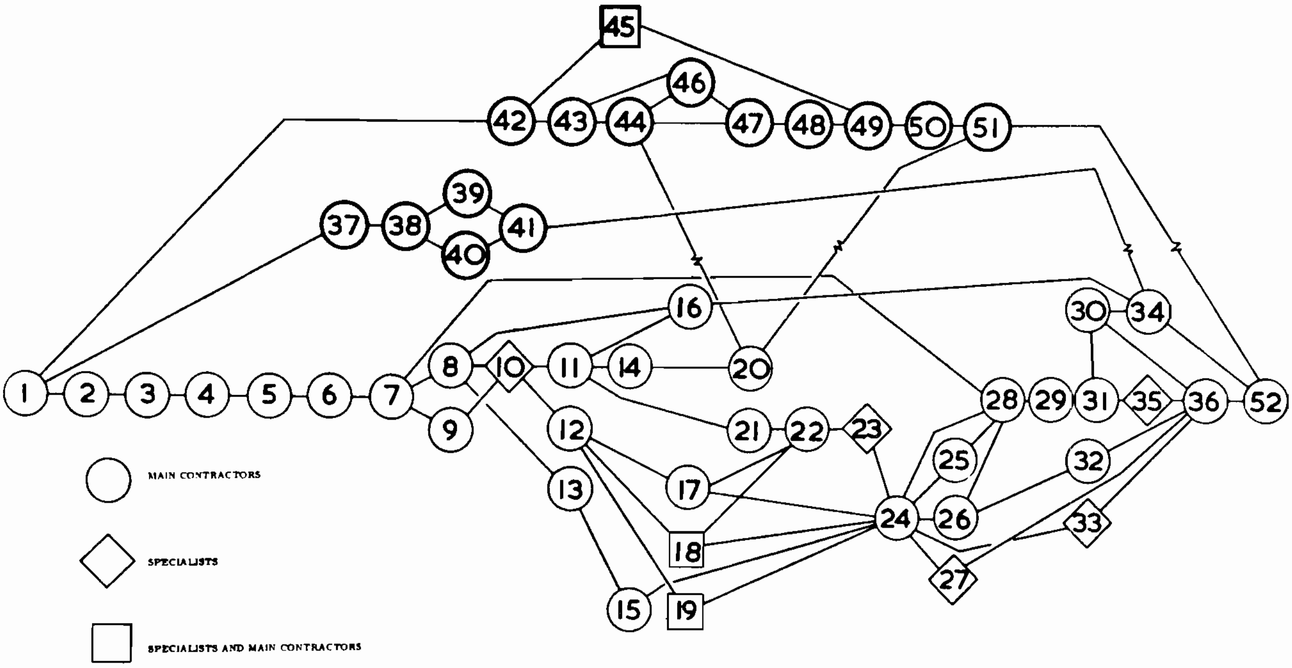


Fig. 1. Precedence diagram for the construction of 18 old people's homes.

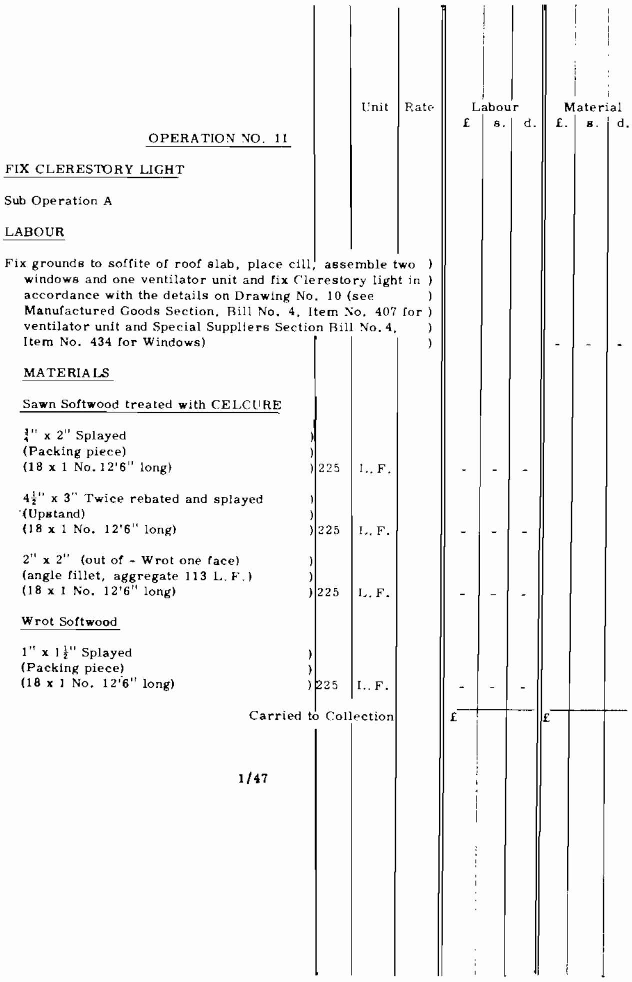
(figure 3). Materials are listed and the amounts are stated in trade terms, where these differ from those of conventional measurement: (this simplifies the work of estimators and buyers in the offices of contractors and materials suppliers). It is expected that estimates for labour will be based on so many man or gang hours or days for each operation, rather than on the "constants" associated with conventional estimating. Temporary construction work and the principal items of plant required are grouped together in a separate bill to give the estimator the opportunity to price the provision of plant on the basis of an outline constructional programme.

Operational bills have been used successfully to obtain tenders for a few buildings of comparatively simple design. In these, the activities of different gangs are clearly defined and are recognised throughout the industry, recognition stemming in part from the widespread practice of sub-letting work to sub-contractors. More complicated or unusual buildings present many problems, especially when an activity analysis shows that the design is so complicated that few activities provide uninterrupted work for permanent gangs.

The advent of critical path methods of analysis has given fresh impetus to the development of operational bills, because the "operations" in operational bills and the 'activities' of critical path analysis embrace common concepts. Limited experience has shown that the precedence diagram, giving the operations, can be quickly converted into a critical path analysis by the successful contractor. And that this, in turn can be updated during construction and used as a method of controlling the work of gangs to make the best use of the resources that are actually available. Hence it would seem that a system of communication based on a common concept of an activity (or operation) could be used in four of the important functions of the building process; tendering, production planning, control of operations on site and feedback of cost information.

The central problem

The argument presented has shown that bills of quantities in their present form could be modified to better act as a channel of communication of cost information in the building industry. Studies of operational bills in which buildings are analysed by operations, that is by the activities of critical path analysis, offers the prospect of describing buildings in terms of site processes so that the information in the bills is of use to architects, quantity surveyors, contractors, materials suppliers, sub-contractors and to site agents.



		Unit	Rate	Labour			Material		
				£	s.	d.	£.	s.	d.
OPERATION NO. 11									
FIX CLERESTORY LIGHT									
Sub Operation A									
LABOUR									
Fix grounds to soffite of roof slab, place cill, assemble two windows and one ventilator unit and fix Clerestory light in accordance with the details on Drawing No. 10 (see Manufactured Goods Section, Bill No. 4, Item No. 407 for ventilator unit and Special Suppliers Section Bill No. 4, Item No. 434 for Windows)							-	-	-
MATERIALS									
Sawn Softwood treated with CELCURE									
¾" x 2" Splayed (Packing piece) (18 x 1 No. 12'6" long)	225	L.F.		-	-	-			
4½" x 3" Twice rebated and splayed (Upstand) (18 x 1 No. 12'6" long)	225	L.F.		-	-	-			
2" x 2" (out of - Wrot one face) (angle fillet, aggregate 113 L.F.) (18 x 1 No. 12'6" long)	225	L.F.		-	-	-			
Wrot Softwood									
1" x 1½" Splayed (Packing piece) (18 x 1 No. 12'6" long)	225	L.F.		-	-	-			
Carried to Collection				£			£		
1/47									

Fig. 2. A page from an operational bill.

The prospect is heartening but the problem of the content of the information to be exchanged is unresolved, for it is yet to be shown that operational bills resolve the conflict of interest between:

(i) The need for precision. Estimators working at speed and under pressure must be able to identify the character, scope and location of an operation. It is also important that descriptions shall be sufficiently precise to admit only one interpretation—if not confusion and litigation must follow. The task of interpreting operational description is simplified by the materials listed with each operation and by operational drawings for these show, at a glance, the relation between an operation and other work at its boundaries. Unfortunately operational drawings, often involving perspective drawing of one form or another, are time consuming to prepare.

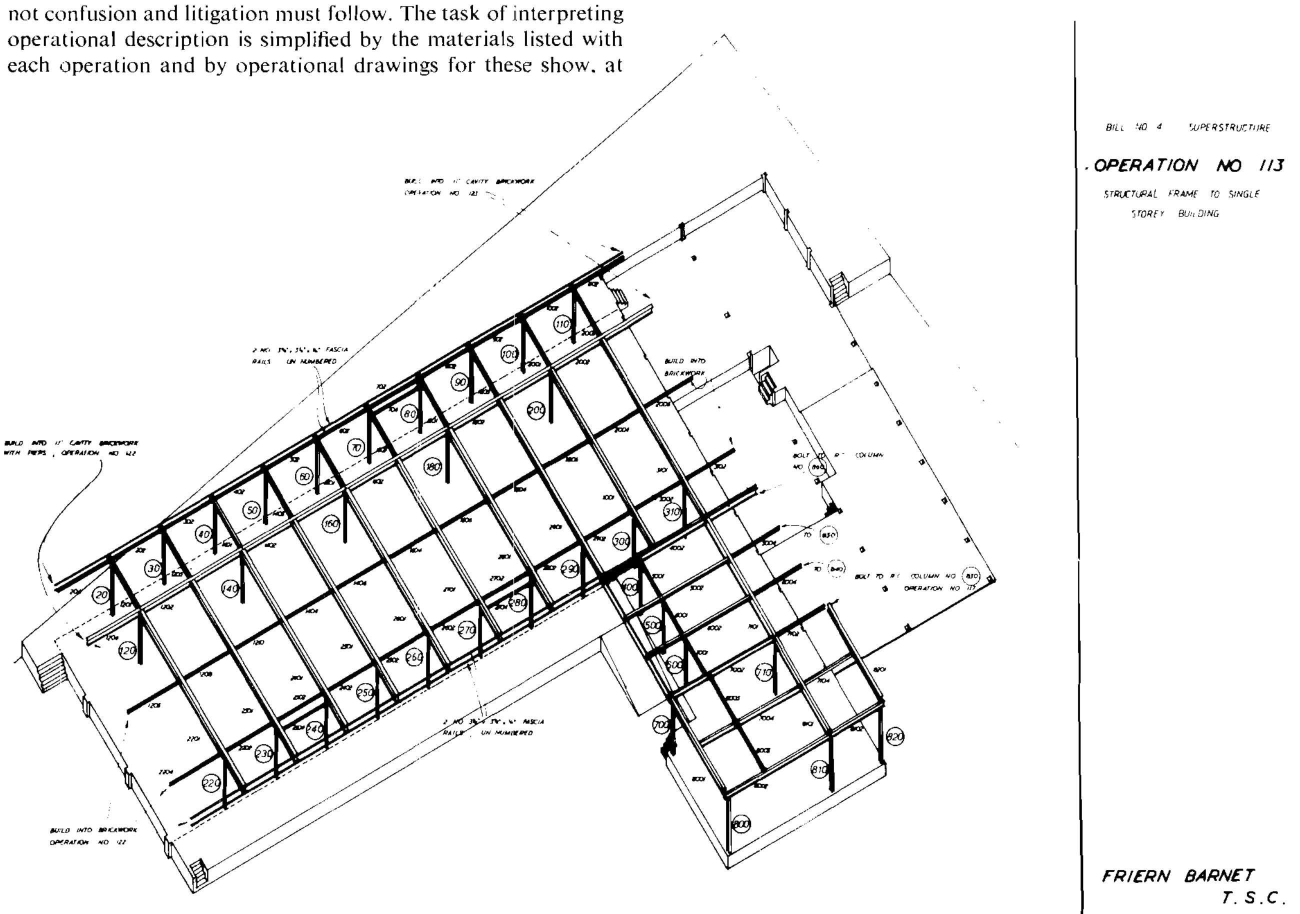


Fig. 3. Operational drawing for the structural frame of part of a school building.

(ii) Feedback. It will be recalled that the starting point of this paper was the need to provide feedback of cost information, in order to relate design to production. In the current study of operational bills the question of feedback has yet to be faced. The essential requirement is the avoidance of unique descriptions for operations differing only insignificantly in content for, if this occurs, it will be difficult, if not impossible, to transfer the experience obtained on one job to another. That is the advantage gained by the analysis of a building by operations will be offset by the absence of a simple measurement of work content and the ability to generalise particular experience.

Hence the central problem of communication of cost information would seem to be the resolution of the conflicting requirements for precision of description, on the one hand, and for generality, on the other. The study of operational bills is the first attempt to resolve this problem, the solution of which must provide an equitable basis for tendering and, by accepting the realities of site processes, offer the prospect of feedback of information from site to designer.

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Acknowledgments

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Time and cost control in modern programming techniques

By Mrs. G. Ciribini Guanerio and
V. Carnemolla (Italy)

It is known that, when carrying out works requiring considerable capital for a long time, it may happen that final results deviate from forecasts; therefore it is necessary that, after having arranged for a rational planning and organisation in view of securing the best utilisation of available resources, the process of time and cost expansion should be kept under control, so as to promote the corrective measures necessary to ensure that the foreseen economic objectives be maintained.

Consequently, besides the programming techniques and their multi-various applications, some special procedures have been employed in estimating actual costs of works, with the aim of effecting a systematic control during progress. These procedures are based on continuous data reading and their efficiency and usefulness are still greater, from the viewpoint of promptness and reliability of information, when, particularly in complex works, electronic computers are used. The present paper illustrates briefly a possible extension of some concepts of permanent cost control to programming techniques.

Timing

Timing has two separate fundamental phases: a first phase of study, prearrangement and optimisation of the plan, and a second phase, during execution, when a control of forecasts is made through a systematic analysis of indexes showing the trend of operations.

The study of the plan is made by the method of critical procedure or PERT. This method, in comparison with the traditional programming techniques, offers the advantage of a clearer identification of the order of time sequence of the activities forming the work and of the precedence bonds to be observed. It also enables arriving at the determination for each activity, of the permissible delays, in the sense that such delays are compatible with the observance of times prefixed in the programme.

This procedure involves an analysis of the activities of which the cycle is composed and reproduces their sequence making use of graphical representation called network or graph.

Supposing to assign to each operation a corresponding duration ("operation time"), possible time shifts of activities may be determined with the help of some algorithms suggested by the graph theory. As we have already said, these calculations are performed, in the more complex cases, in a shorter time and with more reliability, using an electronic computer.

The operations of major interest are those for which the admissible delay is nil, or lower than a prefixed value. These operations take the name of "critical" or "subcritical", respectively, because the regular course conditions the duration of the whole programme, obtained by adding together, in their sequence order, the durations of critical activities. While the plan is being carried out, these activities should take place at the appointed dates; therefore they deserve the utmost attention, to avoid delays that will bear on the completion date. These are the concepts on which the programming technique under the name of PERT-BASE is based.

Timing with costs

Neglecting the techniques derived from PERT-BASE, where durations are established with concepts other than estimations, and originate from statistics and the theory of probability, it is interesting to underline that, surpassing the purely time aspect, programming techniques have enlarged their field of research and application, to include the costs of activities which form the work and to consider them as variables dependent on execution times.

Times and costs are thus linked together and both become an object of planning, encompassing the whole production cycle in a single vision. The link between costs and times is not always known, nor is it always easy to represent their relationship in analytic form. Generally speaking, costs have a tendency to decrease as time increases. If the function representing this link is known, the total cost of a programme can be lowered without altering the total time, by simply extending the duration of non-critical activities up to the values which correspond to the minimum cost.

Viceversa, when the greater cost corresponding to a certain time decrease is known, it is possible, reducing the times of critical activities determined through PERT-BASE, and of the new activities which are being formed as a consequence of reductions applied, and proceeding by incremental costs, to attain a reduction of the whole programme with minimum cost increase.

Thus setting on both times and costs, if the number of activities of the plan is relatively limited, and if the link between costs and times is a fairly simple analytic function, e.g. linear or parabolic, it is possible to find, by successive approximations, a group of solutions for the programme comprised between that involving the minimum total cost, and that involving the minimum time of execution. Finally, introducing an evaluation of other costs, such as passive interest, loss of income, etc. which, contrary to the preceding ones, are an increasing function of the total time, the optimum programme will be singled out as corresponding to the time for which the total cost function obtained by adding the two preceding ones is a minimum.

Implementation and control

Once the plan is defined and a forecast of execution times and of partial and total costs of the work is made, the work is started. During this phase, which develops gradually, since individual parts of the work are finished at different dates, the estimated data are progressively substituted by real data and the necessity occurs of evaluating the consequences of such variations in respect of forecasts. For a timely knowledge of such deviations, controls of costs and times are periodically made. This control will show the advisability of a revision of the original plan. We shall therefore take into consideration any production cycle, and attempt to ascertain the degrees of development, fixing a certain number of reference levels.

The fundamental levels for operative activities in the field of building construction might be the following:

- preliminary project;
- final project;
- allocations and supply contracts;
- alterations during execution;
- execution;
- taking over.

For a better clarification of the meaning and importance of these various levels, it should be kept in mind that:

– the preliminary project enables corresponding synthetic and summary evaluations to be made;

– the final project, insofar as it involves an analysis of physical quantities and their evaluation by means of estimated prices, as well as a definition of building methods, enables corresponding analytical evaluations of time and expenditure to be made;

– the stipulation of contracts and allocation of tenders, involving the definition of contract prices and delivery dates, enables corresponding analytical evaluations, from which it is possible to deduce the amounts actually engaged and actual supply times to be made;

– the alterations during execution, adopted for technical reasons, bringing up to date the amounts of work foreseen, enable evaluations already made to be reviewed;

– the execution enables evaluations resulting from bookkeeping entries of the work performed, and of the times actually employed, to be made;

– the taking-over tests enable final evaluations of time and cost to be made.

As the construction is nearing completion, it will be necessary, for the activities which have reached a certain level, to bring data up to date and to register any variation found. After this, the ensuing variations in the programme and in the budgetary estimate may be ascertained from time to time through a re-making of calculations, to be entrusted, as for the preceding ones, to an electronic computer. The time required by the programme and the total cost will result from the sum of partial data, and their

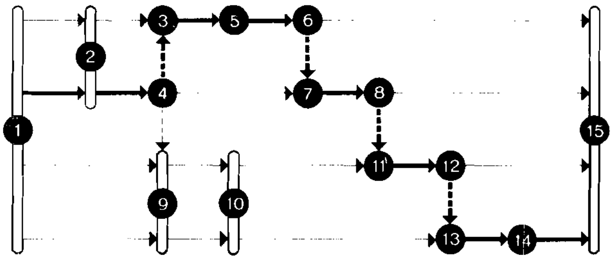


Fig. 1. Shows the network of activities with its critical line. Activities, durations and nearest and permissible latest dates are reported in the following table. [see below]

reliability, which is a function of the carrying out of individual operations, will depend on the distribution of data obtained at the various levels.

The information obtained will show the up-to-date cost and time required for the work at the appointed date, and furthermore, for each level, the percent amount of total time and cost of all activities which have attained the level under consideration.

For instance, if at the date x the revision supplies for the duration of the plan the value D_x and for the cost the value C_x, and if d_{ix} indicates the total times of critical activities at a level i, the quotient d_{ix}/D_x will show the time percentage at the level i.

Similarly, if c_{ix} stands for the cost of activities at the level i, the quotient c_{ix}/C_x will show the cost percentage at the level i.

Consequently, the reliability of the quantities D_x and C_x will be greater, the higher are the percentages referred to the higher indexes.

Of course, as far as times are concerned, the evaluation applies only to critical activities, insofar as any variations in non-critical activities will not affect the duration of the plan.

Figure 1 shows a summary example of timing and cost control, limited to activities concerning the construction of an underground.

Time programme of activities according to the latest dates allowed and modifications found by controls carried out:

- Duration of the programme:
  45 months; for activities 5–14: 35 months,
- Duration at the 2nd control:
  50 months; for activities 5–14: 40 months,
- Duration at the 4th control:
  45 months; for activities 5–14: 35 months,
- Final result :
  45 months; for activities 5–14: 35 months.

The delay 8 – (8) which increases the duration from 45 to 50 months is offset through a reduction of the delivery time 11–12 and 13–14 by quantities (12) – 12 and (14) – 14.

The following table shows absolute and percent time and cost data resulting from the forecast (Tab. 2), from controls (Tab. 3–4–5–6) and from final results (Tab. 7), referred to the various levels in accordance with work performed at the control date.

The levels considered, 5 instead of 6, in view of the simplicity of the scheme used, correspond to the 1st, 2nd, 3rd, 5th, 6th levels already described.

As the construction comes near to completion, the percentages of the higher levels increase steadily and in step with succession of control dates. In particular, 100% is at level 1 in table 2 and at level 5 in table 7.

While the programme is in course of execution in the 12th month, in consequence of contract stipulation for structural works, i.e. at level 3, an increase in construction cost was noted. Since the completion date of the final projects of installations and finishings (21st and 30th months respectively) has not yet elapsed, the greater outlay can be covered partly by altering the project and partly providing for an extra financial allocation. The necessity of such an allocation was brought to the attention 33 months before the completion date of the work.

It was found that a longer time was taken during the execution of structures, i.e. at level 4, 8–(8). This being a critical activity, the delay would bear upon the final completion date, if the programme was not kept under control.

Since, at the date when the delay is discovered, contracts for installations and finishings are in course of being stipulated, the delay can be entirely offset by reducing the delivery times for such contracts, so that the final completion date will remain unchanged.

Type of activity	Events	Nearest dates		Latest dates		Durations	Shifts
		Start	End	Start	End		
Preliminary project, facilities and consolidation	1–2	0	1	0	1	1	0
Final project, facilities and consolidation	2–3	1	3	5	7	2	4
Contracts, facilities and consolidation	3–5	7	8	7	8	1	0
Execution, facilities and consolidation	5–6	8	12	8	12	4	0
Acceptance tests, facilities and consolidation	6–15	12	13	44	45	1	32
Preliminary project, rough-finished structures	1–2	0	1	0	1	1	0
Final project rough-finished structures	2–4	1	7	1	7	6	0
Contracts rough-finished structures	4–7	7	8	11	12	1	4
Execution rough-finished structures	7–8	12	23	12	23	11	0
Acceptance tests rough-finished structures	8–15	23	26	42	43	1	17
Preliminary project installations	1–9	0	1	17	18	1	17
Final project installations	9–10	7	10	18	21	3	11
Contracts installations	10–11	10	12	21	23	2	11
Layout installations	11–12	23	35	23	35	12	0
Acceptance tests installations	12–15	35	37	43	45	2	8
Preliminary project finishing	1–9	0	1	17	18	1	17
Final project finishing	9–10	7	10	30	33	3	23
Contracts finishing	10–13	10	12	33	35	2	23
Execution finishing	13–14	35	43	35	43	8	0
Acceptance tests finishing	14–15	43	45	43	45	2	0

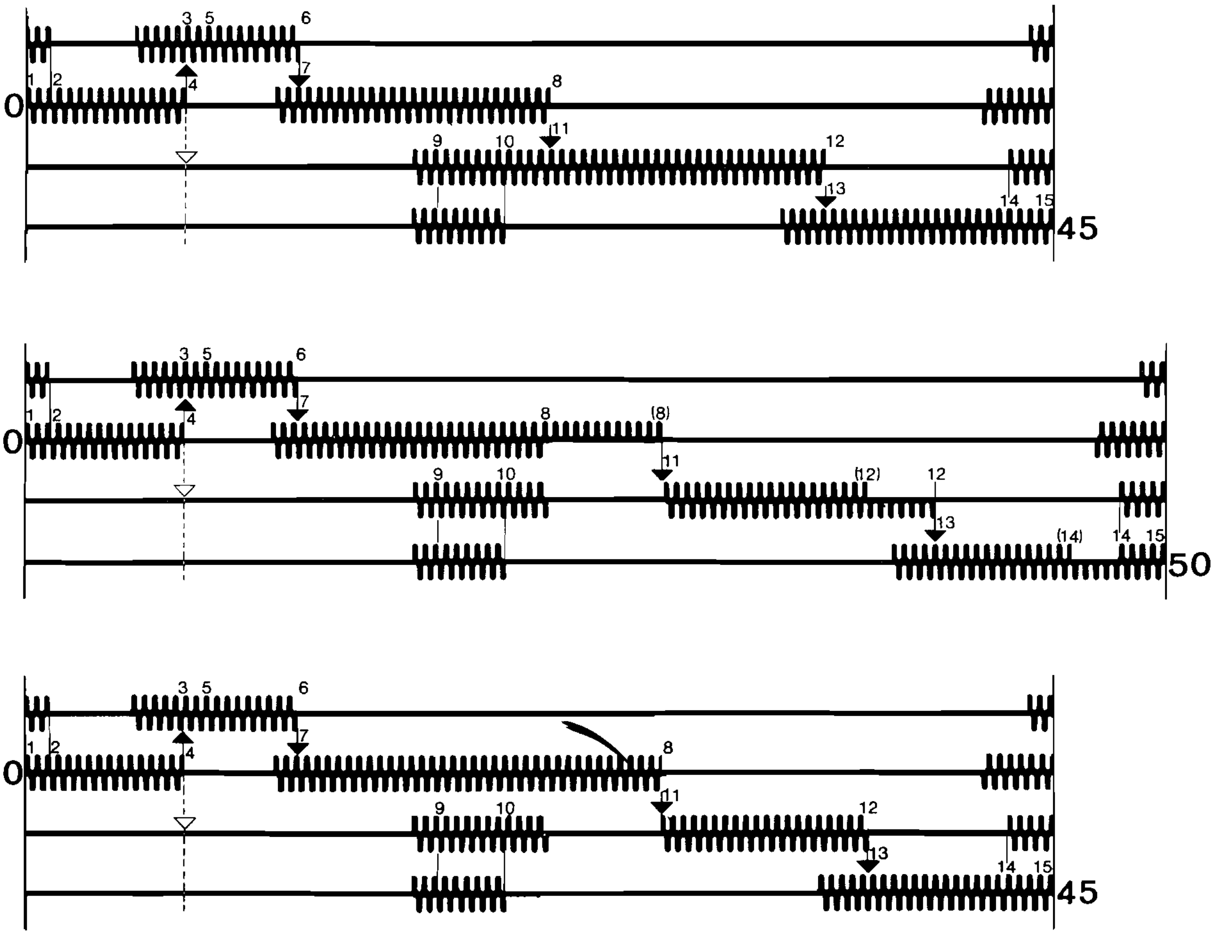


Fig. 2. Shows the time programme of activities in relation to the latest dates in Gantt's graphical representation, as well as alterations revealed by controls carried out.

TABLE 2. Forecast

Activity	Costs	Levels % 1	2	3	4	5	Durations (months)	Levels % 1	2	3	4	5
Facilities	260	12					4	11.4				
Rough-finished structures	1.080	50					11	31.5				
Installations	660	30					12	34.3				
Finishing	170	8					8	22.8				
Total	2.170	100					35	100				

TABLE 3. 1st Control

Activity	Costs	Levels % 1	2	3	4	5	Durations (months)	Levels % 1	2	3	4	5
Facilities	260				10.6		4				11.4	
Rough-finished structures	1.350			55.4			11			31.5		
Installations	660	27					12	34.3				
Finishing	170	7					8	22.8				
Total	2.440	34		55.4	10.6		35	57.1		31.5	11.4	

TABLE 4. 2nd Control

Activity	Costs	Levels % 1	2	3	4	5	Durations (months)	Levels % 1	2	3	4	5
Facilities	260				11.4		4				10	
Rough-finished structures	1.080				47.2		11				27.5	
	270			11.8			5			12.5		
Installations	560		24.4				12		30			
Finishing	120		5.2				8		20			
Total	2.290		29.6	11.8	58.6		40		50	12.5	37.5	

TABLE 5. 3rd Control

Activity	Costs	Levels % 1	2	3	4	5	Durations (months)	Levels % 1	2	3	4	5
Facilities	260					11.4	4					10
Rough-finished structures	1.350				59		16				40	
Installations	560			24.4			12			30		
Finishing	120		5.2				8		20			
Total	2.290		5.2	24.4	59	11.4	40		20	30	40	10

TABLE 6. 4th Control

Activity	Costs	Levels % 1	2	3	4	5	Durations (months)	Levels % 1	2	3	4	5
Facilities	260					11.4	4					11.4
Rough-finished structures	1.350				59		16				45.7	
Installations	560				24.4		9				25.7	
Finishing	120			5.2			6			17.2		
Total	2.290			5.2	83.4	11.4	35			17.2	71.4	11.4

TABLE 7. Final Result

Activity	Costs	Levels % 1	2	3	4	5	Durations (months)	Levels % 1	2	3	4	5
Facilities	260					11.4	4					11.4
Rough-finished structures	1.350					59	16					45.7
Installations	560					24.4	9					25.7
Finishing	120					5.2	6					17.2
Total	2.290					100	35					100

Conclusions. In this manner the dynamics of the time and cost expansion process will be accurately known beforehand and it will be possible, thanks to a complete vision of the situation, to take, if necessary, timely and rational measures. The measures may work first inside and then outside the plan. In the first instance they will have the scope of maintaining the plan's objectives. Therefore, as regards times, they will consist in an acceleration of lagging critical activities, while, as regards costs, they will consist in a reduction in expenditure for those activities where this is still feasible.

The measures of the second type will consist in limiting all the consequences due to the higher costs and times which are about to come forward.

In particular, in regard to the financial aspect, it will be possible to obtain a better utilisation of the financial resources and pre-arrange a plan of future needs with a higher time margin.

Finally, a better definition of any responsibility will be obtained as a result of delay localisation and identification of causes producing them, and useful experience will be gained for later works.

Consultation with contractors on complete documents, and on documents defining the technical trends

By J. Coiffard (France)

Concerning the composition of tender documents, several contradictory opinions can be observed: some prefer a complete document, others prefer a restricted document. It is interesting to find out if there is some relationship between the way of consulting a contractor and the nature of the construction to be executed.

In this paper only two solutions will be considered: the complete working document and the document indicating the technical outline. Intermediate forms will be discussed at the end of this report. Official competitive submissions or limited calling for tenders are not considered.

The ideas put forward are based on the experiences made by the engineering office of which I am the Director. Before approaching the subject, and in order to define the actual background of building activity in France, it seems worthwhile to give a brief account of its historical evolution.

Historical Summary

Before the last war, the following possibilities of calling for tenders were used in France:

– for Public Works: considerably complete documents were issued, the contract providing a payment according to a schedule of prices made up on the basis of surveying results obtained on the job-site after completion of the work.

– for housing: apart from some special cases applying the same method as above, a reduced form of technical documents was generally used for the calling for tenders.

In this last instance, the amount of the contract was a lump sum, the contractors engaging themselves for the quantities as well as for the unit prices. This procedure would have supposed an entirely worked out project, both from the architectural standpoint, which was realized, and from the technical standpoint, which was never realized. The results very often were deceiving and economically disastrous; the designs were carried out one by one according to the requirements on the jobsite, delays occurred, the cost increased as a consequence of inaccuracy and of so called "additional" works.

The small amount of building in France before the war limited the dangerous influence which this anarchy could have had on the national economy.

After the war, from 1950 on, the Ministry of Housing (at that time called the Ministry of Reconstruction) encouraged an evolution of technics and building methods by the following means:

– considerable increase of the volume of programs (500 to 2,000 dwellings);

– introduction of technical offices which were to furnish their technical knowledge to the architects and to draw up highly elaborated documents;

– application of industrialised systems, namely the heavy prefabrication, being under the control of the "Centre Scientifique et Technique du Bâtiment" (Building Research Centre).

This tendency was submitted to several fluctuations, but gradually it made its way and turned out to be very beneficial for productivity: 2,500 to 3,000 hours/flats in 1950 against 700 to 800 in 1963 for industrialised constructions.

At the same time, the Ministry of Reconstruction, using the presence of consulting engineers in the teams occupied with the elaboration of the projects, required tender documents containing all technical dispositions of the project which had to be determined by very detailed drawings, estimates and bills of quantities. Thus, for a unit of 1000 flats some 1300 drawings were considered necessary to constitute a complete working document which was submitted to the contractors when calling for tenders.

As far as large housing operations were concerned, a tendency towards a reduction of tender documents could be observed in our group of consulting engineers during the 10 years which followed. This reduction especially concerned information regarding the manner of execution of works and special details of it. However, the documents defined the exact dispositions of the finished work and the technical line of performance, which both allow to assign a program to a certain "family" of techniques or systems.

Does this mean that the practice of delivering a complete tender document has been abandoned?

This is what we will see thinking over the different possibilities of application for each type of document.

The complete document of calling for tenders

The complete document defines with precision and in all details the work to be done.

Composition

On the one hand, it determines the general stipulations of the tender and of the resulting contract.

On the other hand, it includes the architect's drawings and as many technical sub-documents as there are different types of work, each of them defining by written and designed documents:

– the limits of the service which each contractor is expected to furnish;

– the precise definition of materials and tools to be used, their position and their quantities;

– the means of execution and the sequence of the different operations;

Means of establishment

In order to set up a complete document, it is necessary to make a choice between the different specifications of materials and between the different means of execution. Thus it will be possible to choose the most suitable equipment for a given program: technical characteristics, shape, dimensions, time limit for delivery, execution facilities, etc....

Advantages-Disadvantages

The complete document calling for tenders renders possible the establishment of a detailed design, by coordinating the different categories of works and by foreseeing the equipments which will give the greatest satisfaction in the greatest number of domains. This represents one of the advantages of this type of document; we will come back to this point when speaking of the various fields of application of this way of calling for tenders.

Another advantage consists in the facility of judging these offers: all contractors pricing the same work, the choice relies on a few elements only: they are on the one hand the cost and the execution times, easily comparable, and on the other hand the qualification of the different tenderers, which requires a more subjective valuation.

A third advantage, this time not for the client but from the national standpoint, is the gain secured by the fact that the technical studies are only done once. With this document the contractor has no more technical design to do, and at the moment of submission, his work is limited to the study of prices. Repetitions of technical studies are avoided which, in the contrary case, would have been necessary for each tenderer and would have represented unproductive expenses which would have increased the contractors' prices.

The main disadvantage of a complete document lies in the fact that it does not lead to a minimum price, competition being considerably restrained. Moreover, even if the design is very precisely elaborated, it can happen that certain selected solutions are not those which the respective contractor usually handles, especially where his tools are concerned (for instance means of lifting).

Application fields

The scope in which this type of document will be employed can be divided into two distinct fields:

– simple works which are not repeated and which are executed by traditional means.

These works may be given to small contractors who do not possess a proper technical office or their own special system. The precise definition of the required service will allow to apply to this type of contractors whose prices generally support relatively small overhead charges;

– very complicated works, or parts of works, or those corresponding to a very well defined project.

It can for instance be worthwhile to determine in advance the equipment of certain sections of a work which is limited in its volume for aesthetic or space reasons. If all technical characteristics are satisfied, it is possible, by making a reasonable choice of tools, their position, their connection, of various design possibilities, of structure, localities, etc..., to obtain a solution which gives a maximum of effective volume within the rest of the construction.

For special works in a precise program, the contract can imply a restricted choice of materials. For instance in a laboratory: the utilizers may prescribe the nature of working tables, the trade mark of experiment boxes, the quality of pipe networks for liquids, the general space dispositions, etc. The same case may occur for so called "in-town" buildings, dimensions of which are determined by the surrounding buildings or by town planning regulations.

The most suitable form of contract which meets this kind of calling for tenders is the lump-sum contract, which excludes technical risks and additional works.

Document defining the technical trends

This document defines not only the dispositions for the completed work but also the method of execution which will allow the assignment of the project to a certain group of technics or systems.

Composition

Identical to the complete document and in addition to the general stipulations of submission and contract and to the architect's drawings, the document defining the technical trends contains a certain number of sub-documents which do not necessarily correspond to a determined class of works.

The first sub-document outlines the general technical procedure chosen for the work, for instance: industrialised shutterings which would determine the tolerances of execution. These tolerances will allow the choice of a prefabricated front panel, and the contractors will so get an idea of the choice of technical trends which is determinant for the coordination of the entire work.

Each of the other sub-documents is concerned with one category or group of works. They determine the technical conditions for the materials, their position and their quantities, with respect to a certain form of execution. The contractors' offers specify the system desired and complete or modify the bill of quantities by special stipulations proper to their method of execution.

Advantages-Disadvantages

It is the most elaborated document which will offer the possibility of putting into competition several systems covered by a patent.

The appreciation of the offers replying to this type of document is not as easy as for those replying to a complete project. Comparisons must be made between the different services offered, the corresponding prices and time limits for delivery.

Once the contracts are awarded, the studies must be continued, along with the contractors, designed in order to coordinate the different categories of work. Eventual discrepancies are removed by asking certain contractors to establish new prices for other equipments or other methods of execution. These prices, having been discussed without any competitive influence, can be higher than they would have been at the moment of the competitive tendering. However, this phenomena does not appear regularly and generally covers only small amounts of work.

This is in fact only a small drawback compared to the main advantage of this procedure which consists in calling into competition different industrialised systems. The lowest price for a structure with repeated elements can be obtained by this method.

The complementary study which will be carried out after analysis of the offers when the prices are known, helps to provide the realization of a homogeneous construction observing very strictly the cost limit.

Application fields

The field of application of this type of document covers all the constructions with repeated elements, for instance flats, schools, etc.

In France, the principal field of application is that of social housing, particularly where framework and wall panels are concerned. This seems normal if we consider that this kind of construction represents a great part of the turnover in building-trade.

Intermediate forms

This last example shows that for the same programme all forms of documents may exist for each category of work, from the complete document to the document of technical trends.

If, when calling for tenders it is desired to extend the competition on certain categories of works, it will be expedient to set up a document of technical orientation for these corporations. But in this case, the documents concerning the other corporations cannot be complete, the final choice of materials and tools remaining uncertain. According to the importance of the technical relationship between the corporations for which an extended calling for tenders is desired, and the corporations one wants to define, this last document will be more or less precise.

It may happen, that all types of documents co-exist in the same programme, but this case is rather unusual.

The most common intermediate form between the complete document and the document of technical trends consists in defining the main dispositions of construction according to each category of work, of materials and tools, leaving to the contractors the possibility of varying certain components.

This method allows the establishment of coherent documents for tender including the technical coordination of all corporations, and it permits the extension of competition on the points which are not precisely defined by the program and which seem economically unfavorable.

Conclusion. Which should be the forms of tendering procedure? Calling for tenders for complete projects should be reserved to constructions for which variations cannot be accepted. Such cases are not frequent in France and their percentage of turnover represents a very small part of the building-trade.

Calling for tenders with documents of technical trends should be applied to operations which justify the execution by industrial means in order to reduce the cost and the number of workmen. Such will be the case for operations with repeated elements, for instance a program of 1000 flats.

For intermediate operations, the form of calling for tenders should be intermediate as well: the document tending more to one method or to the other according to the business outlook and the degree of technicality of the programme. But in any case, the limits of services required from each contractor have to be perfectly defined, which requires an excellent coordination of the whole project.

The various forms of contract award

The various forms of contract award can be summarized in a general scheme with regard to the regulations applied to Public contracts which cover a great part of the construction-business.

The more flexible procedure which is applied to private contracts is mentioned for information only.

Public contracts, contracts with local communities or organisations for social housing.

These contracts can be concluded:
- further to a public tender action (limited or unlimited)
- further to a competitive tender action (limited or unlimited)
- or as a direct adjudication without competition.

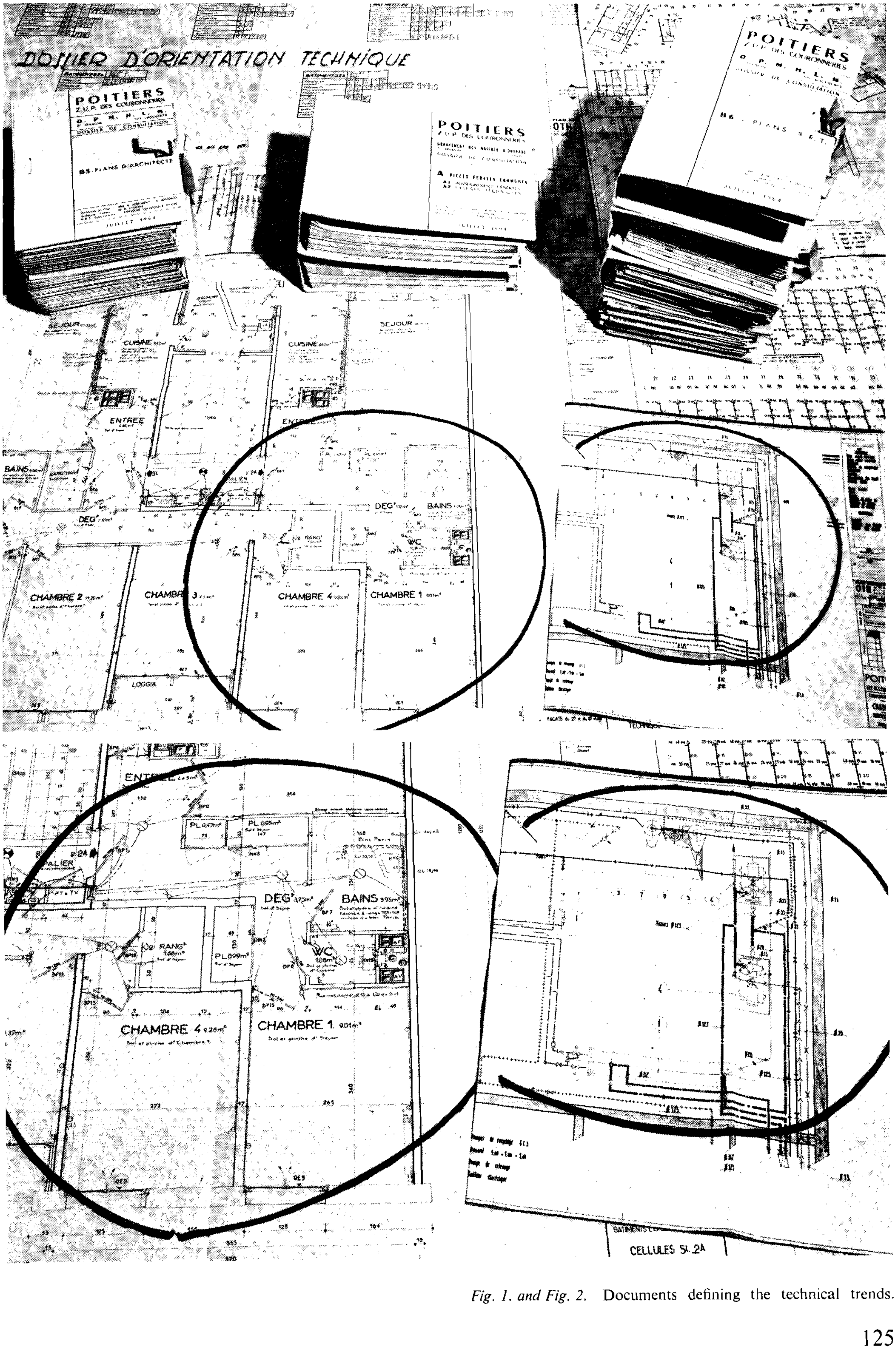


Fig. 1. and Fig. 2. Documents defining the technical trends.

Moreover, building contracts are generally lump-sum contracts which entirely define the services required and which fix in advance the cost-price.

Public tendering. Public tender action means that the contract has to be concluded with the contractor who has offered the lowest price. He is the "lowest bidder".

Competitive tendering. The competitive tender action must be distinguished from the public tender action by the following possibilities:

a. for the Public Services: to choose freely the contractor of their preference with regard to his capacities, although he may not be the lowest bidder.

b. for the contractor: to submit a proposal which may include, if such is expressly mentioned, a variant of the project as provided in the contract by the Public Services.

It is important to know that the so called unlimited consultation form is the largest consultation because all the candidates may submit a proposal, whereas the limited consultation form is reserved to those of the contractors who have been selected for sufficient capacities and references by a special committee.

Another point to be mentioned is the fact that for both, the competitive and the public tender action, a maximum cost limit is fixed beyond which no adjudication will be made. If the case occurs, it will be subject to a new competitive, public or direct tender action.

Direct tendering excluding any competition. A contract is called direct if the Public Services engage a contractor of their own choice.

Particular case of competition. Another form of competitive tendering is the adjudication concours which is used by the Public services if a particular technical, aesthetical or financial problem justifies special research.

The competition is based on a programme established by the Public Services which specifies the special tasks required and which may also fix a maximum cost implied by the execution of the work.

The document concerned includes an estimate of the general conditions to be observed; it must be distinguished from the document defining the technical trend.

Private contracts. The award of private contracts is distinguished from that of Public contracts by the absence of public tendering and by the restriction to limited or direct tender action.

It results from these principles that the calling for tenders with *complete documents* interests the public tender action and the competitive tender action without variants.

The calling for tenders with a *document defining the technical trend* is only applicable to competitive submission with variants.

As a matter of fact, the competitive tender has been very often applied during the last 10 years, the public tender having been slightly neglected, and we can say that there are nine competitive tenders to one public tender.

The critical path method

Comparison between the block or planning network ('potentiels tâches') and the arrow or progressing network model (PERT)

By J. Coiffard and A. Deloro (France)

Since 1962, our agency has applied the critical path method to the coordination of job site activities. We now frequently handle programs including several thousands of activities. So far, our experiences have been based on office buildings, but we bear in mind the extension of this practice to dwelling and hospital constructions.

On this behalf we will record the progress made by means of the critical path method until now and will examine the obstacles to be surmounted in order to give to this technique its full importance in France.

Different authors having already presented the PERT and CPM methods, we should like to point out the "Potentiels Tâches" method which is less well-known but which in our opinion is more easily applicable to planning and scheduling in construction, especially in Europe.

Account of the first uses of network analysis techniques

Advantages of the critical path method. A building site is a very complex organization because of the great number of concurring activities and their interrelationships. Thus can be justified the rapid development taken by the application of critical path methods in France since their first appearance in 1962. By now, the principles and possibilities of network techniques are almost taken for granted everywhere.

We briefly recall that these methods allow the determination of the critical path of a planning, the precise determination of resource margins, the drawing and adjustment of curves reflecting manpower foresight and, in particular, the analysis of consequences due to deficiencies of any sort (weather, changes in the project, delays in supply of resources, etc.), and the research of solutions solving these deficiencies, at least partially. We also remember that electronic computers can supply a quick control of this information whenever needed.

In opposition to the conventional scheduling, the network planning techniques made it possible to become aware of the large progress which can be made in coordinating activities. The anachronism of the old way seems particularly amazing when considering that nearly a million workers are concerned with the construction industry and that very often several hundreds of workers are occupied at the same time on the same site.

The technicians who have had the opportunity to practise network techniques owe to them a new way of thinking and approaching site planning and scheduling. With the conventional diagrams they were reduced to a statical survey and a mere recording of occurring incidents (delivery delays or deferred starting of jobs, project modifications, etc.). The information provided by network analysis enables them to understand the mechanism of interrelationships between the different activities and to investigate the means of solving such problems.

Finally it must be pointed out that the network approach is not at all reserved to a high level management with special scientific education. The experiences made show that middle management becomes easily familiarized with the modern methods of planning and scheduling, or at least with their practical application to the jobs. Contrary to such assumptions, it seems that in spite of the considerably advanced concepts and mathematical thoughts involved by the network approach, it represents a tool which enables a much larger number of technicians to treat planning and scheduling questions.

Difficulties to be overcome in the application of the critical path method. Unfortunately, most of the effective and potential advantages here mentioned have been considerably compromised until now because of unsatisfactory management within the organizations and of insufficient preparation of most of the job sites, for which the owners, architects and engineers ought to be blamed.

Contractors. Most of the contractors are not yet capable of taking full advantage of the possibilities offered by an advanced and strict planning method. They still work from day to day without any planning providing the distribution of craftsmen between their different sites. In France there are certainly not more than 15 to 20 contractors who have a real planning office or a proper analytical control. Old practices of paying craftsmen by the piece still being used, the development of the new method is hindered and the situation aggravated.

For these reasons, it will be wise not to experiment with an advanced planning and scheduling operation if contractors with modern organizations and a minimum of trained management cannot be chosen. Even if such favourable circumstances are achieved, the experience shows that the top-management must assist the responsible job-managers in perceiving all the consequences which this planning will have on their work and the importance of foreseeing the necessary manpower and the orders to be passed. Moreover, a thorough check up of the contractors' availabilities in necessary manpower and materials must be executed by the site management. This entails an immense work for the management, inevitable, however, if bad dispositions or indiscipline of one contractor is not to interrupt the whole program and reduce the other contractors' efforts to unsatisfactory results.

It must be said that the difficulties due to shortcomings in manpower are very important in France and are very often the reason of a contractor's failure.

Architects and engineers. The advanced planning and scheduling of a job site of some importance is a difficult and complex operation. As a matter of fact, it requires specialists in network approach, and their importance has not been realized in France until now. It also requires a large knowledge of manpower efficiency, of cost resources, partial execution times, storage surface and industrialised building methods.

In France the number of organizations incorporating such personnel is very small. Hence, not only the education of top management must be encouraged but also of middle-management capable to organize, manage and plan job-sites.

Taking into account that a great number of contractors are not used to work under the rigid pattern of advanced planning and scheduling methods, the responsible site managers will have to proceed step by step on this way of improvement and must keep in mind the compatibility of their aim and the contractors' capacities. A great number of failures in application of the critical path method in France are due to the unrealistic sense of certain architects or engineers who try to check exactly with the hour, even with the minute. A highly elaborated planning system easily induces to complete reliance, but the degree of schedule analysis must not be superior to the order of possible time differences which cannot be avoided in construction.

Owners. In a way, the owners are also responsible for the present uses in the French construction industry and for the delays occurring in the contractors' reorganization.

Very often, their impatience makes works start too early, at a moment when not all the contractors have been chosen or when the designing is far from being terminated. Sometimes the program has not been entirely defined or the building permit has not been obtained. In such a case all efforts of planning and scheduling and organization are compromised from their beginning on. The progressing of jobs suffers from the repeated interruptions due to delayed decisions. The more an owner alters his decisions or comes back to previous solutions, thus giving a bad example, the less a contractor will observe the required sequences.

As a matter of fact, very often the owners lack sufficient knowledge of planning questions or are not equipped to force the architect or engineers to consider the urgency of problems which depend on their decision.

Nowadays, the advantages of applying network planning systems to construction works seems almost indisputable. Their importance will even grow with the increasing adaptation of the different professions concerned with construction to their large possibilities.

Comparison between the PERT and the 'Potentiels Tâches' methods

Differences between the two methods. The PERT method is of American origin and is well-known all over the world. The "Potentiels Tâches" method is of French origin (Mr. Roy of the Society of Economics and applied Mathematics) and is becoming known in Europe.

Which are the practical differences between the two methods?

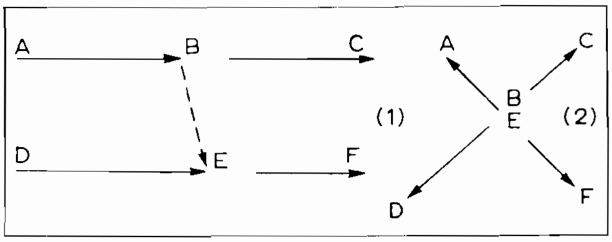
The PERT method, or arrow diagram, represents activities by arrows, the arrow heads representing events. The unique constraints considered are those of a strict sequence. This means that they want to express that the start of an activity cannot begin before the termination of another activity. Except in the case of dummy activities, which we shall treat further on, it results that an activity can be defined by its duration, by the manpower needed and the two arrow heads between which it is situated.

The "Potentiels Tâches" or block diagram uses, on the contrary, arrow heads to represent activities and the arrows correspond to constraints. Thus it is possible to take into consideration a much larger and more complete scale of constraints. One can express not only that a given activity "i" cannot start before the termination of another activity "j", but also that the beginning of "i" can occur only a certain number of days before or after the completion of "j"; it also can be said that "i" must intervene at the same time as "j" or later than a certain number of days after termination of this activity, or at last, that the activity "i" cannot begin before a certain date depending on no other activity. The data which identify an activity are therefore much more numerous and complex.

Of course, they still include the duration of an activity and the manpower needed, but the constraint system to which it must comply cannot be defined by indicating two numbers, as in PERT. As a matter of fact, the number of activities which influence the considered activity must be stated, and for each of them an algebraic number must be given which represents the difference between the starting date of the considered activity and the starting dates of the activities on which it depends.

Whereas the arrow diagram can give all data concerning an activity on one written line, a whole sheet of paper will be necessary for the block diagram of one activity, but the data of the same are more complete and more precise.

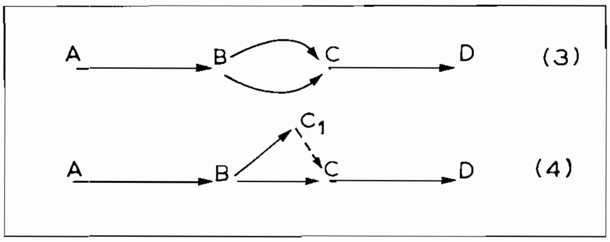
We will now consider the introduction of dummy activities in the PERT method. We said that each activity is identified by its duration and its two extremities. We will consider four activities AB, BC, DE and EF, determined by their arrow heads ABC and DEF. This expresses that BC can start after completion of AB, and EF can start after completion of DE. If it has to be expressed that EF cannot begin before AB is terminated, the network cannot be drawn as shown below (fig. 2), for this would imply that BC depends on DE.



However, by introducing a dummy activity of a duration "null", it can be expressed that EF depends on AB by intermediary of this dummy activity (as shown by fig. 1).

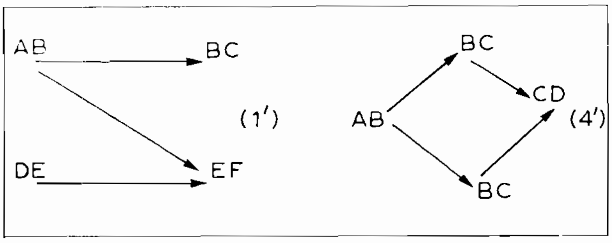
Another case of introducing dummy activities can occur if two activities are both dependent on a third activity and both influence a fourth activity.

The network shown by fig. 3 cannot be accepted as it is, for



there would concur two activities with the same origin which could not be distinguished from each other if the dummy activity would not be introduced (see fig. 4).

The block diagram would not require, for the cases (1) and (4), the introduction of dummy activities. The corresponding networks are the following:



Dummy activities having no basic signification they can easily irritate those who are not familiar with the mathematical abstractions. At any rate, they are a source of mistakes as their application is very complex.

Advantages and disadvantages of the two methods. There is no question of judging the qualities of the two methods and of dividing them into definite ranks. The PERT and the "Potentiels Tâches" methods are tools of the same family, one does not exclude the other and both have their proper fields of application.

The PERT method is more simple and rougher, but it is less efficient than the "Potentiels Tâches" method. Its network being less complex, it seems that its advantages are greater. The more a network becomes complicated the more it is necessary to introduce dummy activities which, in the end, are inconsistent with the simplicity of this method.

The PERT method will be particularly convenient for the treatment of problems implying networks which are composed of parallel chains which can be very long but not very numerous and which show few interdependences. In other words, the activities composing one chain can only be related to the activities of another chain by a small number of constraints.

In construction, however, activities are connected to each other by a great number of constraints. The amount of constraints can be two and a half times greater than the amount of activities; the relevant networks are of course very involved. The PERT operation we have examined shows ⅓ dummy activities. It results that the block diagram ("Potentiels Tâches") seems more convenient for construction than the arrow diagram (PERT).

Where construction is concerned, PERT presents another great disadvantage which consists in its inflexibility in exploitation. We will in fact examine how each one of these methods reacts upon the later introduction of alterations and readjustments of the data which are due to a further elaboration of the project, or to delays on the job-site.

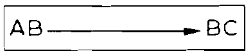
The introduction of dummy activities and the chopping up of certain real activities being both necessary in the PERT system, the break down into activities of this method depends on the system of constraints and even on their density. Therefore the breakdown into activities causes new problems every time the project is changed, activities are deferred, delivery or starting delays occur; and consequently the network itself has to be reviewed every time.

In the block diagram ("Potentiels Tâches"), on the contrary, the break down into activities is not dependent on the constraints.

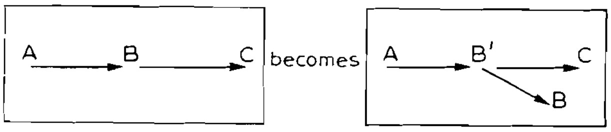
Moreover, there is no modification of the network to be made as far as new constraints connecting two activities are not introduced or eliminated. Delivery or starting delays, new appreciations of the duration of some activity or of the time lying between two activities will not imply modifications of the network, and in the majority of cases, this network has not to be reviewed. This also avoids the repetition of many mechanical calculations, especially the block ranking calculation which depends only on the break down into activities and on the quality of constraints.

Example: We had assumed at the beginning that an activity BC could not begin before completion of AB. But during the works it turns out that BC can start in the middle of AB.

The block diagram needs no change.

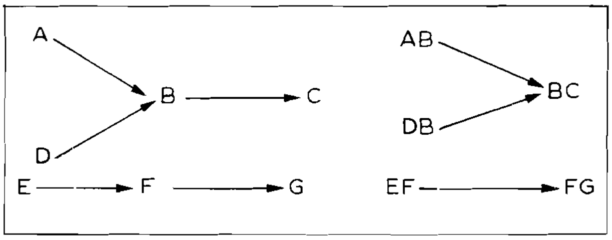


In the arrow diagram, AB has to be chopped up:



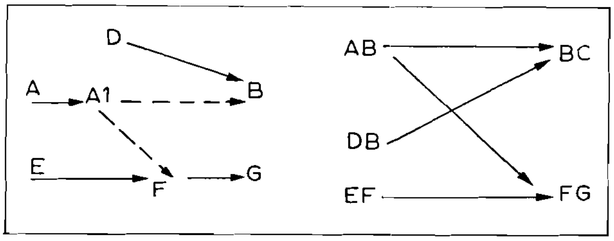
If a real constraint connecting two activities is introduced, both the block and the arrow diagrams have to be modified, but the modification of the block diagram is very often more simple and quicker than that of the arrow diagram.

Example: We will examine the following network case:



PERT "Potentiels Tâches"

If we assume the introduction of a constraint joining AB to FG, the networks change as shown below:



The arrow diagram has to be entirely modified; the modification of the block diagram can be done immediately.

In short, it can be said that the advantages of the PERT method which seem to lie in its simplicity are not so obvious where construction is concerned, and the changes cannot easily be introduced in this system.

For these two reasons, we consider that the "Potentiels Tâches" method corresponds better to our field of activity and is preferable in Europe where a great number of modifications of data are introduced during the works.

Conclusion. The benefits and the rapid progressing of the critical path approach in construction let us guess that its general introduction to all job-sites of some importance can be expected in two or three years.

The incompatibility between requirements of modern organization and insufficient management will induce an accelerated development and reorganization of the different construction jobs. Thus the network approach will have a beneficient influence on the present underdevelopment of this industry.

However, it is useless to hope to overthrow construction traditions from one day to the other. Years will pass before our job site preparation will be as perfect as it is now in the USA. Before reaching this aim, we need very flexible management methods, and as such can be recommended the "Potentiels Tâches" method.

Prefabrication of piping

By E. Gabrielsson (Sweden)

In Sweden there are a great number of contractors of various size and technical capacity in the heating and plumbing field. Consequently, competition is very keen for bids on relatively simple and well prepared installations, especially for appartment houses. It often happens that a small company without an extensive technical and administrative organisation is able to offer the lowest bid.

Being one of the biggest firms in the heating and plumbing business (900 workers and 250 engineers and clerks) we have been discussing different possibilities to increase the profit on these objects and to maintain this part of the market. These discussions resulted in moving the process of the installation work, handling manufacturing of piping, from the building site into a modernly equipped workshop.

The main reasons for this move were:

The working conditions (light, heating, tools and machines) in a workshop are superior to those on a building site, and, consequently, a higher productivity can be achieved.

The modern mechanical building methods decrease the working time at our disposal on the site and encourage different forms of prefabrication.

The wages in Sweden have always been higher in the building trade than in the engineering industry.

Necessary reorganisation

Although our company was one of the biggest in its field the erection work was taken care of by a great many branch offices working under almost similiar conditions to the small heating and plumbing contractors. To meet the changes of the technical process it was found necessary to decrease the number of the existing branch offices and increase the technical and administrative efficiency of the remaining ones. The number of branch offices was thus reduced from 16 to 7, two of which were newly-established in big cities. Moreover, special draftsmen were trained by the head-office in the required kinds of piping for heating and plumbing, technicians experienced in industrial rationalisation were hired and machines and tools for a central workshop were purchased.

Prefabrication system

The system described does not necessitate the use of new material or new pieces of apparatus, nor does it change the layout of the conventional net of piping. This method means that, after a close study of the whole installation process, each separate part of the work is done in the place and by the person, giving the most profitable result as far as the whole of the installation is concerned.

This method is based mainly on:

- a close study of the existing programs and drawings of the installation; confirmation at personal meeting with involved parties;
- simple drawings of the various pipes;
- preparation and specification of construction and transport of own products, as well as details and apparatus purchased from other manufacturers;
- detailed establishment of the working methods to be used as a basis for the piece rate of installation.

The planning starts with a close study of drawings and programs provided by the client and the builder (from architects, consulting engineers, etc.) These are checked with the programs and drawings of the installation. The existing possibilities and necessary changes to meet the requirements of the prefabrication method are then discussed at a meeting with all parties.

On the basis of existing programs and drawings the preplanner works out drawings for manufacturing of pipe details in our workshop. These drawings show the exact shape of the details and contain a specification of the required material. Each drawing is numbered and every pipe is labelled with a number. Apart from the drawing, a table is made up showing all prefabricated pipes of the same type in the building. Layout drawings are also made up indicating where the different pipes are to be installed in the building. Afterwards the drawings and specifications are worked out, the principles for storing and transport to and into the building are decided and the order of the operation is cleared. Our responsible personnel check the material and the disposition with the other parties involved. The drawings and specifications are then sent to the work shop and to the purchase department.

Important problems

After this general background and description of our pre-fabricated method it may be of interest to learn some of our essential problems in connection with the application of this system.

1. Agreement with the unions

2. Time and motion studies

3. Internal information and training

4. Tolerances

5. Site operations

1. Agreement with the unions. The leading men of our unions are well aware of the fact that better organisation and working methods lead to better wages. After making some compromises in the beginning it has been possible, during a period of 5 years to reach a general agreement on the rates for both manufacturing and site operations based on time and motion studies. The piece rates for manufacturing and site operations are independent of each other and also of the price list for conventional installations.

2. Time and motion studies. The time and motion studies of this new installation system have been done to achieve the best method for rational site operations. They have also been done to measure the time of operation in order to estimate the piece rate and to examine the necessary delays. It can be noted that during the seven years of our studies no strikes or other disturbances have taken place.

The collected material now covers all normal operations of piping installations in buildings, which material is now prepared to serve as a basis for calculation and synthetic time standard.

When new objects are studied the task of the time study man is to give a detailed specification of the operations stating suitable equipment and tools and, using these facts as basis, to estimate the piece rate.

3. Internal information and training. Most firms in the heating and plumbing installation business have for many decades been using the same unchanged methods and have, as a rule, promoted their more skilled fitters to foremen. Whilst the mechanical industries have used the services of skilled technicians we in our field, have not done so. Consequently, when new methods are introduced they often meet with a certain resistance which has to be overcome in the way of effective internal information and training. This also applies to our customers to whom the ideas have to be sold and who have to be supplied with detailed information. To gain the advantages of the new method certain counter-efforts are also of importance.

4. Tolerances. Earlier it was doubted whether the tolerances at the building site made prefabrication of piping advisable. After having completed thousands of units, we can state the following.

When dealing with buildings erected by prefabricated methods no special measures have to be taken to install prefabricated piping in the buildings.

When dealing with conventionally built houses, however, the existing possibilities of the structure have to be utilised to absorb the expansion movements of the piping and apparatus.

5. Site operations. The figures 1–6 illustrate different steps of rationalisation concerning prefabrication of piping. All kinds of pipes for heating and plumbing are sorted out for a certain part

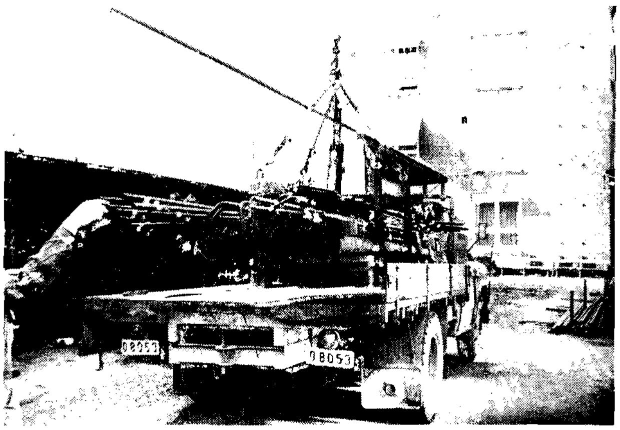


Fig. 1. Transportation of prefabricated piping.

of the building at an early stage and are made up into a parcel. A truck transports the parcel to the building site. At this time the pipes are completed as far as possible, i.e. equipped with insulation, valves, couplings, branches etc. On the site the parcel is disposed in a place indicated by the builder without having passed through the hands of the fitter. Either our fitter, together with the driver of the crane, or the builder alone is responsible for the transportation into the building according to earlier agreement, fig. 2.

The radiators are packed by the manufacturer according to our specification as can be seen on fig. 4. One parcel contains radiators for the same building unit as our parcel of pipes (in this case 30 pieces for one floor or 5 appartments). Fig. 5 illustrates the importance of the benefit of making each operation at the place

Fig. 2. Hoisting piping into the building.

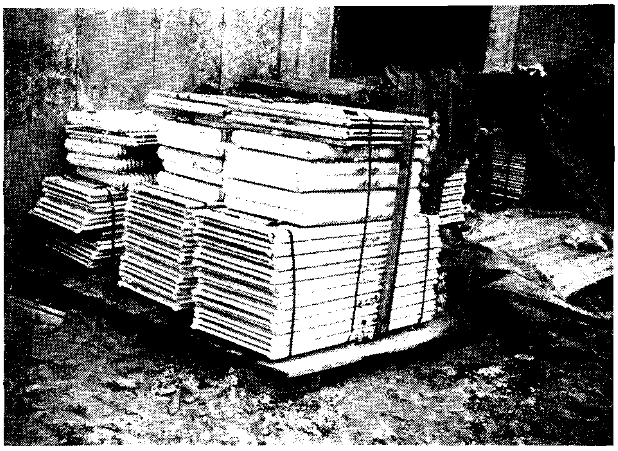


Fig. 3. Method of transporting radiators.

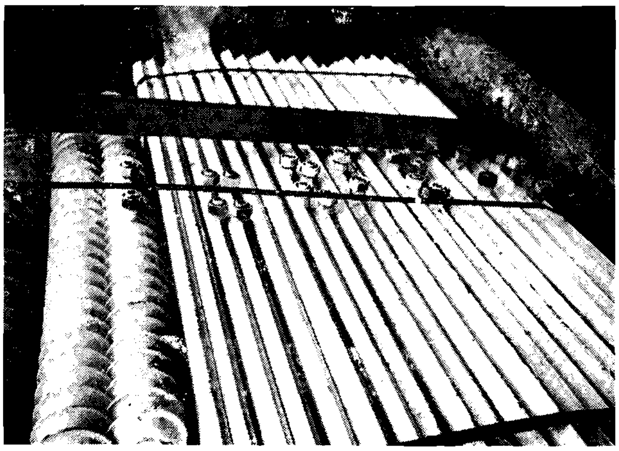


Fig. 4. Detail of packing of radiators.

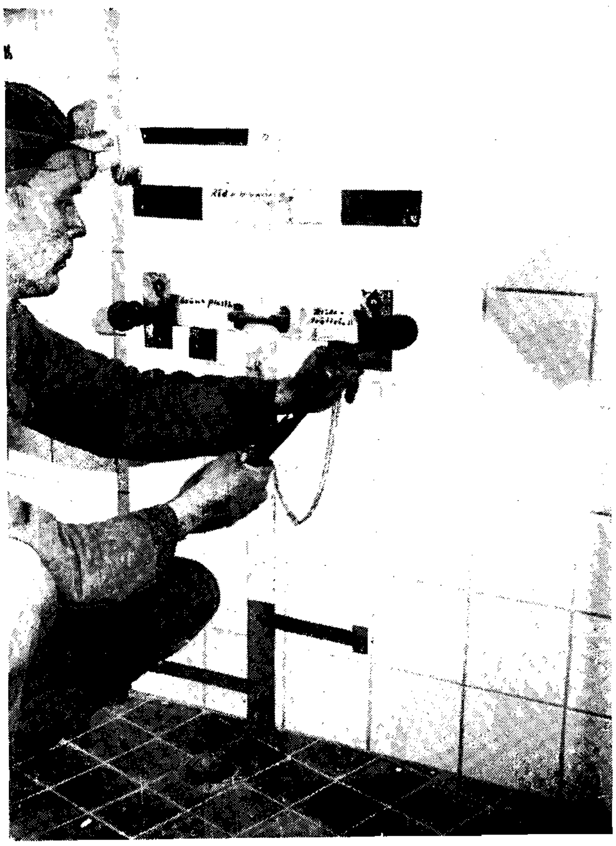


Fig. 5. Installation of apparatus.

Fig. 6. Use of pneumatic screwdriver.

where it can be executed most rationally. Earlier the fitter had to fasten the connection of the radiators on the site. Now the radiators are delivered fully equipped.

A drill pattern equipped with water level and rubber plates was introduced to facilitate the installation of the apparatus. Fig. 6 shows a pneumatic screwdriver introduced to shorten the installation time for the apparatus. This tool has been used for a long time in the mechanical industry but not in our field, as far as we know.

Conclusion. The advantage of this prefabrication method is that the installation time at the site has been reduced to 30% compared to that of the conventional way of working. On the other hand, the requirements are

- that the serial size is big enough (min. 2—300 flats);
- that there is time enough for projecting and planning of the installation and,
- that the builder is aware of the fact that a rational production demands co-ordination of all operations.

Applications of Critical Path Network and the development of job costing by computer on the construction of the Sydney Opera House

By D. C. Gore (Australia)

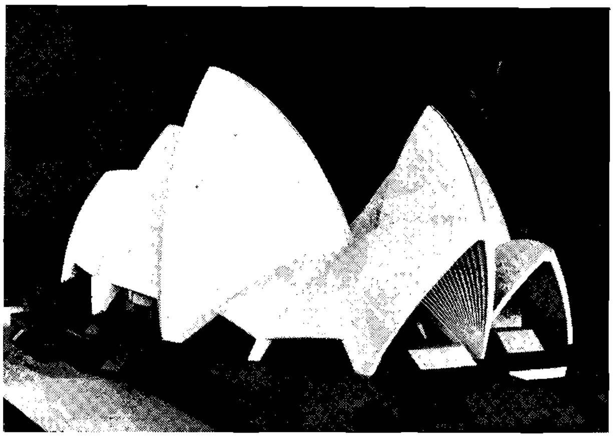


Fig. 1. View of a model of the completed Sydney Opera House

As a result of a world wide competition, the New South Wales Government chose the design of Jørn Utzon of Denmark for an Opera House to be built on Bennelong Point, a rocky promontory in Sydney Harbour close to the main city area. The building contains two major concert and theatre halls plus three smaller theatres, giving a total seating capacity of 4,800 people. In addition, the building is designed to cater for all the essential services for production of opera and plays, such as Carpenters' Shops, Plumbers' Shops, makeup and wardrobe areas, dressing rooms, administrative offices, bars and a restaurant. Total cost of the building is now estimated at approximately £ 17.4 million Australian.

The architecture of the building has been described as sculpture in concrete and this is indeed an apt description for it consists of a concrete podium surmounted by a series of tile clad concrete shells, the largest of which is 220 ft. from ground level at its peak and 150 ft. wide at its springing points. They are constructed of precast prestressed concrete segments and the building is perhaps unique in that free-form shells have been so adapted that repetition precasting can be used.

Contracturally, construction of the building has been divided into three contracts: Stage I – Foundations and concrete podium; Stage II – Casting and erection of shell rooves and associated concrete work; Stage III – Finishing trades and installation of machinery.

My company, M. R. Hornibrook (N.S.W.) Pty. Ltd., has been entrusted with the contract for Stage II and this paper will deal with the organisation of this contract, the scope of which involves approximately 20,000 cu.yds. of concrete of which 10,000 cu.yds. is represented by approximately 2,000 precast components varying in weight from 6 to 14 tons. In addition, there must be made and erected 4,400 precast concrete tile lids involving approximately 1,300 cu.yds. of concrete and 1,000,000 tiles. Insitu concrete absorbs the remainder of the 20,000 cu.yds.

It was specified that all work, including precasting, had to be undertaken on the site where control could be exercised, that accent had to be on a superior finish to all concrete and retouching of concrete surfaces after stripping of forms was not acceptable. Also, the requirements of accuracy of casting and positioning of built-in metal components was extremely stringent.

Each shell is made up of a series of arches, each complete in itself. The arches are tapered so that in cross section they increase from almost a rectangle approximately 4′6″ × 1′6″ at the springing point to a triangular section with a 12 foot base and 6 foot height at the crown. The arches abut each other so that the base of the triangular sections become continuous to form the exterior surface of the shell while the interior of the shell shows as a fanlike series of ribs. The arches are unique in that they are heavier in section at the crown than the springs, they are inclined to the vertical – they are not co-planer i.e. there is a horizontal included angle at the crown. There are 140 of these arches to make up fourteen shells of various sizes. Each arch is stressed and then the several arches are stressed together laterally to form a shell. The complete structure is then clad with tile panels formed to the curve of the shell and bolted to the completed ribs.

Thus, the site organization had to control the placing of 8,000 cu.yds. of high strength, highly finished concrete curved and complicated in shape, the setting up and operating of a casting yard for 10,000 cu.yds. of precast concrete, again accurate in detail, complicated in shape and to a high standard of finish, the manufacture of spherical tile lids which must fit together over the top surface of the erected shells, and finally the erection and stressing together of all these components into great concrete shells 230 ft. high and free standing. It is obvious that such construction represents a challenge in accuracy of casting and erection and that sophisticated control techniques must be used to control and integrate the construction programme. Arrangements were made for the Contractor and the Consulting engineers, Ove Arup & Partners of London, to work in conjunction in the design stages so that erection and precasting techniques could be co-ordinated with the design of the building in the early stages and various erection techniques were planned by my company in close association with the designers. This particularly applied to design of telescopic steel erection arches which could be made to conform to geometry of each rib in the structure and so support the segments during their erection. Another technique developed by this co-operation was the method of precasting where the end of each segment was used at the bulkhead form for its neighbouring segment, thus obtaining completely matched jointing surfaces so that jointing during erection could be by means of a thin epoxy resin layer; thus, when the segments were stressed together, the geometry of the full rib as cast was reproduced. This early co-operation between designer and contractor has proved invaluable in many ways, not the least of which was the development of an atmosphere of mutual respect and trust between the two parties.

During this initial period, the contractor's organisation was oriented towards design and some experimental construction work so that new techniques could be tested in prototype. On moving to the site, a completely self-contained site organisation was established. Responsibilities were divided into three major sections – Construction, Design, Accounts and the construction area under the Project Engineer was again divided into three more or less self-contained sections – Precasting, Insitu Concrete, Erection and Stressing. Each section had its own construction and engineering staff responsible to the Project Engineer as co-ordinator.

However, future planning and overall control of the project justified a separate department and a Planning Engineer was attached to the Project Manager for this purpose. The Planning Engineer's prime responsibility was to develop and apply a critical path network. Originally, due to limitations in the size of computers available, two networks were established of approximately 1,500 activities each. These controlled the precasting yard, and the erection and insitu concrete work. Subsequently, as work proceeded and activities were completed, these two were combined to give an integrated network of approximately 1,900 activities.

The Planning Engineer makes a survey weekly of all items which should be in progress at that time and reports to the Project Manager the status of each item, i.e. whether it is critical, ahead of schedule or on schedule. Additional effort is then directed to tasks which are falling behind. The complete program is reprocessed every two months or whenever special circumstances may make it desirable. When additional work was added to the contract, sub networks were compiled and integrated with the main networks. Similarly, when particular co-ordination was required over short periods, sub networks with durations measured in half days or hours were produced to cover these particular aspects. These were solved by hand and used for detail control and the logical setting out of the work.

From a study of the Critical Path Printout, it became obvious that storage of precast segments would prove inadequate, as the amount of storage space was limited and offsite storage undesirable due to damage in handling plus costs involved. Provision of sufficient area for storage was critical as the casting yard production was maintained at a uniform rate whereas the rate at which segments could be erected was affected by structural requirements of insitu concrete placing. The same situation applied to tile lid production as erection of these lids is controlled by lateral prestressing between the arches.

From the Critical Path Printout, graphs were drawn plotting segments erected and segments cast against time, and from these the actual storage requirement for segments was calculated. As the program was updated, new graphs were drawn to give the current storage demand. The critical path technique was also utilised initially in basic planning of the casting yard by using gang restraints for labour in an endeavour to obtain the most beneficial movement of gangs through various rib forms. This was done by trial and error to obtain the division of labour which gave the shortest duration. However, in retrospect, it is suggested that similar programmes which are available from most computer companies would be a more effective method of undertaking this initial analysis.

Printouts of computer solutions to these networks were sorted to the three basic construction sections of the job. The controller of each section is given the full program as it applies to his section and the Project Engineer receives a complete printout to enable him to co-ordinate the three sections. Experience has shown both foremen and tradesmen accept critical path planning and cost controls and comparisons of their efforts, provided management shows them by its interest and enthusiasm that the whole scheme is producing results, giving control, and being used constructively.

Lead on by the success and facility of computer programmed critical path network, a costing system was developed also using a computer. The basic requirements of this system were that it had to show cost trends for job control purposes, produce an overall job cost reconcilable with accounts' ledgers, produce the result within five days of the cut-off date at the end of the month, include items which had been received on site before invoices were received and lastly it had to not involve field staff with too much paperwork. As a manual costing system was already in operation on the job, computer programming was tailored to fit in with this system in order to avoid a radical change of system when the job was under way. If a project was commenced on a computer costing system, then the type of coding used would be chosen to suit best the job and the computer system.

However, following the existing Dewey decimal system, the major sections of the job were coded to their essential components, i.e. site overheads, plant, concrete production, precast segment production, tile lid production, insitu concrete, stressing, waterproofing, erection, major subcontracts and additional work, and each component was subdivided into: 1) Labour; 2) Temporary Materials; 3) Permanent Materials: 4) Subcontractors; 5) Plant; 6) Work done by our company offsite (mainly work undertaken in our Steel Fabrication Shop).

This gave all told some 700 divisions for costing. In this section, costs were expressed as money and this could be reconciled with the Accounts. When computorized from input data which is described later, the standard cost sheet was reproduced. The information reproduced by the computer was in this section the same as previously produced by hand except that estimated values for all goods received but not yet invoiced were included.

For immediate job control and the pin-pointing of possible cost drifts, the computer program recorded and kept current the manhours utilized on current sections of the work. These sections were small, down to a separate pour of 20 or so cubic yards, or the turn round of one form unit in the casting yard. Quantities were also recorded and the computer output included a production rate of each unit or group of units. Everyone from Project Manager to foreman was thus able to see the labour content of each small section of the job and to watch labour trends on similar items of work.

To achieve this, the input information was kept as small as possible. Practically all of it is information which was normally recorded but not correlated. The input to the computer is as follows:

(1) List of all orders placed for goods and services containing order number, description of goods, supplier, cost code and estimated value of purchase. This list is prepared by the Purchasing Officer. Each order should preferably be confined to one cost code.

(2) Site delivery sheet which registers all goods that arrive on site and lists order number, supplier, description, delivery docket number and percentage of order delivered. This list is prepared by the gatekeeper. It was essential to record the approximate percentage of order delivered so that on large orders the cost sheet can be debited with the cost of actual deliveries.

(3) List of all invoices received giving order number, filing reference number, supplier and actual amount of invoice and an indication as to whether or not order is completely delivered. This list is prepared by the Accounts Office.

(4) Total amount of weekly wages cheque prepared by Paymaster.

(5) Daily Work Sheets—these were prepared by the Superintendent of each section of the job. Total manhours worked per day in the section were recorded and a subdivision in manhours was made to each task undertaken during the day and cost code attached to each task.

(6) List of accounts received applicable to costs which are not physically checked at the gate, e.g. an account for electricity consumed. These were given a dummy order number and delivery sheet to comply with the system. This supplementary list was also prepared by the Accounts Section.

(7) Quantities of work done. These were recorded by the Section Superintendents on their daily work sheet.

The computer then carried out the following functions:

i) Totalled the manhours from the daily work sheets in each cost code and divided the wages cheque in this proportion and allocated them to the cost sheet giving labour costs to each section.

ii) Listed estimated values of all orders which had not been delivered, and so produced a total which was an immediate future commitment.

iii) Allocated to cost codes the estimated value of all delivered items and, when delivery was complete, replaced in the costs the estimated values by actual invoice amounts, the estimated value being obtained from the Order List and the actual or invoice amount being obtained from the List of Invoices.

iv) Listed manhours on each task by an area code and cost code, and from production quantities calculated a production rate for each task.

For reconciliation purposes, a list of items which had been included in cost by estimated value was printed so that the printout then was able to balance with the Account Ledgers. Various other codings were also obtained as a by-product to facilitate accounting procedures. These were a print of the Purchase Journal sorted by cost code and by invoice reference number, and a "payment advice slip" giving a list of invoices sorted by suppliers so set out that it could be included when cheques were sent to suppliers in payment of monthly accounts. In addition, a variance table was printed to locate major errors in estimated values.

This briefly is an outline of the system as applied. It enabled the Project Manager to obtain prompt and up to date information on his actual job costs for financial control, for estimating finishing costs and for observing and acting upon cost trends. It enabled the Project Manager and the Field Staff to keep a tally on all labour (always the major variable) and to follow the results of their efforts to improve the efficiency of all sections of the work.

It gave to the Project Manager and Accounts staff a reconcilable cost sheet with the component of each cost dissection listed out to simplify the analysis of suspicious cost movements. It gave to the estimator a complete manhour analysis of various tasks for future costing. Other advantages for future application are:

(1) The input is simple and could be handled by untrained staff on isolated jobs;

(2) More than one job can be costed simultaneously;

(3) The cost of producing the information is directly proportional to the volume of work done.

It is suggested that the final step to be taken in this computer cost analysis is to code the various work items in accordance with the activities of the critical path network thus, on updating the network, the extra factor of work actually completed for a set cost at a set time is included. By this method, the cost sheet could be made to read the actual costs in labour and material included in completed activities, actual costs included in activities in progress, value of materials delivered to site and not yet included in completed or partially completed activities i.e. stock on hand, and value of materials ordered but not yet delivered i.e. future commitment. This additional step is not a difficult one and would have been used on this job had not an existing cost system been in operation while the computer program was being developed. It would give a complete cost picture for control with a minimum amount of recording work by site staff and the results would be obtained promptly and at a cost proportional to the size of the job and extent of input.

In addition to the use of computers for costing and critical path network analysis, they were utilised on the job also for complete calculation of payroll, provision of geometry, deflections and stress in the steel erection arches for various loading conditions on each of the 140 arches which make up the shells. Programs were written to solve surveying calculations necessary to establish position of the shells during erection and also for statistical analysis of concrete results as obtained from the site batch plant. In all these applications, time and cost savings were achieved.

Computers are not a new tool in engineering design calculations. However, the extent of their use in this country at least as a management tool for the construction industry has been limited. The potential offered by them to the construction industry is immense and I trust that this paper may stimulate further developments in this direction.

C 8

R. Guiducci

The Italian dwelling problem and national planning

By R. Guiducci (Italy)

In consideration of national planning, the outstanding problems for research are those of fixing a habitable urban standard, determining the real needs and outlining all economies possibly attainable.

Definition of habitable standard and real needs

The objective to attain is the index of 1 inhabitant/room in the shortest time possible, considering this index as necessary and sufficient at the European level. As far as the real needs are concerned it has been found that the average data does not reflect the true reality and moreover covers enormous regional and social imbalances.

Tekne Company, asked to make an inquiry for the National Planning Committee, has adopted the computation method that considers the ratio family/inhabitants instead of the generic inhabitants/room. In that way the exact ratio between the number of members of a family and the number of rooms at their disposal can be evaluated. Thus the coefficient 1 takes its correct meaning as a real index of density of population.

If we consider all possible compensations and calculate a 2 per cent yearly depreciation rate of building estate, it appears that, in Italy, the need for rooms was 26 million in 1961; such a need would reach 43 million rooms in 1973 and 54 million in 1981. It shows also that the index inhabitant/room of 1.06 has come as an average from a density index of 2.03 as regards 34 million inhabitants and from an index of 0.72 as regards 13 million inhabitants. The difference between the two indexes shows how enormous still are the social differences in Italy. Furthermore it has come out that in 1961 about 75 per cent of houses were without water installation, water-closet, electricity or bath-room. Naturally this lack of services existed in popular and economic buildings. Unfortunately this type of building, financed by the government, after having reached its peak of about 24 per cent dropped in 1961 to 13.5 per cent of the national building production.

Despite these deficiencies, in Italy the building production was, in 1961, about 1,300,000 rooms per year, insufficient to fulfil the needs even if the term was 1981.

The fulfilment of the needs implied the necessity of doubling the building production in Italy. This doubling was, however, possible by using the labour, construction costs and dimension of houses built by private enterprise. These three facts implied the absolute necessity of a national building program which allowed, through several interventions, a labour reduction equal to the volume built, a cost reduction up to 30 per cent and finally a house dimensioning that takes into account the real composition of families.

Definition of urban and economical standards

This second inquiry, already made by Tekne for the National Planning Committee, faced, first of all, the problem of identifying the suitable dimension of towns.

The installation costs, viewed from an economical standpoint, have been divided in two groups:

- costs for the town utilities construction (gas, electricity, telephones, lighting, sewerage, water system, roads, transports etc.);
- costs for the town general services (schools, hospitals, administrations, culture, parks, etc.).

Taking as samples some Italian, German, American and French towns the facts discovered were the following: a) firm costs as regards telephone, gas, electricity; b) decreasing costs for lighting, water system, sewerage; c) at first decreasing then increasing costs for roads; d) increasing costs for transport.

The curve of the global costs is, as seen from the graph, (fig. 1) concave at the top showing a very small dimension of costs which roughly corresponds to 250,000 inhabitants. This state proves that the scale economies act up to a certain point, being then annulled by the congestion. Verification has also been done as regards the density of population.

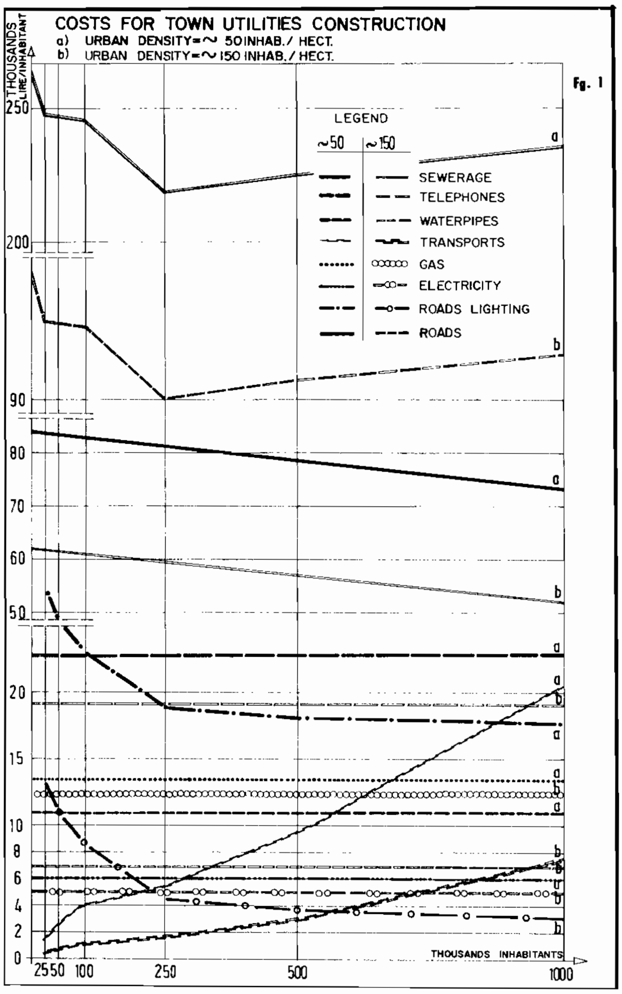


Fig. 1.

As far as the town general services are concerned some types of increase, (see fig. 2), have been obtained for certain quantities resulting from the fact that some installations can be carried out only in given dimensions and they become overcrowded after a certain time.

Therefore a global diagram was plotted which included both the construction of utilities and general services works of a town.(fig.3).

This diagram shows that it is impossible to speak of a dimensional best, but rather of an increase for a determined "quantity". The curve indicates a series of maxima and minima. Therefore, in order to determine the construction of a new town or its growth it followed that a programmed growth so as to reach one of the minimum points is necessary.

Moreover it appeared useless to talk of divided costs such as dwelling costs, infrastructure costs, cost of equipments and its subdivisions, but it was necessary from the point of view of a rational and economic program to speak about 'costs of dwelling per cubic meter equipped', where all direct and indirect costs concerning a residential quarter have been inserted and summed up. As regards the urban standard to attain, the first step was the idea of arranging all over the territory the "town-effect", that is everything which is indispensable to modern life.

These can be summed up as follows: intensity of communications, possibility of concentration of efforts, parallel completion of all specialisations, tendency towards instruction up to high levels, perfect and up-to-date services, complete and different enjoyment of leisure time, etc.

The result of the inquiry was that, to obtain these requirements does not depend on the dimension of the town, but on the ability

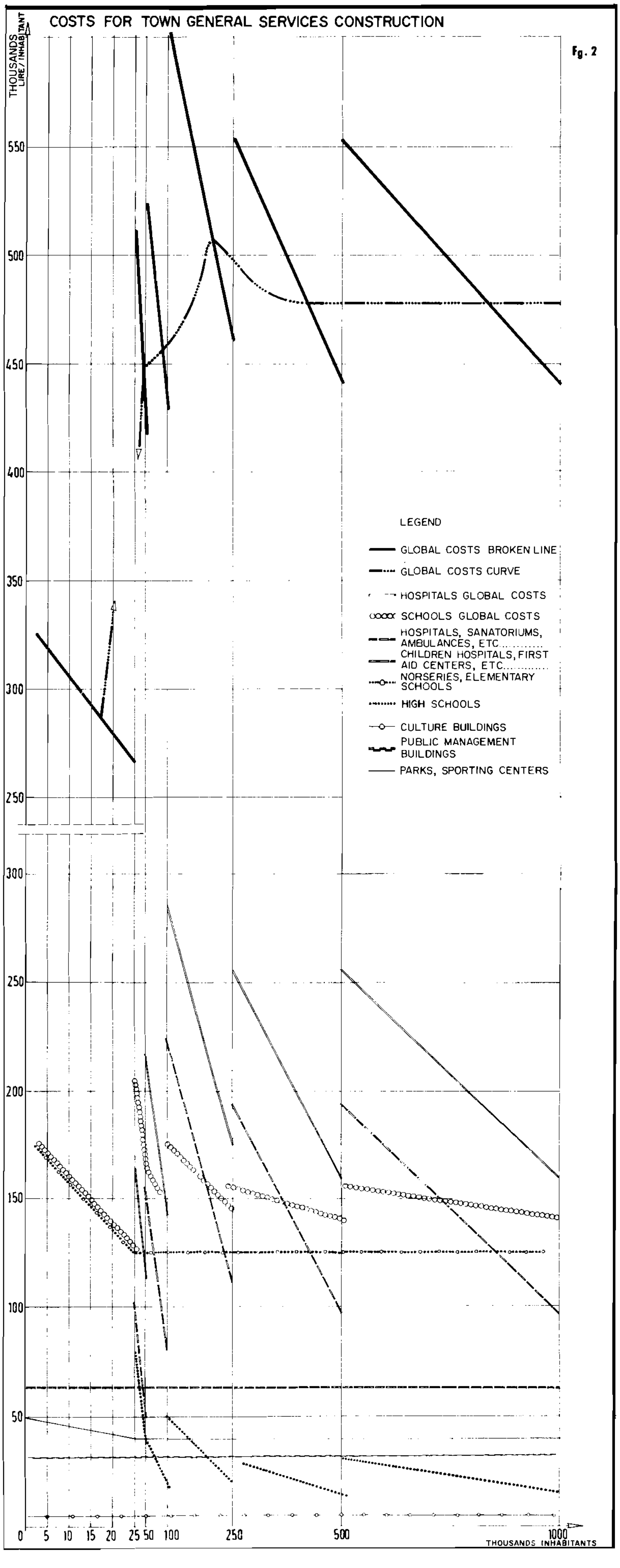

COSTS FOR TOWN GENERAL SERVICES CONSTRUCTION
THOUSANDS LIRE/INHABITANT
Fg. 2
550
500
450
400
350
300
250
300
250
200
150
100
50
0
5
10
15
20
25
50
100
250
500
1000
THOUSANDS INHABITANTS
LEGEND
GLOBAL COSTS BROKEN LINE
GLOBAL COSTS CURVE
HOSPITALS GLOBAL COSTS
SCHOOLS GLOBAL COSTS
HOSPITALS, SANATORIUMS, AMBULANCES, ETC...........
CHILDREN HOSPITALS, FIRST AID CENTERS, ETC............
NORSERIES, ELEMENTARY SCHOOLS
HIGH SCHOOLS
CULTURE BUILDINGS
PUBLIC MANAGEMENT BUILDINGS
PARKS, SPORTING CENTERS

Fig. 2.

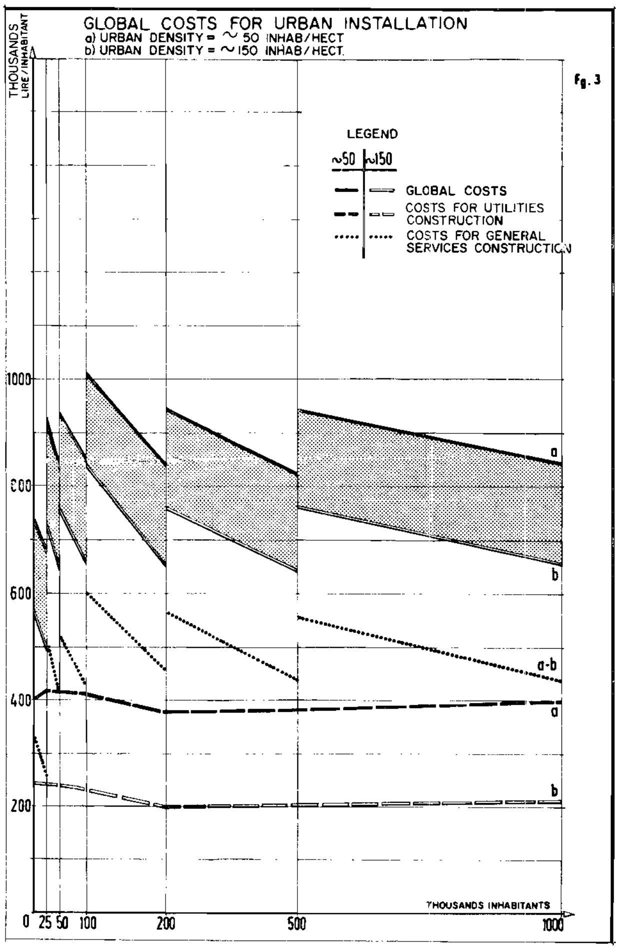


Fig. 3.

to spread, in a rational and organised way, activities and services over a suitable urban area.

Therefore the objective fixed was the achievement of the "town-effect" on a regional and national scale avoiding, in all cases, the harmful aspects due above all to overcrowding and irrational distribution.

From an operative point of view some basic objectives, which allowed to carry out the program within the cost limits envisaged, were indicated during the planning stage. The problems to face were, therefore, the following:

- to step from draftsmanship into an industrialised building with direct help from the government wherever necessary;
- to modify the present building regulations by reducing the volumes and modernising the disposition of services equal to the dwelling value;
- to build units whose dimensions would allow the exploitation of series, continuity and repetition;
- to plan an increase in organic quantities;
- to locate centers and places suitable for an increase in the most favourable conditions and also according to a rational distribution of the population taking all possible advantages from the positive conditions already existing and avoiding the disadvantages of congestion.

Because of modern methods, there results the possibility of reducing the costs up to 30 per cent and in the meantime fulfilling the needs by 1981, supposing, in this case, an increase of the national gross income of a rate of 5 per cent and calculating the building investments equal to 6 per cent of the national income itself; a percentage already reached in the last five years.

This program, with the necessary adaptations, has come from the 1st Italian Quinquennial Plan which has been worked out under the presidency of the Minister of the Budget, Antonio Giolitti and officially presented the 27th of June 1964.

At this point we will have in Italy a new period in which town planning and dwelling problems will, at last, be laid down in a modern and rational way. No doubt the attainment of these objectives will involve both political and technical difficulties, but we think, however, that it is possible, even if gradually, to approach the solution of these problems which are so important for the development of our country.

The influence of repetition on time consumption of site operations

By R. Hugsted (Norway)

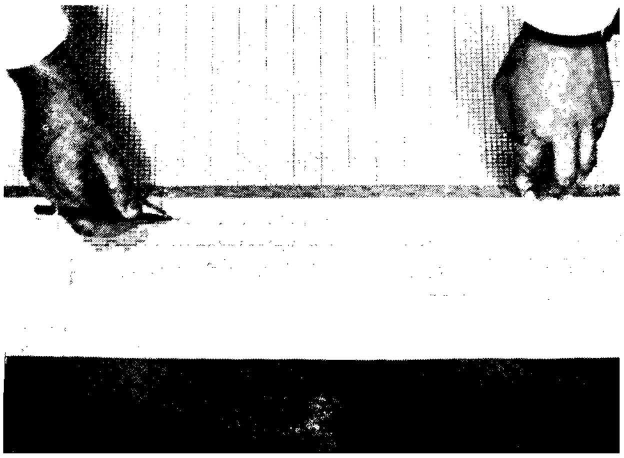


Fig. 1. Use of measure stick in planning.

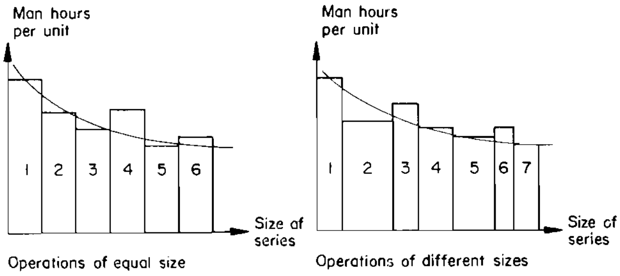


Fig. 2. Recordings of time consumption of operations may be done for operations of equal or different size. As the process continues there will be a tendency of decreasing time consumption but there will always be a limit as long as the method remains the same. This limit is called the basic time.

The Norwegian Building Research Institute has for some years been working with planning systems for building operations on sites. A planning system "terminplan" based on bar chart technique and devised for repetitive building work has been used for some time.

In such a plan, working gangs are organized and co-ordinated based on time consumption computed for the working operations. The computing of work time is based on time consumption rates for the different operations. These time consumption rates should express production attained with trained workers when the different processes run smoothly and without interruptions. One specific gang may do one or more operations and a standard rate must be fixed for each operation.

The plans made are primarily regarded as tools for management on sites, though they are also important as means of control for top management and for coordinating different contractors on the same job. The main objections put forward by management on sites concerned the starting up of the work and what extra time was needed before the processes were running smoothly and co-ordinated. Every site manager and foreman knows from his own experience that this takes some extra time. Working plans which did not take this into consideration would not be accepted as fair play, as the real progress of work would always be lagging behind the planned progress.

It was easy to agree that the gangs should be dimensioned and co-ordinated according to trained labour and working processes running smoothly. Somehow, we had to introduce corrections at the first stages of the process to account for initial extra time consumption.

Repetition and training effect

Each gang of labour is specialized on one or more operations and as the work proceeds the operations are repeated. This provides for the gangs and the labourers a better understanding and training in what to do and how to do it. The lowering of the time consumption for a specific job as the job repeats itself is often referred to as *the effect of repetition* or *the effect of training*.

A definition of the number of repetitions may be difficult. In most jobs there are many repetitions which may be selected as reference. In shuttering of concrete slabs, there may be repetitions of the same set-up within one building and within different buildings. Within one set-up there are numerous repetitions with respect to posters, beams and scuttles. The same considerations could be made concerning other operations. Further, some repetitions may be continuous, others may be discontinuous and interrupted by other operations. All this makes it very difficult to give a precise definition of the term "repetition". We would rather state that there is always some sort of repetition in building performed by trained workers. The effect of this may be called the effect of repetition, or, preferably, the effect of training.

This effect varies from site to site. It is influenced by the work organization and the planning of the building operations. It would not be the same if the work is performed by labourers unknown to the processes as compared to labourers with experience. The influence of the different conditions cannot be measured separately. We may, however, before the work starts, make corrections for the effect of training or repetition and thereafter follow this up as the job goes on and make comparisons between the corrections and the actual development.

A simple way to do this is to record man hour consumptions for successive operations which may be equal or of different sizes, Fig. 2. We assume then that after some time the time consumption will reach a base which corresponds to the observed curve. The standard time consumption rates should, therefore, correspond to this limit. Corrections in time estimates could be made corresponding to the observed curve.

It should be noted that the corrections thus made do not necessarily refer to a certain number of repetitions but rather to the time of the process. This is logical because the planning also refers to the time. The result is that the different gangs are allowed to use some extra time for a certain operation at the beginning of the job. This is what site management and foremen have experienced and such a correction will make it easier for them to accept a plan.

Theoretical considerations

The training curves in Fig. 2 may be used as empirical curves but we have found it practical to use curves corresponding to an analytical formula. Any time consumption refers to the process performed with total training effect, which means that the process has been going on for so long a time that no further training effect occurs. Such a time is called a basic time and is thus a limit for the method concerned. The standard times used in planning should be basic times. In the planning, time consumptions for different work and sections of the building are computed. These time consumptions are all basic times. The different gangs are co-ordinated and dimensioned according to the basic times but when drawing up the plan we wish to make corrections for the training effect. This is done by a graphical method based on the following formula:

$$T = B + L e^{\div B_0/L}(1 \div e^{\div B/L})$$

T is total time, including correction.

B is basic time.

B_0 and L are parameters deciding the initial speed and time correction to be made.

The total time correction, ΔT, made may be expressed as:

$$\lim \Delta T = L \cdot e^{\div B_0/L}(1 \div e^{\div B/L}) = L \cdot e^{\div B_0/L}$$

$$B \to \infty$$

The speed of the process at any time – B – may be expressed as:

$$\frac{dT}{dB} = 1 + e^{\div B_0/L} \cdot e^{\div B/L}\,.$$

Thus the initial speed is:

$$\frac{dT}{dB} = 1 + e^{\div B_0/L}\,.$$

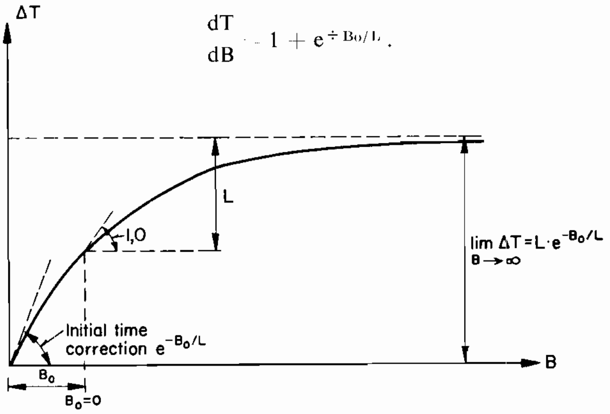


Fig. 3. Curve for correction $\Delta T = L \cdot e^{\div B_0/L}\ (1 \div e^{B/L})$. The speed of the correction at the starting point may be expressed by $k = e^{\div B_0/L}$. If $B_0 = 0$, the process will start with speed 1 which means half speed compared to the basic process. Total time correction will be $\lim_{B \to \infty} \Delta T = L \cdot e^{\div B_0/L}$.

The speed of the basic process is always one and the expression $k = e^{\div B_0/L} \cdot e^{\div B/L}$ may be taken as the speed of the correction. It is practicable only to look at the correction and how it varies with the basic time B. This is done in Fig. 3. If $B_0 = 0$, the total correction is L and the initial speed of the process is one meaning that the process starts with double time requirement compared with the basic time requirement. This explains the parameter L which is called "the halving time". (Halveringstiden). If B_0 is negative, the process will start with a slower speed: if it is positive, it will start with a higher speed. In planning processes the initial speed should be selected together with either the total correction to be made or the halving time L. For a chosen L the total correction will be higher than L for $B_0 < 0$, lesser than L for $B_0 > 0$, and L for $B_0 = 0$.

Use of the model

The model has been worked out for use in planning building operations. Something should therefore be said about the planning technique. The aim of the planning is to organize and co-ordinate different labour gangs and to know where these gangs will do work at any time and what operations are to be performed.

The material available for the planning is usually descriptions of the buildings with quantities of work and drawings. The contractor must use this material in planning his dispositions, but as the drawings and descriptions are worked out in order to describe the quality and quantity of the finished building, it is not necessarily suited for planning the work. The planning includes the following steps:

1. A study of available material.
2. Dividing the total work into separate sections and deciding the sequence of these sections.
3. Dividing each section into working sections for the different operations. The size of the section is selected with regard to the different types of working operations.
4. Computing the quantities of work for each section and each operation to be performed.
5. Fixing basic time consumption rates for each operation and computing total time consumption for each operation on the different sections of work.
6. Fixing the progress of the work by selecting some critical operations and dimensioning the different gangs according to this.
7. Drawing up of the plan.

The separate gangs perform work from one section to another. The working section may be equal or not, according to variations in building lay-out. Often, as in the case of apartment blocks, there may be a hundred or more equal sections on which work is organized as a flow line. This involves a form of repetitive work. Even if the working sections are not equal, they will be of the same magnitude for each separate gang performing one or more operations. There is thus a form of organizational repetition which is essential because it results in higher productivity as the work goes on. There is also a training effect caused by the working together of separate men in each gang and the separate gangs. Further each gang is specialized in one or more operations.

The theory described in section 3 is used for correction of basic times in planning. A special measure stick has been worked out which the planner uses to make out the total time, including correction, on the planning sheet when the basic time consumption is known. Measure sticks for different gang sizes and different "halving times (L)" are worked out.

In practical planning, experience has shown that the work on the first working section will often start at half speed, i.e. a working rate 100% higher than the basic rate. This means, $B_0 = 0$ and a time correction for the gang time equal to L. The time correction thus always refers to a certain gang size and the total time correction in working hours is L multiplied with the number of men in the gang provided the work starts at half speed. This corresponds with the point 0 on the measure stick. If it is judged that the work should start with a speed slower than half speed, the starting point should be moved to the left from point 0. This means $B_0 < 0$. For instance $L = 50$ and a working rate 200% higher than the basic rate gives $B_0 = \div 33$ and total correction in gang time equal to 70. Moving to the right from 0 on the stick means starting with initial speed higher than half speed.

The measure stick is thus simply used as a means of distributing a time correction in the initial part of the process. It is easily observed on the time scale when the process has reached its normal basic rate.

The follow up of the planning is an essential part of the planning itself. Graphical comparisons between planning and results are used. This enables the planner to work out new basic time rates and compare these with the rates used in planning. He may also compare the correction made in planning with the actual extra time used at the beginning of the job. Thus both parameters L and B_0 may be determined for the different gangs. These statistical data will give the planner better judgement and better planning data.

Examples of the effect of training

The effect of training varies greatly for different types of work. Some work may be more or less steered by machines, hence the influence of training will not be great if the machine operators are skilled. Other work is more dependent on manual labour where the training effect will be more influential though there are great variations also here. As an example let us take a look at some

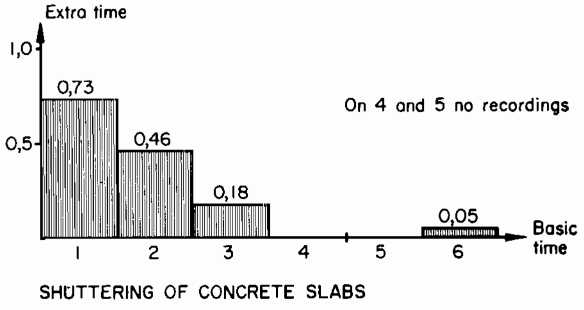
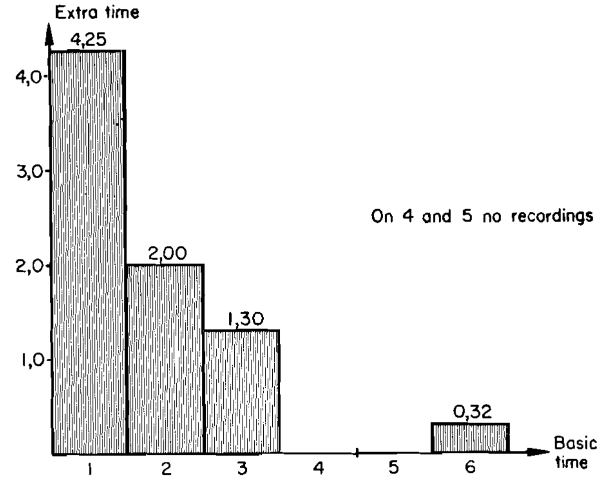
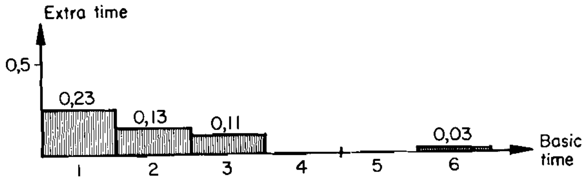


Fig. 4. Recorded extra time on different floors for shuttering of concrete slab.

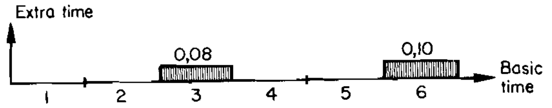


ERECTING PREFABRICATED COLUMN SHUTTERING

Fig. 5. Recorded extra time on different floors for erection of prefabricated column shuttering.



6a SHUTTERING FOR STAIRCASE WALLS



6b POURING CONCRETE FLOOR SLABS

Fig. 6. a) Recorded extra time on different floors for shuttering work in staircases. As the work is performed traditionally with trained labourers and with very little working space only a small effect of training is recorded. b) Recorded extra time for pouring concrete slabs. The work is steered by the crane which requires more time as the height of the building increases.

recordings in connection with an office block. The concrete construction involves a flat slab on columns. The shuttering work was recorded for the slab itself, the column heads, the edge girder and the column shuttering. The result is shown in Fig. 4–6. Only extra time is recorded as the basic time is put equal to one.

Fig. 4 covers ordinary slab shuttering work of large quantities with many types of repetitions. Fig. 5 covers work with prefabricated shuttering for columns, evidently the effect of training is much greater here. Fig. 6a covers more complicated work with very little working space in staircases, hence there is no great effect of training. All work is performed by skilled labourers.

Fig. 6b covers the pouring of concrete slabs with crane. This work is steered by the crane, hence no effect of training occurs. Instead there is a slight increase in time consumption which may be explained by a lowering of crane capacity with height.

Evidently, there are great variations in the effect of training for different types of work. One thing which can at present hardly be measured, is the influence of planning and the steps taken by management to influence the organization and execution of work. In one case, 790 working hours were used in erecting loadbearing walls and floors for a housing block. The next block which was equal in size and construction was erected with the use of 580 working hours. For this block management had tried to improve work organization, using more specialization and trying to eliminate double handling and waiting times.

Conclusion: Experience gained in planning building work and in work measurements on sites has shown that time consumption decreases as the job goes on. This is referred to as the effect of repetition, or, as preferred by the NBRI, *the effect of training.* This effect is influenced by the organization and the specialization of the work, the repetition of working sections and the repetitions involved in each single operation.

For planning purposes it is preferred to compute time consumptions with reference to processes where no training effect occurs. Consequently, the time consumption rates used are referred to as basic rates. Corrections should be made for starting up the processes. This means that the job always begins with a timeconsumption rate larger than the basic timeconsumption rate.

The correction is computed with reference to the basic time in such a way that the correction is large at the beginning of the process and decreases as the work goes on. So far experience has shown that the time consumption rate at the start of the work is often 2 times the basic time consumption and that it will take 1–2 months before the process reaches the basic stage.

However, more experience is needed for a safe use of the method described and more data will be available in the future.

In order to use the method described, the planner must have knowledge about the basic standard rates. He must then choose the initial time consumption rate and the total time correction to be made for the process. A follow up is necessary to gain experience in using the method and work is going on in this direction.

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Home building productivity research

By R. J. Johnson (U.S.A.)

The National Association of Home Builders is a voluntary, non-profit trade association organized for the purpose of serving the home building industry. We have approximately 44,000 members in about 380 affiliated state and local associations. The builder members of this association construct about 1,100,000 single and multi-family dwelling units each year.

One of our principal programs is research which has as its objective the development of information and ideas that will assist the industry to produce a better home for a lower cost. This program is carried out through the Research Institute of NAHB and consists of special field studies, laboratory research, industrial engineering studies, cooperative research and development work with manufacturers on materials and products, and the design and construction of research houses. In 1964, the National Association of Home Builders formed a wholly-owned subsidiary corporation, known as the NAHB Research Foundation, Inc. The Foundation began operations January 1, 1965. Its Board of Directors consists of 17 men, six of whom are selected from among non-members of NAHB to represent broad related fields of interest such as architecture, education, finance, building codes, public communications and science. The Foundation performs all of the research and related services for the NAHB Research Institute. It also performs sponsored research, testing and development for the home building industry.

The character of the home building industry in the USA

An appreciation of the changed character of today's home building industry in the United States of America is fundamental to understanding the reasons for, and potential benefits of this study (hereafter referred to as TAMAP – Time And Methods Analysis Program).

There has been more change in the character of the home building industry in the U.S. since the end of World War II than in the preceding 2000 years. Before World War II, most of the houses were built on a "sold basis" for a "known buyer" at an unknown or at best a negotiated price. Builders built these houses one at a time, cutting and fitting thousands of little pieces at the job site to make the product. This process involved six to nine months or even a year, and the home buyer made many product decisions.

Then there was really no home building industry. There was a home building craft. Today, almost the reverse is true. Approximately two-thirds of the new single family homes are built *for sale* to an "unknown buyer" at a predetermined price. Builders are assembling houses on a manufacturing kind of basis – in many cases using large component parts. Typically this is accomplished in 30 to 60 days.

Today's new breed of home builder has much more in common with manufacturers than he has with the pre-war builder. Today's builder, like a manufacturer, creates an entirely new product *for sale*. The builder engages in repetitive operations. Even simple operations may be jigged to lower the required skill and improve quality and productivity. Like manufacturers, the builder uses many types of production tools and mechanical equipment.

Today's builder is a businessman rather than an artisan. He is management oriented, production oriented and sales oriented. He has an organization of competent specialists. Like manufacturers, he is concerned about his image and what his customers think about him and his product. He does this because he intends to stay in the home building business. He buys a volume of materials, inventories them, frequently performs shop operations on them, and schedules their delivery to the site. He is concerned about efficiency, productivity and the whole construction process. The builder makes the design and the product purchasing decisions. He makes these to the very best of his ability in an effort to satisfy his customer – the home-buying public. The desire to excel accounts for some of this change.

The pressure of competition is the real stimulus. In this home building climate, the findings of TAMAP have great potential.

A severe price squeeze is superimposed on these fundamental changes. The competition between builders and for other goods and services is severe and getting more so every day. No builder or no manufacturer has a monopoly or anything like it on any house, product, equipment or tool. The buyer has many choices. The builder is confronted with sharply rising land costs, gradually increasing wage and materials costs and high sales and financing costs. The manufacturer is confronted with severe competition for all of his products; a difficult marketing and distribution system; ever increasing pressure for additional models, colors, thicknesses, weights, textures, and functions of products; and rising labor and materials prices. Both builders and manufacturers are faced with many cost increasing problems which, for the most part, acting alone they can do little about. For example, industry wage rates, basic material prices, land development standards, or local code requirements are all cost increasing factors which the individual builder or manufacturer can do little about. Actually what both the builder and manufacturer need is something which they, themselves, can do to lower their installed costs. It was in this atmosphere that Project TAMAP was developed.

Description of the study

Since its establishment in 1952, the NAHB Research Institute has recognized the need to improve productivity to reduce cost. To know whether cost can be reduced, it is necessary to know precisely what costs are, in terms of labor and materials.

Since before the turn of the century, industrial engineering, or TAMAP as we are calling it, has been recognized as a useful method to reduce cost in factories. However we, like most people, doubted that it was applicable to site conditions. In 1960, we applied industrial engineering to the installation method of a new kitchen cabinet system in the Research Institute Laboratory. To make a long story short, the installation time was reduced from 25 man hours to 7 hours and 32 minutes.

About the same time, the Research Institute, in cooperation with the Stanley Works, studied the construction of 14 component panel houses with industrial engineering techniques to compare this method with conventional construction and to try to determine the applicability of industrial engineering to home building. We decided that industrial engineering techniques were applicable to home building.

In January of 1961, the Research Institute agreed on a cooperative basis with The Stanley Works, New Britain, Connecticut, and builder Mr. Bob Schmitt, Berea, Ohio, to undertake a full-scale, 2½ year study of the entire construction process for a house – first, built "as is" and, second, "as modified" by the result of the first year's study.

Now, how was the study actually done? The study team was headed by a chief industrial engineer and consisted of a materials analyst, five work study analysts, and a photographic specialist. More assistance was supplied by additional architects and engineers from the staff of the NAHB Research Institute and Mr. Schmitt's organization.

The five work study analysts were trained as a group in work measurement and rating. There was one work study analyst for each workman. The analyst recorded with a continually running stop-watch exactly what the workman was doing and the amount of time it took him to do this job. He also rated the work pace of that worker so that *normal* times could be established.

A fundamental part of time study is the rating of the worker. With training and practice, the rate at which people are working can be determined readily and accurately (within plus or minus 5%). The base 100 is used as normal and ratings are made on a percentage scale to convert *actual time* to *normal time*. For example, 4 minutes actual time at 125% rating equals 5 minutes of normal time because the man is working faster than normal. Then it is customary to adjust *normal time* by a factor reflecting necessary items such as personal time, fatigue and unavoidable delays to convert *normal* time to *standard* time. After deducting the actual time of these items on the job (personal time, fatigue and unavoidable delays) from normal time, 25% was added to adjusted normal time to obtain the *standard* time. (In American industrial practice, a 17.5%–22.5% allowance for these items is typical in factory situations.) Thus, it is possible in one study to obtain accurate, practical man-minute times for work. All labor times are reported in costs, for convenience, using 5 cents per man minute – $3.00/hour for all men. This is not far from the actual average and greatly simplifies reporting and analysis.

While the timing crew was being trained, two men were on the site studying the builder's organization and his building process. Multiple activity charts were prepared. A special schedule was prepared describing what was to be done by all of the men on the job, each hour and fraction thereof, during the whole construction process.

In addition, a written detailed description of every operation required to build the house was prepared. During this time, the builder's supervisors and managers were acquainted with the objectives and procedures of the project.

During the entire construction process, the work study analysts recorded exactly what each workman was doing and how long it took, along with the pace rating. Work was broken down in the smallest elements possible—as little as 0.02 of a minute. Of course, idle time, personal time, and waiting time was recorded and identified.

We have over ¼ million work element observations for the construction of each *before* and *after* house. This makes it possible to put back together all of the cost elements in precise detail, so that exact costs can be identified for any operation. We know, for example, that on the average it takes 0.16 of a man-minute to obtain, position and drive a 16d nail and that it takes 0.07 of a man-minute to obtain, position and drive a roof shingle nail.

We also recorded several thousand random work samples in other parts of the development to compare performance on the whole with that on the TAMAP house. In general, this substantiated performance on the TAMAP house as typical for the entire subdivision.

At the same time, all material was accounted for. The data recorded for material included the material description, model or type, supplier, manufacturer, size, amount delivered, amount used, amount of waste and scrap, unit cost, cost per house, how it was used, how it was handled and the movement of the material on the site.

In short, we determined precisely how much of what kind of material was used and how much it cost. For example, we know that in the construction of the first house there were 45,330 nails, screws, and staples, but we only used 34,603 in the second – a very significant reduction.

The basic objective of the whole study was really to solve problems. Problem solving is a 6-step process consisting of (1) gathering the facts; (2) analyzing them; (3) identifying and defining the problem; (4) selecting a solution; (5) trying it out; and (6) using it if it is practical. So far I have described the gathering of facts.

The second step was to analyze these facts on the first house. The data were organized in a form relatively easy to evaluate and more than 200 apparent problems were identified. Some of these were identified during the work study. For example, we determined that a very large percentage reduction in the time for finish trim could be obtained with a sharp plane compared to a dull one. This identified the problem of *how to have and keep sharp tools*.

A critical questioning attitude during the building operation identified wasted plywood for roof sheathing as a *design dimension* and *cutting* problem. Detailed observation of the truss assembly process identified this as a *methods problem*. The time used by the supervisor distributing the foundation blocks, two at a time from a central pile near the foundation, identified a *materials handling and a supervision problem*.

The data identified high ratio of concrete to labor cost in the foundation and slab work. This highlighted a *materials cost saving* potential. *Engineering analyses* of the wiring system and foundation was another method of identifying problems. In addition, problems were identified in the category of scheduling, supervision, production control, inventorying, purchasing and use of materials. In effect, we used a critical questioning attitude with respect to almost everything by asking the questions:

What is achieved?	Why is it necessary?
Where is it done?	Why there?
When is it done?	Why then?
By whom is it done?	Why that person?
How is it done?	Why that way?

Once the problems were identified, Mr. Schmitt, his assistants and workmen, reviewed them with the study team. Many of the solutions were developed by the builder's men, with the help of the study team, and for a very good reason. When the problems get solved by the supervisors and workmen, they are much more apt to stay solved.

The same detailed procedure was applied to the second or "after" study house. It was basically the same as the first house except for a few material and design modifications the builder wanted to incorporate, and for the differences suggested by the solutions to the "before" house problems.

Detailed analysis of the data from the second house identified more problems. Some are new, some, of course, are the same old problems that were not solved on the first house. And so, this process of improvement can be a continuing benefit in reducing costs, identifying better methods, and achieving the highest value possible.

Some of the solutions must wait for new tools, new materials, new products, better handling equipment, and many other items over which the builder has no direct control. To the extent possible, the NAHB Research Institute is trying to identify these items for manufacturers.

Everyone connected with the project thinks the results have been startling. We have identified dozens of items and several hundred dollars worth of cost saving opportunities. We know that many people would like to have identified a particular figure representing the cost saving difference between the first and second houses. Frankly, this figure cannot be made available. It is the builder's private business. More importantly, it is not necessary to have this figure to gain all of the benefits from this study. The actual figure is not applicable to any other house or building operation in the country but all of the principles and many of the examples are valid for other home building operations.

This was a special study. It involved about ⅓ million dollars worth of time and direct expenditures on the part of the participants. A study as detailed and comprehensive as this is not necessary for any builder or any manufacturer to identify for himself a number of very useful facts – facts which will help him reduce his costs or produce a better or more competitive product. It appears to be relatively easy to obtain the first one-third to one-half of the potential cost saving. The subject and methods are not so complicated that professional builders need special training. In the beginning the builder needs to obtain some detailed facts on time and materials and methods for any part of his operation which he suspects is most subject to improvement. Then he can analyze the facts, select a solution, and compare results. Manufacturers, on the other hand, will generally need detailed studies of the entire installations process, on-the-job, of their product to obtain the information necessary to make their products more competitive.

Description of the study houses

Both houses were identical except for the changes in methods and a few minor design and dimension changes identified as desirable to achieve better productivity in the construction of the second house.

Each house was 24 ft. × 52 ft. – 1152 square feet of living area, with a 10 ft. × 24 ft. attached and covered breezeway and a one car garage 13 ft. × 22 ft. They have three bedrooms, one and a half bathrooms (the "half" bathroom has a lavatory and water closet and plumbing "roughed in" for a tub or shower), living room, dining room, kitchen and utility area. In addition, they have ample closets and interior storage area. They are concrete slab-on-grade, one story frame houses, sheathed with plywood and covered with horizontal siding. The roof trusses have a 4/12 pitch and are covered with plywood sheathing and asphalt shingles. The interior is covered with gypsum board and both interior and exterior is spray painted. They have perimeter heat ducts and a counter-flow, hot air system. The breezeway and garage attached to the home provides a basic "L" shape. The homes sold for $16,700.00 each including a $4,000.00 lot, dishwasher, refrigerator, garbage grinder and built-in countertop range and oven. It is well insulated and the price includes insulating glass in all windows.

The volume of liveable space is 9216 cubic feet (8 foot ceiling height). For comparative purposes, the volume of space in the garage (8 feet high) may be considered at $\frac{1}{2}$ actual volume or 1144 cubic feet and the volume of the breezeway may be considered at $\frac{1}{3}$ actual volume or 640 cubic feet; thus making a total equivalent volume of liveable space of 11,000 cubic feet (311.5 cubic meters).

Results

Many significant and surprising facts were determined. For example, the materials to labor ratio (at $3.00 per hour) was about 4 to 1 for the direct costs of construction for both houses. (The direct costs of construction consists of labor and material costs directly assignable to the construction of the house. It does not include indirect costs (which are minor), overhead, sales cost, financing cost, land or general and administrative costs.) On the "before" house, some $270.00 worth of materials were wasted or scrapped and there was almost 85 man hours of "down time" (waiting for equipment, tools, assistance or instructions) on the "before" house.

The labor hours summary may be particularly interesting to the delegates at this Congress since my own experience in talking with many European builders, engineers, architects and scientists concerned with home building indicated their great concern with labor hours. The builder had built a number of houses similar to the TAMAP homes and had estimated the total direct time for construction of this home to be 776 man hours, not including nine relatively minor categories of labor which were typically subcontracted. The actual man hours required for the "before" house was 390 which because the pace of the workers was above average equaled 459 standard man hours. In addition there were 147 standard man hours of subcontracted work or a total of 606 standard man hours. This is equal to 1.95 man hours per cubic meter of equivalent liveable space and includes pouring the concrete driveway and all site work on the lot except a very minor amount of rough grading which was considered a part of indirect costs.

The "after" house required a total of 560 standard man hours or 1.8 man hours per cubic meter of equivalent liveable space.

The apparent large reduction of 317 man hours between the estimated amount and the actual measured standard man hours may be due in part to an inaccurate original estimate but must be primarily attributed to two items—preplanning and supervision. The written description of work to be done—prepared for the convenience of the study crew and to enhance their accuracy—greatly aided the supervisors in their work planning. In addition, although the time study analysts made no comments to the workmen, they did indeed provide a mild form of supervision.

The 46 man hour improvement between the "before" and "after" house was due to many small cumulative improvements. This improvement is no fluke or merely the result of the special study. The builder is continuing at this level and even making additional improvements in productivity. It should be pointed out that the large apparent improvement in man hours is not net, since none of the time of the study crew is included in the overall total. Nonetheless this study and many subsequent smaller studies demonstrate that productivity of even efficient building operations may be increased by the application of industrial engineering to site construction. A number of builders in the U.S. have retained industrial engineers to work full time and they report that total cost reduction exceeds the added cost of the industrial engineers.

Most surprising to many was the relatively high cost of materials compared to labor and the opportunity to save materials by preplanning their use. This high materials/labor ratio held even for plumbing 4 to 1, electrical about 3 to 1 and heating about 9 to 1. The only significant operation where the materials/labor ratio was reversed was in nailing. There the ratio was about 1 to 4 except for finish nailing (including setting the nail and puttying) where the ratio of materials/labor increased to 1 to 13. This by the way highlights an unusual opportunity for manufacturers to devise a lower labor cost method of installing finish trim—a satisfactory contact adhesive may be one answer.

One of the most dramatic materials cost savings between the "before" and "after" homes was effected in the footings, fill and slab construction, where the total cost reduction was $150.41.

The application of engineering analysis to the footings reduced their width and saved $57.26 worth of concrete as well as $2.03 worth of labor. Careful grading of the layers underneath the slab to use the most soil possible and the least amount of stone (gravel) to comply with the specifications saved $28.26 worth of stone and even saved $3.60 worth of labor.

On the "before" house it was noted that the materials/labor ratio for pouring and finishing concrete was 12.2 to 1. Further analysis showed that the concrete used exceeded the theoretical amount required considerably—probably because the average thickness of the slab was greater than required because of inadequate attention to the final elevation of the subgrade. So in the "after" house the subgrade was carefully carried to its correct elevation and this netted a concrete saving of $86.46, but extra labor costs (which were later reduced) reduced this net to $69.26—a total saving on these three items of $150.41.

There are many other examples of cost reduction: The use of exterior wall panels fabricated in the builder's shop saved $32.92; the fabrication by the builder of roof trusses in his own shop saved about $85.00 on the "before" house and about an additional $25.00 on the "after" house due to improved methods of truss fabrication; a new method of laying shingles saved $14.85; balancing the siding crew and allowing only one man to cut siding saved $61.06, three-fourths of which came from the reduction in amount of siding scrapped and wasted; minor changes in roof dimensions and preplanning roof sheathing layout saved $26.35 worth of plywood roof sheathing; preplanning the electrical distribution system and other related changes saved $33.90; and even $16.43 was saved by utilizing short base trim pieces in the closets instead of a supposedly lower cost but extra 1″ × 4″ base trim material. These are but a few of the examples of savings.

However, these examples only illustrate a specific case documenting the opportunity to improve value by the application of fact finding, analysis, problem identification and solution. No two builders have exactly the same set of conditions under which they build so we have tried to devise principles from these studies which may be applicable to most, if not all, home building operations. Although our work in this field has only begun, we think the information obtained so far provides a good basis for setting forth the following principles:

1. Provide adequate and good supervision. There was good supervision to start with. But the supervisors thought they were contributing to productivity by working some themselves. This was a mistake. The supervisor should not try to be a part-time worker. He should neither try to be a procurer of materials nor be charged with that responsibility. He must have time to have a clear plan in mind and on paper of exactly what is going to be done, when, and by whom. This leads to planning.

2. Prepare a written detailed description of the entire construction process including a work time schedule. Foremen, supervisors and management need to cooperate in the work plan preparation. In addition, a multiple activity chart is useful. This is just a brief daily schedule, hour by hour, of what each man is going to be doing including an alternate for bad weather. This also provides an important production tool if materials, tools, equipment and number of men are included. A brief written instruction, handed to each man at quitting time, describing what he is to start doing the next morning saves wait time, make ready time, and clarifies start-up job duties.

3. "Work" the plan of the house. Eliminate all unnecessary pieces of material and plan dimensions to reduce waste and scrap. Use modular dimensioning wherever possible. Lay out plan to large scale (1″ = 1′ – 0″) and, for example, position each stud.

Then determine whether it is actually needed. In the TAMAP study approximately $76.00 worth of unnecessary studs and labor were removed from the "after" house. An important part of working the plan is setting up an information feedback system from the site to the drawing board. If unnecessary pieces are being used or wasted or if there is a poor detail, the foreman or supervisor should be responsible for observing this and reporting it back to the office so that the plan can be changed.

4. *Make an engineering analysis of the design and use of materials.* Make certain that the least amount of the highest value (not cost) material, for the intended purpose, is used. If overdesign is required, make certain there is a reason, i.e., market demand, codes, design life, etc.

5. *Examine materials.* Make a complete materials list for one house. For each item, record the material, its description, model or type, supplier, manufacturer, size, amount required, unit cost, cost per house and, if available, amount used and amount wasted and scrapped. Begin with the highest total dollar figure and ask questions about each item, such as: Why use that quality? Why buy it from that supplier? Is there another way to accomplish the same task with other types or sizes of materials? Is that grade necessary? In short, try to reduce total materials cost.

6. *Determine the total man hours by major phases or parts of the operation.* Do this from the multiple activity chart, work description, time cards or previous experience. Start with the large time categories and make a check – a wrist watch is accurate enough in the beginning. Then ask questions such as: How much time does it actually take? Do the men appear to be working efficiently? Do they have to wait for instructions, materials or tools? Could some of the operations be done better some place else? Is the crew size too big or too small? There are numerous examples which seem to indicate that productivity is usually increased by reducing the number of men doing a task. Try to reduce crew size.

7. *Analyze materials/labor ratios in those operations where there is a relatively high dollar volume of either materials or labor.* In cases where the ratio of materials to labor or vice versa exceeds three or four to one, the chances are good that some total dollars can be saved by spending a little more on the low-cost portion or by special attention to the high cost portion.

8. *Study the entire method of buying and controlling materials.* In the TAMAP study and within the framework of building materials distribution and sale in this country, substantial savings were made on the "after" house. This was accomplished by establishing a materials puchasing corporation, using a warehouse to store materials and fabricate components and by placing all materials purchasing responsibility in one man. In manufacturing, the profit potential in a 4% reduction in material cost is equivalent to about a 20% increase in sales. Or, put another way, in the TAMAP houses, a 6% reduction in material cost was equal to about a 25% reduction in labor costs.

9. *Reduce materials handling costs.* In most manufacturing industries, the labor for handling materials represents about 20% of total labor costs. In home building, we suspect, from the TAMAP data, that this is about 40%. Since materials handling costs add nothing to value and are relatively high, give special attention to their reduction. Where possible, use mechanical equipment and buy palletized, wrapped or strapped materials and *have them delivered as close to the actual point of use as possible.* In the "after" house, many materials handling benefits were achieved by careful planning. The builder subsequently developed a "phase" or "job" box system. Boxes were made-up containing all the tools and materials needed to complete a task whether it was stake-out or electrical installation. The box is made-up in the shop, delivered to the site by fork lift truck at the right time and returned minus materials but with tools. This is done for all operations except those with a very large volume of materials, like framing.

10. *There are a lot of little things that, together, are important.* Try to encourage the men to use sharp tools. Ask them to build or provide for them an organized tool box. It took twice as long, on the average, to find an occasionally used tool as to use it. Encourage the men, particularly the foremen and supervisors, to keep thinking about finding a better way to do the job. Provide the carpenters with leather pouch nail bags and show them the advantage of wearing it on the side instead of on the front.

Try to work out a system wherein the foreman or the men, or both, report labor times in somewhat greater detail so more facts will be available to you for analyzing and comparing costs.

Use a box for all waste and scrap. It keeps the job neat and easier to work on and highlights the material waste problem. Tell the foreman and the workmen how much materials cost to try to encourage more respect for materials.

Conclusion. We believe that almost every builder and manufacturer can find some benefits in this study. In the last analysis, industrial engineering is fundamentally an attitude of management – top management – which says: "There is a better way to do it and that way can be found if the facts are obtained, analyzed, and acted upon." To this I would add what every professional builder and manufacturer knows – namely, that he can find many small cost saving ideas by studying his own operation. We believe that the big story in TAMAP is that it demonstrates that the sum total of these savings can be large enough to substantially improve productivity. As such it deserves the serious attention of top management – the builder and corporation president.

M. Kaczorowski and W. Czajka

Objective expenditure in industrialised and traditional house-building

By M. Kaczorowski and W. Czajka (Poland)

The concept of industrialised building is understood in various ways. Rationalisation, the introduction of chain work, mechanised site operations and the use of large prefabricated components are quoted as distinctive features of industrialised building. Qualitative premises and the fact that the aforementioned methods are applied appear inadequate for appraising the characterising feature of production. We propose therefore to establish the development of industrialisation on the basis of the economic and technical factors characterising the significance of applying the appropriate technology to industrial production. The bases on which such factors should be worked out are the amount of factory prefabricated component units used for erecting the building, reduced site work and the attendant freeing of building technology from certain effects of product fixity. These factors express the ratio between the amount of work put into product "a" and the total work (operating and incorporated into the product) "b", measured on the site according to the formula F = a/b (1) (This work operates on the site; it was put in at a previous stage, incorporated into products supplied to the building site, and also into the equipment used for assembling components in the building). a and b are usually worked out in relation to the cost of operating work incorporated into the product. Synonymous values are thus obtained, fully comparable, providing a sound basis for economic calculation. But to effect a correct calculation, prices should refer to real costs, at the same time as being balanced prices. The price system in Poland does not meet this requirement. For this reason it has been suggested that expenditure should be estimated in relation to "work calculation" (2) (a proposal put forward in respect of socialist economy by A. Bebel, O. Leichter, and in the Soviet Union by S. Stroumiline and Warga) that is to say, to the calculation of objective expenses incurred on the building site according to actual working hours spent on producing the materials used on the site. This value may, of course, be added to operating work hours. (3) Following Polish nomenclature, continuous labour expenses include work done by workmen of the so-called "industrial" group, viz. directly employed on production. Expenditure on work that goes into turning out the product is calculated as working hours, per production unit, by adding up actual hours without applying any sort of coefficient to reckon their paid value. Expense calculation is effected on the basis of index numbers of modern concerns in different fields of activity.

Table 1 shows value F registered for five buildings of various types.

TABLE 1.

	Building* No. 1	2	3	4	5
Coefficient F	17	10	17	30	40

* Building No. 1: Load-bearing partition walls brick-built, floor made of small size prefabricated components;

Building No. 2: Homogeneous walls and floors;

Building No. 3: Load-bearing partition walls made of cast concrete, floor made of large blocks (0.24 × 1.20 × 1);

Building No. 4: walls and floors made of large blocks (as above);

Building No. 5: Walls and floors made of large panels (of room size).

The table indicates that the limited use of large components (building No. 3) is not enough to obtain higher coefficient values. The higher values are found in buildings made entirely of large components (buildings Nos. 4 and 5). An analysis of construction in progress, assuming that the heavy structural work is carried out on traditional lines, admits of the assumption that 60% is the limit value for the attainable coefficient F as large panel building improves.

Technological efficiency. The estimation of the economic efficiency of industrialised building methods depends on two values: the effective value obtained and that of expenses.

Effective value. Designers and builders of houses erected according to industrialised methods aim therefore at obtaining the same effective values as in traditional building.

This end is rather hard to achieve as freedom is reduced in relation to lay-out of accommodation; such lay-out shows less flexibility and is more difficult to fit to household requirements. Microclimatic conditions in concrete-built surroundings and their effect on occupiers' health and comfort have not been definitely ascertained.

The problem of the moisture-proof behaviour of large component external walls is still at issue. It is nevertheless to be expected that the effective value for dwellings built on modern lines will not only equal but actually exceed the standard obtaining in houses built on traditional lines, when designers and contractors have mastered the new technology. On this assumption the economics of modern building are going to depend very much on the volume of work put into house building and occupation, including technical maintenance.

Expenses in operating work and in product-incorporated work

The main coefficient for the running expenses of a building consists of the aggregate sum of labour employed on the building site and elsewhere. Changes in the ratio between labour spent on the building site and labour spent elsewhere, alter in the ratio of materials used; reduction in building weight and cutting down the building cycle may also be of advantage. It is a fact that industrial building requires more skilled labour (63.1 %), and semi-qualified labour (24.3%) than building on traditional lines (59.6% and 22.2% respectively). Nevertheless the qualifications required nowadays of building workers (operators, assemblers, welders) are gained in less time than those of craftsmen (carpenters, masons, plasterers).

As regards running expenses, maintenance and heavy repair work, adequate experience is still lacking to appraise the trend of evolution in this field.

Among the advantages enumerated early in this paper stress should be laid particularly on higher productivity. This increase is due not only to the reduced number of operations (on account of the greater dimensions of component parts) and to mass production of components, but also to generalising repetitive site work, through frequent repetition of the same building made of the same component units. Such a system allows a rise in average productivity amounting to 20 to 30% as compared with the building erected in the first place, thanks to work in rotation, particularly at the assembling stage. This reduces considerably the building cycle.

The figures shown in Table 2 illustrate expenses incurred in the erection of the five afore-mentioned buildings. These figures, which reveal the virtues of the various techniques, are based on research carried out by the Housing Institute in Warsaw.

Other conditions governing the development of industrialised building

The advantages of industrialised building may be turned fully to account by

– 1) its concentration in greatly developing areas where building is very active and where the lack of labour is keenly felt. The reason is that it is easier to muster a labour force in self-contained continuous production firms than on building sites. It is easier too to organise in such centres continuous mass production of building components, and to carry them from the factory to the building site lift without unloading;

– 2) the concentration of building operations on sites;

– 3) the discriminating choice of the technology for the production of large-size components, suited to local resources, so as to curtail transport of mass-used heavy building materials (broken stones, ceramic products).

TABLE 2.

Building No.		1	2	3	4	5
Expenses per 100 sq. m of useful surface*						
	expenses for materials					
Expenses:						
concrete in prefab components	cub. m	3.9	2.7	18.0	32.0	39.0
	%	100	100	461	820	995
cement (total)	kg	13200	14800	18300	19000	18600
	%	100	113	139	144	141
cement in prefab components	kg	1200	800	6500	10000	10900
	%	100	67	542	833	908
steel (total)	kg	1650	1370	1450	1890	2100
	%	100	83	88	114	127
steel in prefab components	kg	290	200	950	1400	1600
	%	100	70	330	480	550
bricks	pce	14200	3000	3000	5300	1900
	%	100	21	20	37	13
	labour expenses					
Operating work on site	r-g	2830	2720	2430	1800	1150
	%	100	96	86	64	41
Work incorporated into product	r-g	560	290	500	770	870
	%	100	52	89	138	158
Labour (total)	r-g	3390	3010	2930	2550	2200
	%	100	89	86	75	65
	power expenses					
power	%	100	52	66	88	64
	capital outlay**					
Cost of contracts and equipment in % (capital outlay in production)		100	46	82	121	151

* The useful surface of dwellings means the total area of all floors of the dwelling (all rooms, passages, toilets, bathrooms and kitchen)
** Condition the increase in building production.

No reduction in industrialised building costs has been registered in Poland in the course of the first phase of application of modern technological methods. Such methods have, in fact, caused them to rise in relation to useful area (expressed in terms of prices paid by the proprietor), and have not improved product quality. Nevertheless, owing to the State investment scheme, which is big enough to bear temporary losses, it has been possible to pursue large-scale experiments in this field as, all things considered, the new building system promises to be advantageous. Accumulated experiments, the adaptation of new building solutions to the new technology, and their simplification seem to be paying dividends in the way of reduction in operating work per built unit. The production cost of industrialised building is on the downward trend. This tendency makes for favourable conditions for increasing the scope of building production and for a consequent improvement in housing conditions.

C 12

F. Misuraca

C.P.M.—PERT applications on town planning arrangements, designs, and constructions

By F. Misuraca (Italy)

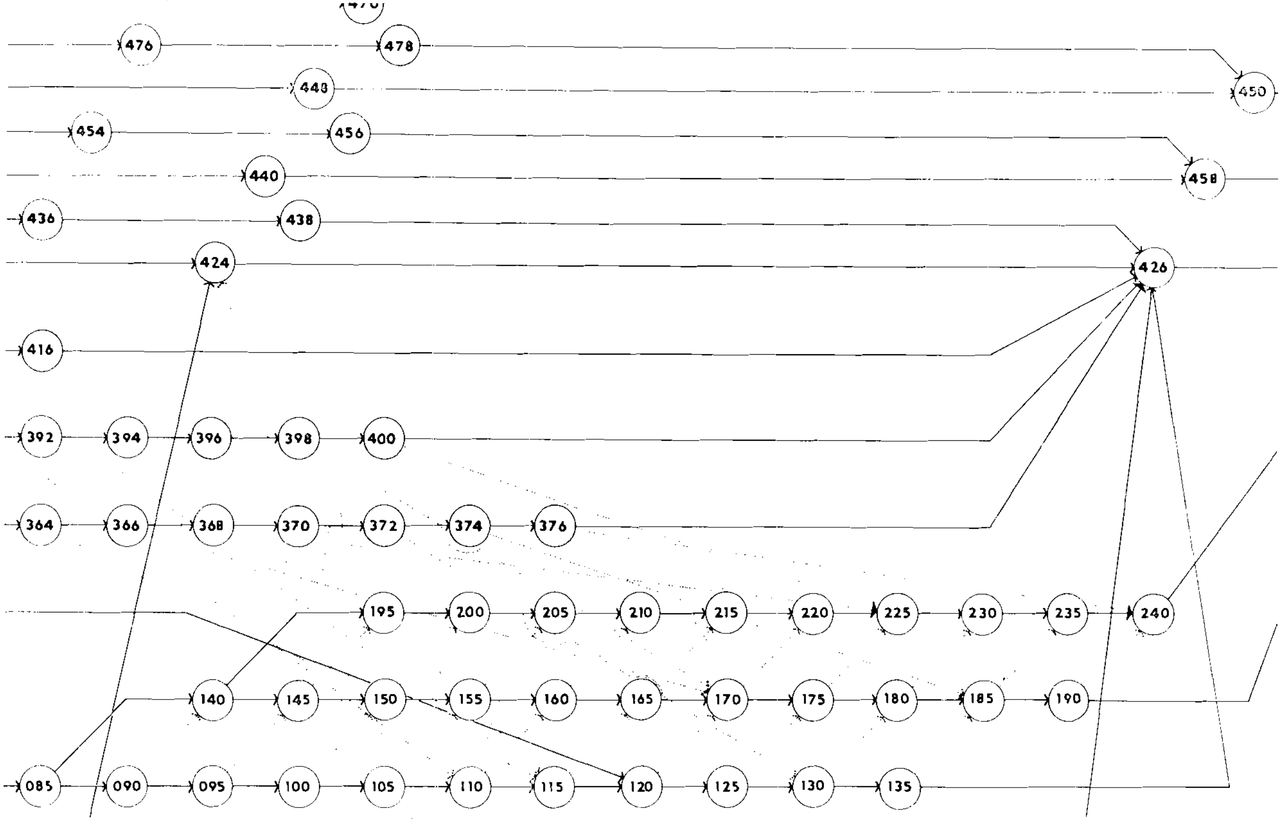


Fig. 1. Part of a *general* PERT. Groups of activities referring to the same operation, as from node 085 to node 240, are elaborated in a separate *detailed* PERT and then, after the convenient modification, re-inserted in the general PERT. Nodes figures are not consecutive in order to insert many other nodes in the detailed PERT.

In the last few years C.P.M. and PERT methods have been applied for the planning of works and for the control, during their execution, both of large and small plans. The results of these applications have always been extremely positive not only for the good development of the work, but also, and in particular, for controlling time and execution costs.

Referring to general building constructions, we have seen that the successive and alternate application of PERT and C.P.M., made on one reticulum and consequently with setting up the program in units on the electronic calculator, has given the best results, making possible the integration of the general planning data, supplied by PERT, with the detailed data of the ratio times/costs given by C.P.M.

Another very interesting application, carried out by Tekne of Milan with our PERT method, concerned the study of the execution times of all proceeding phases for the planning of a large residential district in a town of South Italy. Our experiences on PERT-C.P.M. applications concerned plans and constructions of groups of buildings which were, generally, parts of large industrial districts. Most of these industrial districts have been established in South Italy, that is in zones where their social and geographical structures caused difficulties throughout the realisation of the work: from the choice of the ground to the execution itself.

At first, general PERTs, including concisely all the main phases, were performed. These phases ran from the decision to carry out the installation to the start of the production, considering, not in detail but globally, all the various phases which occur between the beginning and the end of the work. This has made it possible to lay down the working times and, wherever necessary, to suggest the first changes, in order to comply with the difficulties which might rise and which were already envisaged.

From this global project came the study and development of a PERT examining in detail the activity of each group inserted in the general PERT, keeping of course unchanged the times of the group considered, as had been fixed in the general PERT. This allowed a deep and detailed study of the activity of each group such as the research of the ground with its social and economic problems and the necessary technical controls, the working out of the project from general studies to its execution in particular, the construction itself from the foundations to the last finishings, the setting up of the production lines from their examination to their commencement.

In order to examine the variability of the ratio times/costs and to be able to make good choices from an economic point of view, the C.P.M. method is, at this point, applied to the detailed programs described above so as to obtain, in accordance with the customer, the desired results.

These results are inserted in the detailed PERT and then in the general PERT, where a global control is made again so as to guarantee the maintenance of the fixed times and phases during the realisation of the program.

This application of both PERT and C.P.M. systems, made in integrated and successive periods, always using a unic setting-up on the electronic calculator, has given surprising results. It allowed an immediate estimate of the consequences that specific technical and economic choices have on a general program which, as previously said, ran from the decision to carry out an industrial installation to the starting up of the output. These choices are particularly important during the construction of buildings and, in this field, essential both for the planner and the customer.

We have to point out another great advantage of the application of PERT-C.P.M. thus integrated; that is the possibility the customer has to participate in certain choices by supplying him with all the necessary explanations and technical means and showing him, at the same time, the consequences that these choices would have. Thus a closer relation is established with the customer, letting him take part, with a full knowledge of the subject, in the realisation of his project.

Many PERT-C.P.M. applications have been set in installations carried out with industrial housing systems. In these cases the indications and results, from the elaboration of the program, have been essential for the building site organisation and the study of the periods necessary for the prefabricated elements to be ready.

Another application, different to the preceeding ones, but equally interesting, was the execution of a PERT regarding not only all the planning phases but the contacts with public corporations which, in some way or other, were interested in the approval of the executive project, and thus in contacts with the customer. This PERT was drawn for a large residential district that is going to be built at Taranto for Italsider. Italsider is the most important metallurgic industry in Italy and is government controlled. At Taranto (South Italy) Italsider built the biggest Italian metallurgic factory, necessitating the setting up of new residential districts. This zone was the object of an industrial town-plan which called many other industries to the area. About 100.000 inhabitants are forecast for these residential districts.

Since it was necessary to start the works within a short time, a new PERT has been laid down which considered all the essential activities up to obtaining building permission from the municipality. This was necessary because of the great number of people and private or public corporations that, in some way or other, intervened in the procedures.

Working out the PERT, all the critical points sprang up, making it possible to undertake, or let the government authorities undertake, all the necessary steps or law modifications necessary to reduce the time from more than two years to about one year.

Finally we think that the application of both PERT and C.P.M. systems gives specific advantages not only when applied to a single problem, but above all in the case of large constructions, since it allows accurate choices during the preliminary and planning phases as well as precise controls during the realisation. Furthermore it establishes a closer contact with the customer turning this to the advantages of the work.

PERT and C.P.M. are essential instruments even in a whole plan where architects, technicians of all engineering branches, assemblers, economists, financial experts and others rationally take part.

In fact these methods give the possibility of examining in full detail all the single phases of the work as well as of taking, at any moment, all decisions necessary for a good development of the work. We therefore, hope that the elaboration of these programs and the constant application of these methods will be used in professional work such as the elaboration of drawings and the study of detailed execution.

Standard controls for large scale single unit housing

By G. J. Murphy (Australia)

Control has been described as a process of ensuring that performance conforms to the requirements of a plan. Control systems to be effective must be positive, simple in structure and set a realistic standard of performance. They will not be inflexible and will permit, at regular intervals, easily accessible comparison between actual and planned performances and, above all, will reveal causes of variations to enable prompt remedial action. Their application within building organisation fall into a number of categories but can generally be grouped under three main headings:

Finance controls

The limitation of cash expenditure to within the amounts of funds available. These indicate:

- budgeted allocation of funds;
- actual expenditure of funds;
- what are the causes of variations;
- whether revenue expenditure is covered by revenue income.

They are prepared at the beginning of the budget period and will schedule the expected levels of production and expenditure. Comparison of budgeted figures with actual production and expenditure will be made at regular intervals (e.g. monthly) to ascertain variations and their causes.

Cost controls

To ensure money allocated is being spent in the best and most efficient manner. These indicate:

- value of work done during the period;
- actual expenditure on the work done during the period;
- what are the causes of variations;
- for each construction project; what it should cost, what it is costing, and what it will cost in future under a given set of conditions.

These require physical inspection and recording of all constructional stages when the total work performed can be estimated and compared with cost expenditure.

Production controls

To ensure that actual production is up to budgeted level. These indicate:

- budgeted programme of construction for the period;
- actual construction during the period;
- what are the causes of variation.

Production controls are the measure of success or failure of building projects and this paper is largely devoted to the general framework, operating procedures and "on site" application of these controls, which have been successfully operated over several years by the Housing Department of Tasmania.

The housing department

The department is a State Government instrumentality responsible for the acquisition and development of land for housing purposes and the erection of houses. The annual production rate is approximately 600 single unit houses of which 50% (300) are erected by directly employed labour, assisted to a minor degree by sub-contract works. In essence we will be considering production controls of a building organisation employing direct labour with an annual production capacity of 300 single unit houses.

Construction by direct labour (day labour)

In the immediate post-war years the difficulty in obtaining tenders for construction works brought about the introduction of the Department's day labour organisation. This developed in the face of extreme shortages of skilled labour and materials. In early 1954 the Government arranged for a firm of business consultants to undertake an investigation with the object of:

- introducing procedures for accurate cost ascertainment and financial control;
- reduction of material and labour costs per house by improved organisation and production controls.

These investigations resulted in the establishment of procedures which are the basis of controls operating today.

Day labour organisation

The personnel of the day labour building force include a Construction Manager, Supervisors, Standards Section, Estates Clerks, Formen, Leading Hands and tradesmen in all categories.

A central store and timber yard is maintained and within the stores area is contained joiners, plumbers, painters and glaziers workshops. A number of minor sub-contractors are employed but are engaged only when tradesmen are not available and/or to meet temporary increases in production requirements. This process can ensure a constant level of day labour production, as fluctuations up or down can be taken up by sub-contract.

Earlier reference has been made to the three main headings of control (Finance, Cost and Production) and while each is of major importance in the overall administration of the Department, finance and cost controls are largely accounting procedures reflecting the results of production controls. Closely inter-related and forming the basis of all those controls is the establishment of a system of standards.

Establishment of standards

The cost of any building project consists of material-labour-overheads. Each of these can be expressed in the form of standards and for control purposes the construction of a house is broken down into construction stages. The materials and labour required are then allocated to each construction stage.

Material Standards. Material Standards are set for all construction stages, allowances for waste or nearest issuable size being made to cover all normal wastage or breakage. These standards are necessarily broken up into two categories: Fixed items and variable items. Briefly, fixed items are from floor level upwards and contain about 80% of total material cost. Variable items are those influenced by site conditions and include foundations, walls below floor level, drains, paving and fencing. An allowance is made in the materials and labour standards for these variable items for average conditions and can be readily adjusted on issue of site plans. The Standard Prices used are current purchase prices or average manufacturing prices.

Material schedules are kept constantly under review and amended to conform to improved construction methods and/or the introduction of new materials. The value of materials schedules may be seen from the following:

The compiling of issuing schedules is done in the light of what is practical on the building site. Thus, material as well as being issued in correct amounts, will be issued in the correct order, one stage being finished before materials for the next stage are needed.

Requisitioning of materials from store is simplified. Materials are not requisitioned individually but in bulk for the whole stage. The storeman therefore makes up an order in accordance with a standard prepared list. Cartage from store to building site is done with economical loads and sorting of material on delivery is minimized. The progress of construction on a building project is easily checked by examining the stages completed at any time. The Housing Department's materials issue schedules have been developed to a high degree of accuracy when it is seen that of an issue of materials to the value of £ 300,000, the amount actually issued in excess of the schedules was only 0.4%. On a further recent check of materials the excess issues amounted to 0.5% indicating not only the reliability of the issuing schedules but also the efficiency of control of issues.

Labour Standards. This is the most complex of all three categories of cost. For one thing, waste material can be seen lying around, wasted labour is not nearly so apparent and must be tackled differently. From work measurement at construction site, together with the synthesising of times for other jobs, standard times were calculated for each stage of construction. This work measurement established reliable figures for the fair time to be allowed for each stage of construction and provides information whereby different methods of working can be compared. Using these time standards the Department, over a period of some twelve months was able to establish what actual efficiencies could be expected, and therefore what labour costs would result. From this work a labour estimating manual was prepared which shows in detail the man hours, standard wage rate and labour value for each stage of construction.

The man hours allocated to each stage can be readily compared with actual man hours and in fact, this is a weekly procedure – the advantage of having a regular comparison of estimated and actual man hours are fairly obvious and two important factors present themselves, viz. the tradesman knows no excessive demands are made on him and at the same time less than a fair days work will be apparent to the Supervisor.

Using this method of labour standards, the Housing Department has been able to produce over the past years, some remarkably accurate estimated man hours as against actual man hours taken to complete a budgeted works programme. For example, in one year the total estimated labour expenditure was £ 264,943 and the actual expenditure was £ 260,746. Again, on an estimated figure of £ 281,117 the actual cost figure was £ 272,675.

Overhead Standards. The preparation of overhead standards is the function of the Department's accounts section. At the beginning of each financial year, a budget of estimated overhead expenditure is prepared and this is recovered by either a percentage or a flat rate charge on output. These are allocated to cost centres, the object being to spread this expenditure as rationally and conveniently as possible.

Cost centres covering construction overheads are:

Construction (Day Labour) – Flat rate per house

Stores (General) – % on output

Stores (Timber) – % on output

Trade Workshops – % on output

Actual overhead expenditure is readily compared with estimates; the differences if any, showing as under or over recovery of overhead expenditure due to not reaching budget figures in expenditure and production.

Application of standards

Control on the Building Site. Having expressed labour, material and overheads in terms of standards we can now consider operating procedures on the building site.

Control Personnel. Personnel directly involved include: Standards Section. This section, after preparing standards, maintain a constant review and prepare estimates, comparisons and reports for any new house types, new materials or building methods. It is stressed that no variation to standard is permitted until a Variation Order has been prepared and approved. Other responsibilities include checking material issues over or under standard, carrying out field work, checking job times, and discussions with field personnel who are encouraged to submit ideas for reducing building costs. Estates Clerks. This section controls material issues, transport and delivery of materials to individual sites and time-keeping. Supervision. Included in this category are supervisors and foremen who are responsible for control of workmen and the ordering of materials in point of time and sequence.

Operating Procedures – Materials. Upon advice from the construction foreman the Estates Clerk prepares a requisition and at the same time enters the requisition number and date on a Material Issues progress sheet. The requisitions for materials each day are scheduled into truck loads and in proper time and place of delivery. On delivery, the Goods Issued Invoice (G.I.I.) number and date is also entered in the Material Issues progress sheet.

Materials Issues progress sheets ensure;

– Materials cannot be requisitioned twice;

– dates of requisition and delivery are a ready check against any delay;

– materials are set out in sequence of issue and will show up site delay or neglect of foremen to requisition in proper time for delivery;

– Requests for materials in excess of standards are shown separately and can be immediately investigated.

These material excesses are transferred to an analysis sheet and where acceptable reasons are not given the item or items may be subject to further inquiry to establish whether materials have been misused, stolen or rejected as unsuitable.

Operating Procedures – Labour. Foremen for each trade are required to maintain a "Progress of Construction" form for each house unit. This form on the face side indicates the various construction stages, also the actual and standard man hours for each working week. On the reverse side of the form is entered the trademens' names, classification and attendance hours for each day.

This provides the foremen with a ready reference of the efficiency of the tradesmen concerned and these are subject to a weekly review of all trades. Experience has shown that tradesmen do not resent this comparison of actual and standard man hours and tend to show a lively interest in their performance figures.

Upon completion of the various trades, the information is transferred by Estates Clerks to a summary sheet combining all the trades, for each individual house and also for groups of houses contained in a section, thus providing a record of the labour efficiency for houses individually, also in groups, and is the basis for estimating standards for following years.

The use of the term "standard" hours in the various forms may be confusing. It should be clearly understood that the man hours entered under this heading are not necessarily those obtained by time study methods but are in fact estimated man hours based on what actual efficiency could be expected. Over the years "estimated" standards have been progressively reduced indicating the effectiveness of accepting the principle of setting an attainable target with the time study standard as a goal. In most trades this has been fulfilled and in fact, often exceeded.

Operating Procedures – Sub-Contracts. Site control for subcontract works is exercised by the issure of an authority to commence and authority to pay, both being issued by the Site Supervisor. In addition, the Estates Clerk maintains a record of authority for works whether by sub-contract or directly employed labour for each house. This record avoids the possibility of double payment to a sub-contractor for works which may have been carried out by directly employed labour.

Cost-Control. While this control system will not be described in detail, it is of interest to comment on its application as a method of cross checking cost and production figures for labour and subcontract works.

This is obtained by monthly site inspection of all homes under construction to assess the standard cost of work completed, after which, the assessed standard cost is compared with actual cash expenditure for the month. Variation between cash expenditure and assessed standard cost is the measure of labour efficiency and these cost control figures should be comparable with the efficiency indicated by the production control figures. Should there be any marked variation, immediate investigation and remedial action is indicated.

Advantages of control systems

Standards. The standard schedules are the basis of establishing:

– site controls – by providing a practical and attainable measure of material and labour content in a house or building project;

– standard house costs – by the application of material prices and labour rates; works in progress valuations – by valuation at standard cost of the construction stages started during the cost period;

– budget estimates – by the application of standard house costs to the required production output.

Standard Costing. The advantages of standard costing over the former historical costing methods are:

– more reliable costs. Historical costing often penalises an individual project with excess costs. With standard costing, excesses at any cost centre are spread evenly over all projects.

– up-to-date costs readily available. As expenditure is allocated regularly to cost centres true actual costs are available at any time by applying current overall levels of excess cost to the Standard Cost of each project.

– provision of a criterion by which efficiency can be judged. Historical costing methods only tell what projects actually cost, not what they should cost, nor do they permit comparisons to indicate operating efficiency. The standard cost system permits this comparison, so that relative efficiency is constantly under observation. Excess costs are shown up automatically enabling immediate remedial action to be taken.

– control of Changing Costs: Although based on a given set of conditions, standard costs are readily adapted to the effects of any changes likely to arise thus facilitating future estimating.

– purpose. Standard costing, once established, becomes the force which unites the functions of:

Cost Ascertainment

Expenditure Control

Production Planning and Control

Estimating future projects.

Conclusions: The activities of the Housing Department closely resemble those of a normal competitive business organisation constructing houses and there is no apparent reason why these controls could not be successfully operated by others, whether they be Government instrumentalities or private enterprise.

It should not be thought immediate and spectacular results will be obtained but smooth and efficient operation can be achieved if the controls are handled with patience and at all times with the object of setting a practical attainable target within any budgeted period.

The benefits to be derived from these are quite apparent when comparison is made between the Department's prime construction costs on the one hand and rates of pay and material prices on the other. An analysis demonstrated in graph form in fig. 1, clearly indicates that although labour rates have increased by 57% over the period and material costs 46% the building costs have shown practically no increase.

It is important to note that the first controls upon which the procedures now operating were based were introduced in 1954. From that time forward apart from a temporary increase in 1957, building costs have been maintained at a remarkable degree of stability.

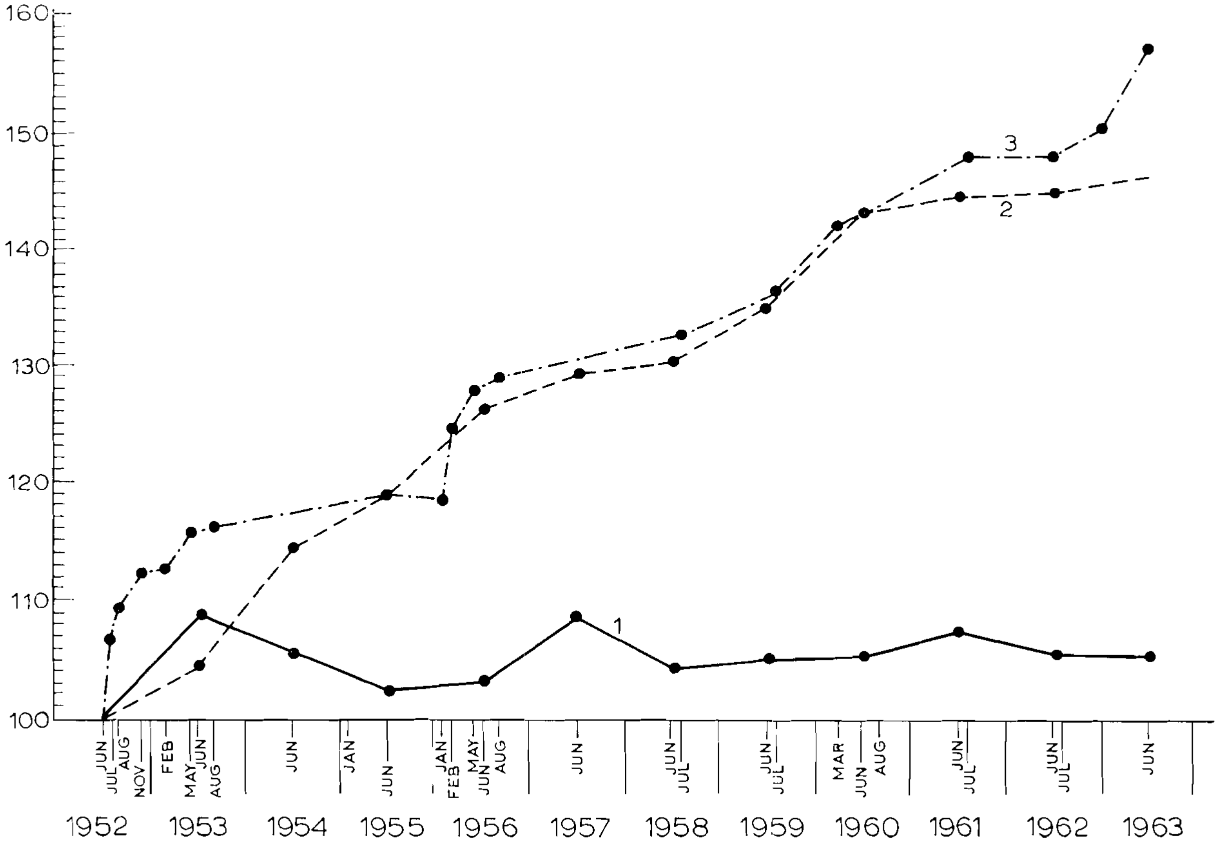
After ten years of operation, the conclusion is reached that the measurement of success of the described controls is directly related to the degree of practical efficiency of the material and labour standards, and to achieve this the following basic principles are to be followed:

1. Materials and labour standards to be set to clearly defined construction stages.
2. Material quantities to be a realistic attainable standard of usage.
3. Labour standards to be set at the assessed efficiency of the work force at the particular time. (Work measurement or time study figures are the goal.)
4. Excess issues of material and excesses to labour standards to be obvious as they occur and action must be immediate.
5. Variation to material and/or labour standards not to be permitted until the completion of the processes of investigation, approval and issue of variation orders.
6. Maintenance of a constant level of day labour production by introducing subcontracts to meet temporary increases in production requirements.

These principles have firmly established the objectives of:

- accurate estimating for budget purposes;
- construction costs conforming to estimates;
- reduced material costs by improved organisation and control;
- reduced labour costs by increased productivity.

The Housing Department has demonstrated beyond doubt that simple and effective controls can be developed and maintained. Finally, the continuing search for refinement of methods of producing houses of desired standard at the lowest cost has brought under consideration the application of these controls to network analysis procedures and their processing by electronic computers.



The central specification

By F. Nielsen (Denmark)

A building specification serves a great number of different purposes, which vary according to the person for whom the specification is intended and according to the time at which the person concerned has to use it. The specification has to serve as a basis for the administrative work necessary for all parties to the building activity, and it must also serve as instructions for the work on the site.

The building owner must be able to base the financial and legal administration of the building job, and possibly also the subsequent administration of the building on it.

Those in charge of the work of building must be able to base control measures (e.g. quality control) on this specification; it must also serve as a basis for the actual management of the work of building, and it may finally have to be used in the current settlement of accounts.

For contractors and suppliers the specification serves in the first instance as a basis for calculations and tenders; next it is used during the planning of the work, and finally it serves as working instructions for those working on the site.

For the authorities, the specification must serve as a basis for the technical and economical considerations in connection with the case and for the subsequent control of the work.

For the credit associations the specification likewise serves as the basis for the technical and financial consideration of the case, for the assessment of loans and, subsequently, also for economical control.

At the first glance it may perhaps appear to be impossible for one document to serve all these purposes. However, it is, throughout, the same thing which is required, viz. a description of the building in question. That which varies is the part of the building of which a description is required, the extent to which the description is to go into details, and the order in which the description should proceed. Consequently, if a "complete" description of the building was available, it would be possible to fulfil the individual requirements by selecting, out of this complete description, the required parts and, if necessary, arrange them in the required order.

The central specification

The central specification is a library of descriptive items covering all common and recommendable structures, methods of construction, finishes, etc. used in ordinary building jobs. Each item is provided with a number for recording purposes (code number), and all the items are transferred to magnetic tape for electronic data processing. By means of the code numbers it is possible to select the items from the tape in a required order. The magnetic tape is kept at a central location and used as input for the computer together with requisitions for the desired descriptive items. On this basis the computer prepares prints corresponding to the different purposes for which the specification is to be used. Such prints may take the form of stencils for duplication or office offset equipment.

The catalogue of descriptive items

All the items on the tape may be printed out by the computer in the form of a catalogue of the items. This catalogue may be written out with the full wording with regard to all the items, and in this form it will on the whole be equal to the general specification of to-day, but due to the fact that the items are recorded on magnetic tape, it is possible to revise or to issue new editions of the catalogue more rapidly. In principle, the use of the catalogue will correspond to the use which is made of the general specification to-day.

The individual specifications

In each individual building job the architect responsible for the project must select the relevant items, which are subsequently duplicated, as they are or after adaptation, to form a specification for the building job concerned. To facilitate the choice between several alternative methods of construction the catalogue may be provided with annotations. In connection, e.g. with painting, information may be given with regard to wear resistance, resistance to cleaning processes, character of surface (glossy or matt), cost, etc.

Together with the preparation of the requisition of central specification items, ad hoc items may be prepared with regard to special methods of construction or other individual requirements in connection with the project in hand, including, e.g., additions with respect to dimensions, locations, etc.

If the individual specifications are printed out by the computer on the basis of the central specification tapes, it will be possible to arrange the catalogue of items with a special view to its application as a basis for requisitions. For this purpose the catalogue need not contain the full wording of the items but merely sufficient information to allow the architect to perform the required selection of items.

This selection is effected by noting down the code numbers of the required items. Incidentally, the coding may be based on a hierarchical system that makes it possible to select items at different levels of detail.

The specification as basis for the administration

To provide a basis for the contractor's calculations, a specification is written out for each contract; this specification contains the special conditions, if any, and a designation of the nature, quality and extent of the individual works and deliveries belonging to the contract in question. For each contract everything of interest to the contractor concerned should be given, so that he need not refer to specifications dealing with other contracts.

For the use of the authorities a technical specification of a more summary nature is written out; it is not arranged according to contracts but according to building components so as to provide a logical, technical survey of the building. Details with regard to quality requirements, etc. may be omitted from this specification, since the authorities will know that, with regard to the building concerned, these requirements are specified in the central specification.

The specification as working instructions

For use either on the site or in the workshop the specification is written out in the form of working instructions. In this case the specification is not arranged according to trades (although of course with delimitations of the spheres of the individual trades), but according to the sequence of the operations which, in principle, means according to building components. Each individual operation, whether of principal or secondary importance, which occurs in connection with the component concerned is, irrespective of the trade to which it belongs, described in connection with the component, and every craftsman who has to do with the component is thus kept fully informed of all the work and deliveries which are required for the manufacture and erection and which he may have to consider in connection with his own work.

In the working instructions many sections, e.g. those dealing with legal provisions or with requirements with regard to the quality of materials, may be omitted since they are of interest only in connection with tenders and ordering of materials and not in connection with the performance of the work.

Integrated application of the central specification system

An extension of the building specification to turn it into a descriptive bill of quantities may likewise be performed by the computer. While noting down the code numbers which select the actual items from the central specification, the dimensions and numbers of the quantites corresponding to the items are written out.

The dimensions and numbers noted are transferred together with the code numbers to magnetic tape (the requisition), and while selecting the items the computer calculates (by squaring and adding up) the quantities. Printing out now takes place as previously mentioned, and for the purposes for which it is desirable the quantities are given in connection with the items. The system may be extended and be applied for the purpose of writing out lists for ordering materials, lists of the amount of labour required, etc.

By electronic data processing, a bill of quantities may be combined with a price list and thus provide a rapid calculation of the total or partial cost of a projected building. Price lists of different types may be used, they may give estimated prices or the prices of the contractor's tender. Irrespective of the nature of the price list it will be possible for the computer to perform a calculation of the cost, and it will be possible at the same time to obtain an analysis of the building cost. This opens up possibilities of further applications to which the central specification may be put, e.g. the following:

- cost estimates, in which unit prices are based on previous cost analyses or special estimated prices;
- comparisons of the costs of alternative constructions and materials and of constructions and materials at different prices;
- calculation of tenders for the contractor (the contractor's price list);
- analysis of received tenders;
- analysis of the capital (investments) required by the contractor during the building period;
- preparation of a plan of the instalments to be paid by the building owner;
- running accounts for the building owner.

Control and statistics

One of the drawbacks encountered when exchanging the familiar manual working method for electronic data processing is the lack of contact with, or anticipation of, the final result. No results will appear in the course of the work, and the possibility of detecting any errors through intermediate results does not exist. To this should be added that the nature of the work with electronic data processing differs considerably from that of the traditional methods, and this may of course, especially at the beginning, give rise to errors and mistakes.

These drawbacks may be obviated partly by establishing a working routine, partly by incorporating a number of control measures in the actual work with the computer. To give an idea of the nature of such control measures it may be mentioned that the computer may, e.g., automatically check whether all the usual building components have been described, whether any building component has been described in two different ways, and whether the calculated quantities are of an order of magnitude which is reasonable considering the order of magnitude of the building concerned (misplaced decimal point).

It will also be possible for the computer automatically to prepare statistics e.g. with regard to the frequency with which the different items of the central specification are used. On the basis of such statistics it will be possible continually to revise and bring up to date the basic descriptive items. Items which are never employed may perhaps be deleted for the sake of clarity—and with regard to items which are frequently subjected to alterations by the users, it may be considered to introduce alterations in accordance with the variations most frequently suggested.

Dwelling cost analysis in relation to the various design parameters

By C. Noel (France)

Note: The graphs and tables referred to in this paper are not included in the printed version but may be obtained by application to the author.

There are several ways of analysing the cost of a dwelling. Two of these are in common use:

– measured work in all its aspects; expenses are sorted out according to the sort of building jobs, regrouped to some extent per building trade or exceptionally into functional units (sets, schedules);

– expenditure analysis, wherein outgoings are classed following the kind of service rendered: labour, materials and supplies, depreciation, profits etc.

These two analysing methods are generally quite suitable for contractors who quote often without being brought into the discussion of the building scheme. Their main object is the estimation and control of building work. On the other hand, neither of such methods provides information on the importance in respect of final cost of the various design parameters. The method suggested by the Centre Scientifique et Technique du Bâtiment (C.S.T.B.) is intended to take care of this point. Its application is particularly warranted before inviting contractors to quote, when there is still time to adjust the scheme. It aims at finding the most economical solutions in keeping with generally suitable quality.

Fundamentals

The method rests at the outset on a price analysis per room, showing the influence of both geometric features (area, height, shape) and purely technical features (materials, equipment).

The cost of a room consists of the price of all the structures and equipment it is made of or which it contains, it being agreed that the partitions between two adjacent rooms are appropriated on a 50-50 basis to the rooms concerned, each room being charged with its own dividing-wall lining.

These structures have been grouped into three categories:

1. Structures of which the cost is proportional to the horizontal area of the room, such as floors, ceilings, floor covering etc.
2. Structures of which the cost is proportional to the development of vertical partition-walls, such as façades, inside walls, partitions, gable walls.
3. Structures of which the cost is not directly dependent upon the area or development of vertical partition-walls, such as equipment, doors, smoke ducts, etc. Thus, the cost of a room may be expressed as $P = H + L + N$, where $H = p_1S$ (horizontal structures), and $L = p_2D$ (linear structures);

or $P = p_1 S + p_2 D + N$

N — cost of equipment and other constants
S = room area
D = development of vertical partition-walls
p_1 — average cost per sq. m. of horizontal structures
p_2 — average cost per linear m. of vertical partition walls.

This formula may be written thus (see C.S.T.B. Specification No. 67)

$$P = p_1 S + p_2\zeta \sqrt{S} + N \qquad \text{or} \qquad p = p_1 + p_2 \frac{\zeta}{\sqrt{S}} + \frac{N}{S}$$

with $p = P/S$.

The novelty of the C.S.T.B. approach lies especially in fixing ζ, particularly in the case of a group of rooms as applied to premises forming a habitable area.

Determination of ζ

a) Isolated rectangular rooms: In this case, ζ is identical with a, called "shape coefficient" (see C.S.T.B. Specification No. 67), defined as follows:

$$a = 2\left(\sqrt{\frac{l}{L}} + \sqrt{\frac{L}{l}}\right); \qquad \text{l and L being room length and width}$$

b) Grouped rooms: In this case, forming for instance a dwelling unit, the previous formula could be applied as many times as there are different rooms. This method would be tedious and lengthy. It seems that the following formula is sufficiently accurate:

$$\zeta = a' \sqrt{n't'} + a'' \sqrt{n''t''} + a''' \sqrt{n'''t'''} + a'''' \sqrt{n''''t''''} = \zeta' + \zeta'' + \zeta''' + \zeta''''$$

a′, a″, a‴, a⁗ — shape coefficient characterising the mean lengthwise extension of the main rooms (a′), the water-equipped rooms plus kitchen (a″), passages (a‴), wallcupboards plus lavatory (a⁗), respectively.

n′, n″, n‴, n⁗ — number of main rooms (n′), water-equipped rooms plus kitchen (n″), passages (n‴), wall-cupboards and lavatory (n⁗).

t′, t″, t‴, t⁗ — % of total dwelling unit corresponding to each of these groups of rooms.

Graphs have been prepared for the purpose of working out separately $\zeta'\zeta''\zeta'''\zeta''''$ following the various values for a, n and t, also these actual values in tabular form for various combinations of a, n and t.

Such graphs will in fact only be used for estimates or a close analysis. For current practice mean values of ζ are given in table no. 1 (available from the author). Extreme values shown in the table indicate the relative importance of errors that may be made.

Application to dwelling cost analysis

The cost of a dwelling may be taken to consist of three parts:

1. Cost of rooms for own use, included in full. These are:

– rooms making up the "habitable area" (living-rooms, bedrooms, service rooms, passages, closets);

– appurtenances for own use (cellars, store-rooms, drying rooms). Such rooms are generally separate from the dwelling unit;

– logias and balconies.

2. Cost of shared rooms, partly included only, worked out either proportionately to the number of dwellings, or in proportion of the area of each dwelling. Such rooms are:

– common appurtenances (garages for bicycles, perambulators, boiler-room, ...);

– accesses (stairs, galleries, halls, landings).

3. Cost of common structures and equipment (not assigned to a particular room); these include:

– roof, foundations, gables;

– common equipment; flow pipes, service branches, main door, approaches etc. As for shared rooms, part only of the common structures is allocated to each dwelling proportionately to the area or number of dwellings, as the case may be.

The application of the fundamentals outlined above will be effected as follows for working out the three component parts of the total cost of a dwelling:

Cost of dwelling unit proper

The dwelling unit proper means the group of rooms making up the habitable area (bedrooms, living rooms, kitchen, lavatory, interior passages, closets). By applying the formula mentioned above:

$$P = p_1 S + p_2 \zeta \sqrt{S} + N$$

or

$$p = p_1 + p_2\zeta \frac{1}{\sqrt{S}} + \frac{N}{S}$$

(the latter formula applies to cost per sq. m. of area S).

The calculation of the three terms p_1, $p_2\zeta\,(1/\sqrt{S})$ and N/S will be effected thus:

Calculation of the term: $(p_2\zeta\,(1/\sqrt{S}))$ or p_2u by taking $u = \zeta\,(1/\sqrt{S})$. The term $p_2\zeta\,(1/\sqrt{S})$ is the cost of partition walls per sq. m. of habitable area S_h.

Determining ζ: a) Graphs have been prepared for use in close investigation. By means of such graphs it is possible to compute the four constituent parts of ζ, viz, ζ', ζ'', ζ''', ζ''''. These graphs are not attached, because of lack of space. They should generally only apply to very close analyses. b) As a rule it will be sufficient to take mean values ζ_m for each type of dwelling and for various length-wise extensions of the main rooms, differentiating between plans with oneside exposure (S.O.) and plans with two-side exposure (D.O.). The ζ_m values are shown in Table 1 (available from the author).

Determining p_2: As already mentioned, p_2 is the average cost per linear metre of vertical walls (external walls, partitions, inside walls). p_2 may be expressed as:

$$p_2 = \frac{p_F \times F + p_m (D - F)}{D}$$

$$\text{or} \quad p_2 = \left[t_f \left(\frac{p_F}{p_m} - 1 \right) + 1 \right] p_m \ldots \qquad (1)$$

in which F = length of façades
D = total perimeter of partitions of all kinds
p_F – cost of façade linear metre
p_m = average cost per linear metre of half vertical partition and half vertical inside wall
t_f = percentage $\frac{F}{D}$

Formula (1) is shown by a graph. For quick reckoning p_m should be taken as the mean arithmetical value of half vertical partition and half vertical inside wall costs.

For accurate computation reference should be made to the specification prepared by C.S.T.B. This makes it possible particularly to work out p_m in relation to the structural part (transversal bearing walls, longitudinal bearing walls etc.) and the outline of the plan.

The full term $p_2\zeta\,(1/\sqrt{S})$ is given in graphs (according to size of dwellings), obtainable from the author.

Determining p_1: As already mentioned p_1 is the average cost per sq. m. of horizontal structures :floors, ceilings, flooring.

$$p_1 = \frac{t'p' + t''p_1'' + t'''p_1''' + t''''p_1''''}{t' + t'' + t''' + t''''} =$$

$$p_1 = \frac{t'p' + t''p_1'' + t'''p_1''' + t''''p_1''''}{100}$$

In the above formula p_1', p_1'', p_1''', p_1'''' are the unit prices applicable to the various groups of different rooms that come into the percentages t', t'', t''', t'''' (these percentages have already been picked out for calculating D). Each unit price is the sum of the prices of the various component parts of the floor:

- ceiling
- flooring
- coating, if any
- floor proper.

The latter component part includes a part, depending on span, of the reinforcement with constant thickness. For quick reckoning p_1 should be taken as between Fr. 80 and Fr. 110.

Determining N: N covers all structures not proportional, either to dwelling area, or to length of partition walls.

N includes installation appliances (sanitary equipment, kitchen furniture, heating or heat radiating appliances, water heaters); feed and exhaust pipes and ducts (cold water, hot water, sewage, smoke, foul air, garbage); doors; shuttering (shutters, venetian shutters, blinds); interior stairs (if any).

A deduction from the cost of these various items should be made for expenses relative to partition walls at right angles with clear openings and door openings (reckoned in the total development D of the partition walls of the various rooms which are all supposed to be closed rectangles).

Just as p_1 and p_2, N depends very much on the qualitative and quantitative consistence of its component parts, which vary according to countries, plans, degree of luxury in building etc.

In France, reckoning with the minima prescribed for cheap dwellings, the following relative figures may be taken:

I bis	II	III	IV	V	VI	VII
Fr. 4900	Fr. 5300	Fr. 5700	Fr. 6300	Fr. 7300	Fr. 7800	Fr. 8300

Cost of isolated rooms (for private or common use)

The 3-component formula should be applied to each of these rooms

$$p = p_1 + p_2 \times u + \frac{N}{S}$$

$$\text{taking } u = \frac{D}{S} = \frac{\text{Development of partition walls}}{\text{Room area}}$$

Calculation of the term $p_2 \times u$: $p_2 \times u$ characterises the unit price of partition walls per sq. m. of the area of the particular room.

$p_2 \times u$ can be given in graphs (according to room size), in which u and p_2 are determined as follows.

Determining $u = D/S$: Three cases have been considered:

a) L and l (sides of the rectangle) are known, then

$$u = \frac{D}{S} = \frac{2(l + L)}{l \times L} = 2\left(\frac{1}{l} + \frac{1}{L}\right)$$

Values for u are given in Table No. 2 (obtainable from the author).

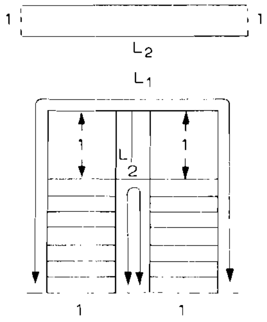
b) Room area S and lengthwise extension $x = \frac{L}{l}$ are known, then

$$u = \frac{D}{S} = 2\left(\sqrt{\frac{l}{L}} + \sqrt{\frac{L}{l}}\right) \times \frac{1}{\sqrt{S}}$$

Values for u are given in graphs according to room size and shape.

c) Both sides l are not realised by either wall.

This is more particularly the case for stairs, some galleries and landings.



In such case $D = L_1 + L_2$; $S = \frac{L_1 + L_2}{2} \times l$;

and $u = \frac{D}{S} = \frac{2}{l}$

Taking, for example, a staircase with a width of stair = 1.20 m.

$$u = \frac{2}{1.20} = 1.66 \text{ m.}$$

Determining p_2: p_2 is the average cost per linear metre of room partition walls. p_2 is found by a simple combination rule, in proportion to each component. A graph may be applied, in which p_F is, generally speaking, the unit cost of external walls.

For quick reckoning p_m should be taken as being the arithmetical average of the costs of the other partition walls.

Determining p_1: p_1 is the cost per sq. m of horizontal structures (or work relative thereto), viz.

– for basement rooms (cellars) or above ground (store-rooms), earthwork, shape, flooring, ceiling;

– for rooms above ground-floor level; floor, flooring, ceiling;

– for staircase; steps and half-landings, including matting, covering of steps and rise of stairs etc.;

– for wells (passenger and goods lifts, ducts); nil.

Table No. 3 (obtainable from the author) provides a range of values for p_1.

Determining N: N is the equipment of each room (see Table No. 3, obtainable from the author).

Distribution of cost of common rooms per dwelling: As a rule the cost of such rooms should be distributed in proportion to the number of dwellings concerned with the use of these rooms.

Cost of common structures

These are grouped into 2 categories depending on the more rational way of allocating them to the dwelling, viz.:

Structures to be allocated proportionately to the area of each dwelling, comprising roof, shafts and foundations.

Structures to be allocated proportionately to the number of dwellings which group, generally speaking, all the structures not actually dependent on size of dwelling, viz.: gable walls (half thickness, the other half being taken as partition wall); entrance door and cellar door; service branches; flow pipes (water, gas, electricity, sewage) and relative ducts; heating installation chimney; common aerials; approaches.

These structures are additional to all those already taken as common room equipment (lifts, stairs, rubbish-shoot), of which the cost is included in the cost per sq. m.

It is difficult to assess a value to the various common structures, in view of their diversity and the variety of ways of assembling dwelling units (superimposed floors, stairway, etc.).

As an indication, it should be noted that, according to work done by C.S.T.B. (Specification No. 502), relative to buildings (groundfloor + 4 storeys) consisting of 10 dwellings per floor, the cost of common structures for a dwelling of three and a half rooms accounts for 10% or so of the cost of the dwelling unit. This term varies of course according to the number of floors, reckoning with the invariability of some items (roof, foundations (partly) doors, approaches), and the number of dwellings (invariable number of gable walls).

Conclusions. The method as outlined is primarily a quick way of estimating building schemes in relation to the importance of various rooms, for own use or otherwise, necessary to make a dwelling unit such. For this purpose it is sufficient to apply the values for the various components shown in Table 3.

Nevertheless, the method has not got a full cost-analysing value unless one goes into the details of the composition of these various component parts. These have been merely mentioned, considering the limited scope of this paper.

The different parameters, of which the influence on cost may be emphasised, will here be recalled to mind:

– Area	(S)
– Depth of dwellings	$\left(\frac{F}{D}\right)$
– Number of rooms	(ζ)
– Shape of rooms	(ζ and a_m)
– Size of each room	(ζ and λ_m)
– Structural part	$\left(\frac{F}{D}, \frac{R}{D}, \frac{C}{D}\right)$
– Ceiling height	(p_2)
– Floor span	(p_1)
– Equipment	(N)
– Unit costs	(p_1 and p_2)
– Importance of appurtenances	
– Importance and kind of accesses	
– Number of floors	(P_0)

It should particularly be observed that, as ζ is the product of the parameter a_m into the parameter λ_m, the various combinations of these two parameters provide a true typology of plans based on the shape, number and relative importance of the rooms that make up a dwelling unit.

Likewise, by means of p_2, a classification can be made of the different structural parts following the relative importance of façades, inside walls, partitions. On the other hand, the method provides no indication of the relative location of the various rooms. (This point was the subject of previous work. See C.S.T.B. Specification No. 303 "An experiment in the typology of dwelling designs" by A. Turin).

To sum up:

1) As an estimating method: Bounds are set to the accuracy of the results provided by this method by the accuracy with which the various component items had been worked out.

If one is satisfied with applying average values (as shown in Table 3 – obtainable from the author), cost values may quickly be ascertained, which are more accurate than those provided by total cost per sq. m. (see Table 4 – obtainable from the author).

If the component items (particularly ζ and p_2) are more accurately computed, it is perfectly possible to apply the method and make it a settlement method.

Such a system appears quite suitable especially in the case of flats sold on a co-ownership basis, as it allows a fair apportionment of the common parts among the different joint owners.

2) As a cost-analysing method: The method provides, in a very simple way, information as to the influence of a whole set of design parameters, already mentioned. Provided the make-up of certain components is examined in sufficient detail, particularly the "vertical partition walls" item, it is possible to ascertain rapidly – in fact at the rough-plan stage – the financial consequences of such an architectural or technical feature.

For the purpose of developing the "analytical" approach, it is contemplated to work out in advance values for the different components (p_2 in particular) corresponding to definite typical features.

Y. Palm

The effect of repetition on building operations

An international study

By Y. Palm (United Nations Economic Commission for Europe)

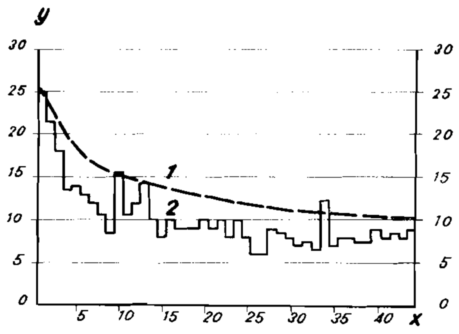
The effect of repetition on the cost, output and productivity of building production has for some time been the subject of special study by the Committee on Housing, Building and Planning of the United Nations Economic Commission for Europe (ECE). The first results of this work, concerning the effect of repetition on the production costs of building materials and components, were published in 1963[1]. The present paper summarizes the main conclusions drawn in a second report, devoted to the effect of repetition on building operations and processes on site[2]. The latter report is based on national information received from eleven countries and has been prepared in close collaboration with the CIB.

Effect of repetition on operational time

The favourable influence of repetition on operational time is due to the increased work tempo achieved by training, but also by successive improvements of work method and arrangements in the immediate environment of the actual operation. The gradual improvement of labour productivity attained by repetition is usually illustrated by means of *improvement curves*, showing the relationship between the operational times and the number of operations completed. An uninterrupted and continuous decrease is seldom obtained in the number of manhours required to perform an operation. The improvement curve often flattens out before falling. It is also in most cases rather irregular owing to the influence of external conditions. Nevertheless, the general pattern of curves referring to different building operations are very similar. It usually seems to be possible to distinguish between two phases in the process of improvement of labour productivity in building, namely, an *operation-learning phase* when the worker acquires sufficient knowledge of the task to be performed and when the time consumption falls steeply and, secondly, a *routine-acquiring phase* during which gradual improvement of productivity is achieved through more and more familiarity with the job and through small changes in work method and organization.

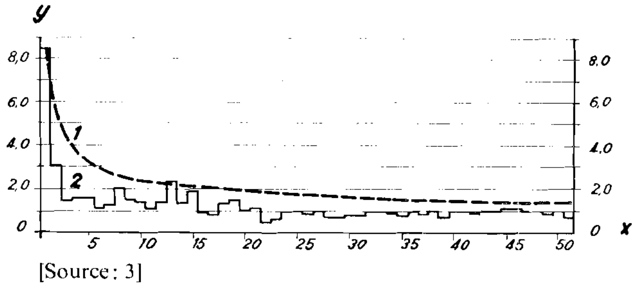
The exact shape of the improvement curve, i.e. the rate of improvement in different phases of the process, depends on the nature of the operation. In the case of simple operations, time consumption often falls sharply and rapidly and a stable operational time is attained comparatively soon (hyperbola shape, see figure 1). The rate of improvement slows down and a stable operational time takes longer to achieve with increasing complexity of the building operation. The shape of the improvement curve for very complex operations is often similar to that shown in figure 2.

In view of the great variety of building operations, it is not to be expected that one single mathematical formula or model of the improvement process could be applicable to every kind of individual operation. On the other hand, the entire group of activities and operations necessary to complete a building or part of a building could always be considered as a very complex over-all operation, similar to the complicated assembling operations studied in the manufacturing industries. The main difference would lie in the almost unlimited number of adverse factors and outside conditions affecting building work. It could be assumed, therefore, that the pattern of improvement in the building industry should be similar to that in the manufacturing industries but that the rate and degree of improvement would be lower. Based on these assumptions, the expected decrease in the average mean value of operational times, for each doubling of the number of executions, should, in the building industry, lie between zero and 20 per cent, which is valid in manufacturing. The actual percentage should depend on the efficiency of the organization of the building operations in each individual case. This hypothesis seems to be confirmed by the results of studies contributed to the report. The percentage improvement of overall time consumption observed at well-organized building sites varies between 8 and 13 per cent for each doubling of the number of executions.



[Source: 3]

Fig. 2. Improvement curve for complex operations.



[Source: 3]

Fig. 1. Improvement curve for simple operations.

Effect of repetition on building costs

To achieve improved labour productivity by repetition could be a target in itself. It should also be borne in mind that, even if no spectacular cost savings are achieved on the building site, the introduction of large series of building components and functional units, through standardisation and typification, has a substantial bearing on total building costs through the favourable effect of repetition on the costs of design and programming, materials and components, and overheads.

In most cases, however, increased labour productivity on the building site is accompanied by a reduction of operational costs, emerging partly from a decrease in direct labour costs and partly from indirect cost savings due to the reduction of construction time.

The magnitude of direct savings in wage costs and of indirect savings in terms of labour on-costs, costs for finance, machinery and equipment, etc. depends to a large measure on the system of labour remuneration. If a purely hourly wage system is employed, the entire economic gain from improved efficiency will appear in terms of lower wage costs. On the other hand, as the earnings will not reflect the results of the work, the operatives will have no great inducement to improve their ability. The effect of repetition could therefore be expected to be comparatively small and thus also the indirect savings emerging from the reduction of construction time. The advantages and disadvantages of a purely piece-rate system of remuneration are the reverse of those of the hourly wage system: small or no savings in direct wages but substantial indirect savings due to the shortest possible construction time. In many countries a combination of the two systems has been found most economic and efficient.

Substantial economic effects of repetition are obtainable already as a result of training, i.e. without any major changes in the organization of technology of the operations to be executed. But series of identical operations may justify more specialisation and also the introduction of new technology implying a higher degree of mechanisation of the work and thus higher investments per worker. It should be borne in mind, however, that far-reaching specialisation creates serious problems of co-ordination, the solution of which often involves an extension of the construction time, i.e. an effect contrary to the general economic purpose of specialisation. Furthermore, investments in better and more expensive equipment are justified only if the series of operations to be executed is large enough to pay back, through lower unit costs, the original investment outlay.

Adverse influences on repetitive work

As distinguished from manufacturing under factory conditions, building operations are subject to a lot of more or less disturbing influences, such as unfavourable weather conditions, access difficulties, instability of manpower, delays in the delivery of building materials or drawings, and special problems arising when work has to be carried out far above ground level. These factors impede not only the efficiency of the work but also the continuity of work rate, which is necessary if a gradual improvement of labour productivity is to result from the repetition of identical operations. To this should be added the major difficulty of achieving real technical continuity (identical operations) caused, *inter alia*, by the necessity of adapting the building to differences in the nature and slope of the supporting ground.

The evidence presented in the report points clearly to the fact that even comparatively small differences in the operations to be executed (operational discontinuity) and time breaks or changes in the personnel executing the work (executional discontinuity) seriously affect the improvement process. In fact, breaks in continuity can, under unfavourable conditions, almost completely neutralize the repetition effect.

Breaks in continuity are, as mentioned, often caused by external influences but can also have their origin in inadequate organization of the work or in the fact that the project does not lend itself to proper organization of the work (e.g. insufficient work space).

Some influence of external conditions can hardly be avoided in building work, but the extent of such influence depends on the nature and the duration of the site work. Wet building processes, such as concrete casting and plastering, are generally sensitive to weather conditions and comparatively time-consuming. The key to increased independence of external influence lies in a transfer of as much as possible of the site work to factories and in the use of dry assembling of prefabricated building components on the site.

Inadequate organization of work on site is often caused by insufficient knowledge of the organization method most suitable to repetitive work and by insufficient awareness of the serious influence of breaks in continuity. A switchover from the traditional improvisation of building work to penetrating preplanning and scrupulous maintenance of continuity is important and necessary.

Some difficulties in the organization of repetitive work, caused by the very nature of the building, can hardly be avoided in the case of single projects, particularly in connexion with urban renewal. In new housing areas, however, it should be possible to tackle these difficulties, either by a close collaboration between designers and building organizations or by the designer himself acquiring sufficient knowledge of the executional requirements.

An increase in the operational time often occurs in the end phase of repetitive work sequences. Knowledge of this phenomenon can help partly to eliminate its adverse effect. In most cases, however, some additional operations are inherent in the end phase and will necessarily result in a slight increase in operational times.

Planning and organization of repetitive work

If construction processes are highly repetitive, new and better forms of planning and organization are needed. If the method of planning and organization remains traditional, the favourable effects of repetition will be partly or entirely lost. Moreover, modern methods of organization may not only help to realize the favourable effect of repetition, they may even contribute to an increase of this effect.

It is usual when trying to utilize the effect of repetition to divide the construction work into a large number of simple operations and thus to procure a high degree of specialization of the operatives. Excessive division of the work, on the other hand, creates serious problems of co-ordination and is justified only in the case of very long series of identical operations.

The policy of the widest possible standardisation and typification of buildings and components adopted in eastern European countries, has enabled the adoption in these countries of an organization method based on specialisation of the site work, the so-called "flow-line" method. The principles of flow-line production are very similar to those used in mass production of consumer goods on belt lines in the manufacturing industries.

The entire production process is divided into a number of specialized operations linked together by a common production rate. In building construction, however, the product cannot be moved from one working station to another; instead, the operatives have to move between different working areas. This fact sets certain limits to the economic degree of specialisation as well as to the possibilities of mechanisation and rationalisation of the site work. Moreover, building operations are more or less unavoidably affected by a number of external factors which from time to time disturb the proper execution of the work. To ensure a stable output and prevent one operation unfavourably influencing another, the work rates have to be rather modest.

The flow-line method is based on a stable output which makes it difficult to allow for a gradual improvement of labour productivity attained by training. Instead, some adaptation of the general work rhythm is introduced from time to time. The specialisation of the work and the firm organisation applied in flow-line construction have, nevertheless, certain advantages and the results achieved, especially in the production of fully prefabricated buildings, are deemed very satisfactory. Constant attention and research are devoted to the perfecting of the method, *inter alia*, by the application of network planning and computer techniques.

Owing to the shorter series of identical operations prevailing in western European countries, far-reaching specialisation is not normally considered useful or economic as the primary means of exploiting the favourable effect of repetition. Instead, close attention is devoted to the possibilities of utilizing the natural improvement in labour productivity attained by repetition. To this end, there is reluctance to organize the work according to a firm time schedule and the greatest possible independence among the different work gangs is aimed at. In this way, allowance is made on the one hand for a gradual improvement of labour productivity but also for occasional setbacks of the work rate caused by unfavourable external factors. Careful attention is paid, as in the flow-line method, to the organization of work within the work gangs and to achieving the best possible balance of their work rates. The co-ordination of gangs is, however, normally left flexible; this has certain advantages but calls for constant supervision of the site works.

Conclusions. The material analysed in the report has thrown some light on the importance of operational and executional continuity on the building site. At the same time, it has shown clearly the difficulties of isolating the influence of one sign of the wide range of factors affecting building production. The possibility for repetition of building operations is only one, and perhaps not the most important, of the consequences of introducing large series of identical building components or functional units in the building trade. Furthermore, the effect of repetition as a whole is often overshadowed by other important factors influencing building production, such as the organization and mechanization of the work, the size of contracts and of building enterprises, the technology used (size of building components, dry or wet processes, etc.). In addition, external conditions and other adverse factors often impede or prevent reliable conclusions to be drawn from data collected on building sites. It is necessary to view the effect of repetition on building operations in the wider context of measures and means aiming at the transfer of building from a handicraft business to a fully industrialised sector of the economy. Further success in the industrialisation of the building trade will, to a large measure, depend on the objective and penetrating analysis of the relationship and interdependence between all the relevant factors influencing the efficiency of building production. International exchange of experience in this field, which has already given some results, will probably prove even more important and useful in the future.

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Site mechanisation; key organising operation

By R. Panerai (France)

The purpose of this paper is to develop the basic view that mechanising heavy work building sites, a useful and even necessary step for a number of reasons, has, in particular, the advantage of providing such sites with guiding principles of organisation. This is a vast subject for discussion: it concerns all medium and large size heavy work building sites, irrespective of techniques applied. However, the sole assembly of prefabricated components, all produced in an outside factory, is an extreme case to which the following discussion but partly applies.

It is a fact that the organisation of fairly important building jobs, on traditional lines, is very tentative, particularly so when it is left to the discretion of the local site foremen. There is a mixture of common sense considerations and of systematic mistakes due to failure to appreciate certain factors. Should one heavy crane be used or two medium ones? Should one shuttering gang only be taken on (maximum work continuity but longer time for completion) or more (lower output but shorter time for completion)? and so on... The daily work organisation is even more haphazard. As shown by analysis, there often occur excessive changes in working stations, a cause of decreased labour efficiency.

The major benefit of site mechanisation is that it makes for plainer organisation, by reducing a wide range of diverse operations to a small number of key groups, among which of course basic selection will determine the necessary gradation. An introductory observation will make things clearer.

When engineers are engaged in building a concrete runway, the key operation to be considered is the progressing work of the vibrated concrete laying machine. All anterior operations depend on it, so that this machine works at its operational speed. Thus, key mechanisation makes it possible to work out the specifications for the concrete mixing plant, means of transport and relative personnel. Posterior or accessory operations, such as drains, joints, etc. should also be organised and planned according to progress with the main operation with, of course, the varying degree of flexibility that the required time of completion may allow.

Construction of an underground gallery (excavating machine), or of an ovoid sewer etc. are similar examples.

Is it possible to find, on the building site, key machines, the operation of which will outline the general pattern of site organisation? It occurs to one to pick out hoisting equipment, at any rate in France, where the use of powerful slewing pillar cranes has particularly been developed in the course of the last few years.

If use is made on the site of a large amount of heavy prefabricated components, then there is a definite case for an approach to site organisation first paying attention to cranes. Having noted the equipment laid down in the contract, the workstudy engineer should work out a number of schemes, depending on time allowed for completion and on the length of the building. Each scheme should aim at operating the machines at full capacity, with an adequate safety margin. The final choice of a particular scheme will naturally also depend on other factors. But the assembling rate of speed jointly with part casting on the site (floors, columns, piers) will outline the overall pattern of the building site. From such rate of speed should be inferred anterior prefabrication operational speed, that of armature etc. It should also provide the workstudy engineer with guidance in planning subsequent operations, the subordination of which is less obvious (smoke stacks, filling up with masonry, etc.), but which every endeavour should be made to follow up with as soon as possible to avoid wasting the time saved on the supporting structure.

There does not appear to be a case for taking the capacity of the concrete producing plant as a determining factor in organisation. Taking first the wide range of available equipment and then the possibility of acquisition at a relatively cheap price, it is possible to adjust the concrete production factor to more compelling requirements.

But the abovementioned example refers to a rather particular case, where the importance of assembling prefabricated components is predominant. What happens on the usual building sites or on sites where techniques applied provide for local fabrication?

Such is the case with a large number of building sites in France, where use is made of shuttering implements, that is to say, elements by means of which whole parts of a building (walls, floors) may be cast in carefully dimensioned, heavy and expensive metal shuttering.

There is no doubt that hoisting and the use of shuttering implements are the two key operations. Reckoning with time allowed, capital outlay and depreciation possibilities, the work-study engineer should decide on the optimum number of shuttering units which, used in regular rotation, will provide a definite and easy-to-control operational flow on the building site. Needless to say, proper coordination should first be achieved with hoisting equipment after the operating load capacity of this equipment has been determined in the various possible schemes (number of cranes and relative performance).

In any case the decision to adopt the shuttering implements technical solution will have previously been made, taking into account first the characteristic features of the building scheme, then economic factors that can be plotted as curves and graphs, showing for each method the profitable operating area.

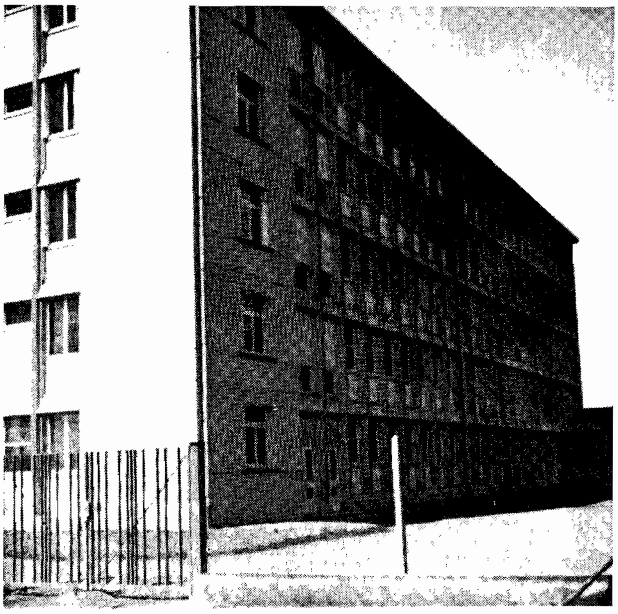

Fig. 1. Technical School. Building for Boarders.

A practical application is briefly described hereafter. It is that of the building for boarders of a technical school erected, *all building trades included*, in six months' time, including foundations on poor and damp soil. Fig. 1 shows the completed building.

The shuttering implements included a heated casting table (Fig. 2), for working concrete on the spot. The floor, when completed, was covered with a heated tarpaulin containing steam provided by a mobile fuel-oil site boiler. Vertical parts, porticos and outer wall panels were prefabricated, the porticos within reach of the crane, the panels in an outside shop (Fig. 3).

Shuttering work covered 40 sq m, repeated daily thanks to the heating appliance. Thus the key gang's *daily work* was accurately planned: dismantling first thing in the morning; at 11 am shuttering; at 3 pm casting. The placing of the corresponding vertical elements was timed to fit in with this working schedule, as well as the prefabrication thereof. The convenience of a regular daily work programme for each gang should be stressed as it facilitates supervision. Building was completed, including painting, 8 days ahead of schedule though time allowed had been closely worked out.

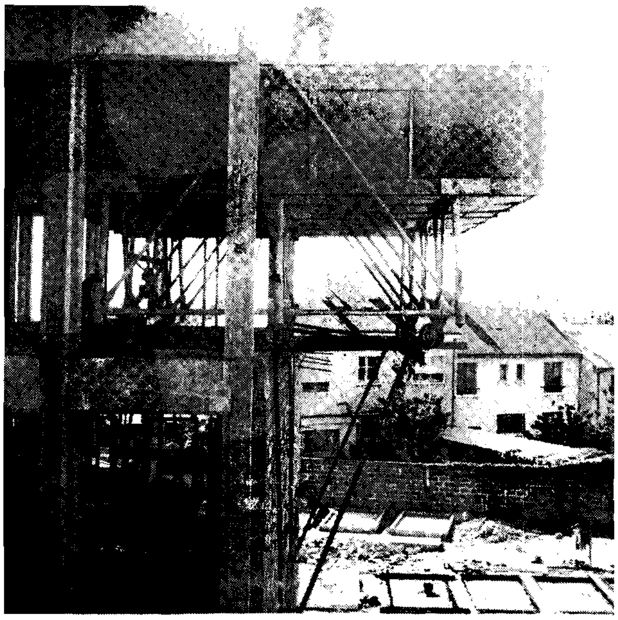

Fig. 2. Heated casting table for floor shuttering.

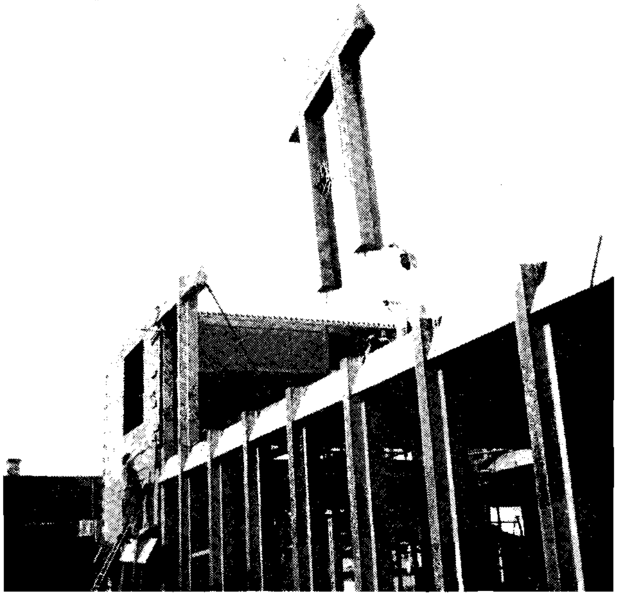

Fig. 3. Prefabricated Porticos.

The equipment consisted of a crane (3 T/25 m), a semi-automatic concrete-mixing plant, shuttering implements and casting-moulds, for prefabricated parts. The cost of this equipment (depreciation, maintenance, power), excluding operators, amounted to 6% of the total contract figure.

In the last part of this report the difficulties and limitations of this building process will be set out:

1) Technical and economic conditions relative to the use of the above equipment are still not well known. The question of depreciation of the general equipment (crane) and of specific equipment (casting moulds) is being thoroughly gone into with a view to more accurate technical costing. Moreover, the operating load of hoists is usually underestimated; sometimes they work at 40% of their actual net hoisting capacity. Such approximations are misleading in selecting methods.

2) Labourers' work should preserve its human quality. Conditions favouring the requisite nervous recuperation must be assured in the system. Hard work should retain its stimulus (the application of some industrial shuttering equipment has led to dislike and caused labour gangs to go). Finally, it is necessary to arouse economic concern on the worker's part by a proper incentive. On the latter point, one may anticipate positive progress in mechanisation. This will make it possible to substitute consistent stimulating wages for task-work practice, which is hardly productive of technical and human advancement.

3) All building jobs are not directly affected by mechanisation; quite a number of them are therefore passed over by the corresponding organisation. Nevertheless, the strictness with which the key jobs are determined spreads by degrees all over the building site. Efforts are made to follow up with minor masonry work, smoke stacks, partitions, by a suitable balance of the relative work stations. Finally, such operations as allow of no actual check are set apart (finishing work, retouch, cleaning); they are committed to specialised gangs whose only law should be speed.

So mechanisation, born of a concern to reduce man's physical exertion by replacing it with the "mechanical slave", makes it also possible to guide efforts to develop site-work organisation and to substitute more rational conceptions for the old over-simple iron-rule method of supervision. It is one of the aspects of the march towards industrialisation.

Cybernetics and computation techniques in the long-term planning and management of construction

By V. I. Ribalski (U.S.S.R.)

The development of cybernetics, the invention of electronic computers and new branches of applied mathematics (such as linear and dynamic programming, theory of mass service, etc.) involve a new approach to the solution of a number of problems in building production and provide optimum solutions where formerly it was theoretically impossible to do so.

Building organisations in Moscow, Kiev, Novosibirsk and other cities perform calculations for the optimum planning of transportation of construction materials and elements, such as the most rational location of the production base of construction (e.g. the problem of the best location and development of cement plants all over the country has been solved) and the most rational determination of the available resources (cranes, excavators, various materials, etc.). For this purpose, methods of linear programming are being used; e.g. the modified distribution method with small matrices and manual calculations; the method of differential rents, the simplex method and a series of other methods in performing calculations by electronic computers (5). Programmes which involve calculations of the best route for constructing highways and railways, laying pipelines, electric lines and other linearly-extensive structures with the help of electronic computers, have been developed and applied. Using small computers we can develop schedules for mass flow-line construction of large panel houses, calculate the requirements of material and technical resources, and so on (3). The concrete automatic plant and a number of construction machines with programme control have been designed (5).

At present, the methods of the theory for operation and cybernetics study (1) are applied experimentally in the management of construction of some large projects in the Ukraine, the Urals and in other regions of the U.S.S.R. Construction is considered as a very complicated probable system. The intricacy of this system is determined by the participation of a series of interacting building and assembly, designing, research and supplying organisations as well as production enterprises in which thousands of people and hundreds of machines take part. The probable nature of the construction system is connected with the fact that it functions in conditions of the medium being subjected to changes (accidental breakages of machines and mechanisms, change of weather, etc.).

The purposeful control which puts (in spite of these outside hindrances) the projects into service in due time, minimizing the production costs, and so on, is concerned with the best manipulation of resources and reserves of production, the size of which is established with the help of the newest mathematical methods. The effective management in the cybernetics construction system performed by electronic computers provides a regular method of finding optimum solutions according to given criteria (cost, time, smoothness of consumption of resources, etc.) on the basis of control information (i.e. the reverse connection), and bringing these solutions to execution in the form of operative plans.

The cyclograms described in this paper and network graphs for complex industrial and power projects are used as a model for a working plan (2).

The experience of the application of network graphs in some large projects in the U.S.S.R. has shown that the process of management of construction with the help of network graphs consists of three main stages.

The first stage is the development of a primary initial network graph and control of its conformity with the design time of project completion. This conformity is determined by calculating the critical path length which defines the total duration of construction. The reserves of time and resources are calculated according to work which is not on the critical path. This circumstance is used in the second stage for optimizing the graph as regards time, i.e. shortening the total duration of construction up to the planned one by means of reducing the duration of the work on critical path. Sometimes, this may be achieved with a mere transition of some resources from non-critical work to critical work (for example, the transition of a crane from one type of work to another) which is supposed to be expedient. In some other cases additional resources from without have to be drawn in for critical work. The optimisation may also be performed according to the cost of the work, uniform expenditure of resources, etc.

The third stage is the main one; it is used for the effective management and systematic control of the course of jobs. Once a week or once in every ten days, information about the course of an accomplished job is collected at the site. The network graph is analysed with the help of an electric computer or manually (when the number of events is not numerous) and we obtain the information about new critical paths and reserves of time and resources according to jobs which, at a given moment, are not on the critical path. This information is communicated to the site where the same day measures for shortening the duration of the jobs, which are on the critical path, are developed and carried out practically.

Simultaneously, the computation centre transmits to the Ministries, supplying plants and other organisations, the informations about work which depends upon them and has appeared on the critical path, thus threatening to upset the time of construction (for example, the supply of the technological equipment).

On the basis of experiments performed for the mangement of individual projects with the help of network graphs and remote electronic computers, an automatised system of simultaneous management of all large projects in the economic region is being designed from a single computation centre. The idea of this large system is that the information about the accomplishment of certain points of the network graph is communicated over the tele-type from each construction site to a corresponding computation centre on a definite day and hour of the week. Having analysed the corresponding network graph, the computer immediately communicates the data about critical paths, reserves of time and required control to the sites (including the new estimates of time obtained according to the principle of self-education), where proper measures are taken. Simultaneously, the necessary information is addressed to the Ministries, supplying plants, planning bodies and other organisations. This must naturally be done through a designed single statewide network of computation centres, a constituent part of which is represented by the computation centres for the planning and management of construction.

Up to this point the paper has dealt with the systems of management of many, but still individual, projects. It should be noted that under the conditions of the planned system of economy, the efficiency of the cybernetics systems of management may be sufficiently improved by means of transferring from the planning of individual projects and building organisations (it provides but the local optimum) to the optimum planning over an industrial or economic district.

In this case, the operative planning must definitely follow the calculations of the long-term planning for the organisation of construction in industrial and economic regions including the establishment of the construction priority and time (within the general task of the optimum location of enterprises); the calculations are performed with electronic computers. The result of such long-term calculations gives suggestions for the full and timely provision of requirements in certain production, correct annual development of building and assembly organisations in these regions, as well as the production basis of construction sites (i.e. their work according to the principle of a continuous flow-line), and eventually the achievement of the best technical and economical characteristics – the minimum of total expenses on the whole production with due regard to its consumption to all the users.

Consequently, it is necessary to obtain the minimum of the functional:

$$\min\Bigg(\sum_{ijl}\sum_{(t_i^l+T_i^l)}^{T}\{[g_{it}^{l}(x_{it}^{1},\dots,x_{it}^{a})+h_{it}^{lj}]\cdot x_{it}^{lj}\cdot[1+E_h]^{T-t}\}+$$

$$\sum_{h\mu i}\sum_{(t_h+T_h)}^{T}\{[G_{ht}^{\mu}(B_{ht}^{1},\dots,B_{ht}^{R})+H_{ht}^{\mu i}]\cdot Y_{ht}^{\mu i}\cdot[1+E_h]^{T-t}\}+$$

$$\sum_{il}\sum_{(t_i^l+T_i^l)}^{T}\left[\sum_{t_i^l}^{(t_i^l+T_i^l)}\cdot P_{it}^{l\,\text{invest.}}\cdot(1+E_h)^{t_i^l+T_i^l-t}\right]\cdot[1+E_h]^{T-t_i^l-T_i^l}+$$

$$\sum_{il}\sum_{(t_{mp}+T_{mp})}^{T}\left[\sum_{t_{mp}}^{(t_{mp}+T_{mp})}\cdot P_{t_{mp}}^{\text{invest.}}\cdot(1+E_h)^{t_{mp}+T_{mp}-t}\right]\cdot$$

$$[1+E_h]^{T-t_{mp}-T_{mp}}\Bigg) \qquad (1)$$

The following indexes have been accepted in the formula:
Certain values:

a – number of kinds of production ($l = 1, 2 \dots, a$);
n – number of possible points of production ($i = 1, 2 \dots n$);
m – number of points of consumption ($j = 1, 2 \dots m$);
T – number of years in the design period ($t = 1, 2 \dots, T$);
B_{jt}^{l} – volume of consumption of production for l kind at point j in year t;
g_{jt}^{l} – prime cost of producing a unit of natural production of l kinds at point i in year t (excluding expenses on raw material) depending on the volume of production (the prime cost does not include the depreciation deductions);
h_{it}^{lj} – expenses for transporting a unit of production of l kind from point i of production to point j of consumption in year t;
R – number of kinds of raw material which provides producing kinds of production ($\mu = 1, 2 \dots R$);
$C\mu$ – number of possible points of raw material production ($h = 1, 2 \dots c$);
B_{ht} – volume of production of μ kind of raw material at point h in year t;
G_{ht} – prime cost of production of μ kind of raw material at point h in year t;
$H_{ht}^{\mu i}$ – expenses for transporting a unit of raw material of μ kind in year t from point h of raw material production to point i of production output;
$P_{it}^{l\,\text{invest.}}$ – volume of investments in construction of enterprise which manufactures l production at point i in year t (established for the calculation of a construction flow-line, when we determine the construction time, expenses on temporary buildings, production base, means of mechanisation, overhead expenses, expenses on shifting the base of building organisations, etc.);
$P_{t_{mp}}^{\text{invest.}}$ – volume of investments in the development of a section of the transport network in year t;
t_i^l – starting time of construction for the enterprise which manufactures the production of l kind at point i (for example, the 5th year of the designing period); the time is established in calculating the flow-line;
T_i^l – duration of construction of this enterprise;
t_{mp} and T_{mp} – similar data about a certain section of the transport network;
E_H – standard coefficient of the investment efficiency.

Unknown values
X_{it}^{l} – volume of production output of l kind at point i in year t (it also defines the time of starting for a corresponding enterprise at point i). If at point i there had been the enterprise manufacturing the production of l kind by the beginning of the design period, its capacity should be taken into account;
X_{it}^{lj} – volume of transporting production of l kind in year t from point i of production to point j of consumption;
Y_{ht}^{i} – amount of raw material of μ kind shipped in year t from point h of raw material production to point i of production output.

In functional (1) the expression $(1+E_H)^{t_i^l+T_i^l-t}$ is used for adducing the investments of each year (during the construction period at point i of the enterprise which manufactures production of l kind) by the time this enterprise is put into action.

The expression $(1+E_H)^{T-t_i^l-T_i^l}$ is used for adducing the investments (which had already been adduced by the time of putting the enterprise into action) by the end of the design period T.

The expression $(1+E_H)^{T-t}$ is used for adducing the current expenses of year t by the end of the design period. In minimising functional (1), the equation reflecting balance correlation of the output and distribution of production must be taken into account.

The long-term planning for the organisation of construction includes three major kinds of continuous flow-line. The first kind is executed by a branch ministry and includes only projects of a given type (bridges, roads, power stations, etc.); with this,

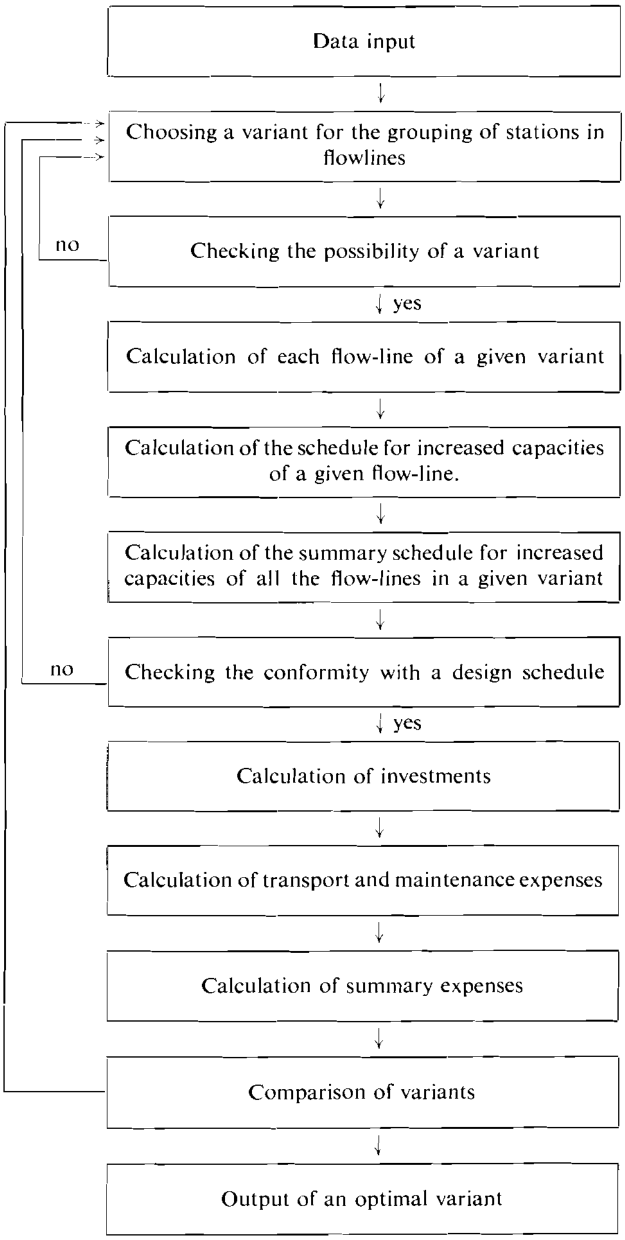

Fig. 1. Block-scheme for calculating the optimum priority and time of the flow-line construction of heat power stations.

the building organisations successively move from one point to another. The second kind includes projects of different types which are situated in one group of concentrated construction, i.e. removal of building organisations is practically eliminated. Finally, the third kind of flow-line operating in coordination with the second one is the fulfilment of separate types of special works (their volumes in one point are not great) by mobile subdivisions (for example laying of chimneys.)

The long-term planning for organising each kind of flow-line and establishing the optimum priority and time of construction for various enterprises (which is connected with the long-term planning) is a very interesting engineering problem which, as experience has shown, can be successfully solved with the help of electronic computers. The ways for solving some of these problems have already been developed (4), especially for heat power stations (fig. 1) and some economic districts of the Ukraine; certain calculations have been performed, and at present, construction is experimentally carried out in compliance with these calculations. Having a satisfactory long-term plan developed in this way, we may choose (out of the plan according to any project or a group of projects) the start and finish time of construction, and tentative data about the intensity and co-ordination of flow-lines of separate kinds of jobs.

With regard to these restrictions we can develop (with the help of a computer) network graphs for constructing a given project or all the projects in the region and organise the management and constant control for the course of construction from a computation centre (taking into account the best manipulation of available resources and reserves).

Such an experience is being carried out in the construction of a large chemical project in the Donbass region and the Burshtin State Regional Heat Power Station which is the first project of the continuous flow-line for constructing heat power stations in the Ukraine. Research work for creating cybernetics systems for the planning and management of construction is being carried out in Kiev by the Research Institute of Building Production of the Ukrainian SSR Gosstroy (State Building Committee) and the Institute of Cybernetics of the Ukrainian SSR Academy of Sciences. A series of large building organisations of the Ukrainian SSR are participating in the experimental installation of the results of this research work. One may hope that the exchange of opinions on the problems raised in this paper will be of benefit to building organisations represented at the CIB 3rd Congress.

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H. Ritter

Means to increase efficiency in traditional building

By H. Ritter (Switzerland)

Work process rationalisation and hence productivity rate depend on two factors, namely *Building method*, and *Work organisation*.

On the one hand, a building method should be selected which provides the most rational accommodation of the working process. Then again, performance of the work and production machinery, in other words, actual building organisation, should as far as possible fit in with the features and requirements of the selected building method.

Such prerequisites should be taken into consideration both in prefabrication and in traditional building, if these are to pay. It has been found so far in Switzerland that, provided work was well organised, traditional building applied to housing was not more expensive and was often cheaper—also in mass building—than prefabrication, quality being similar.

Building industrialisation may be developed not only in actual construction (e.g. prefabrication), but also in work organisation. In this respect, all the potentialities of traditional building have not yet been exhausted and therefore much more thorough rationalisation is to be anticipated. This paper explains a few of the main methods for increasing productivity in traditional building.

Proper and timely preparation of plans

Preparation of plans is a sine qua non of an organised job, because it determines what is to be built and how, fixes operating details and specifies quality. To achieve the highest possible efficiency, it is essential to prepare plans in time; in other words, the construction to be erected should have been studied in all its details. The plans should have been submitted in due time to afford contracting firms enough time to draw up a work procedure with the greatest care. The level of efficiency will be the higher as construction will have been better prepared and as performance of the work will be better organised. Plans should further be prepared in an intelligent way, so that the building method and the sort of construction, and also specified materials and installations are consistent with organised work. An elaborate plan, with a lot of nooks and corners, makes for a less profitable construction than a simple plan.

Complicated shuttering and casting moulds, as well as adjacency in the masonry of the various materials make the work more complex and slower to carry out; hence lower productivity. To make work easier, installations (sanitary, heating, electricity, gas) should be properly arranged, by grouping pipes, ducts and tubes.

Such major requirements in the preparation of plans are rendered, so to speak, compulsory by prefabrication, because all building components are factory-prefabricated. But they may also be taken into account in the traditional, and much more flexible, building method.

Standardised description of productivity

This description gives in detail and for each item, the various jobs which construction comprises, with all relevant data. Productivity description is of the utmost importance in preparing building work and performance. Therefore the way in which various building jobs are described is material: items should come under headings arranged in always the same rational sequence and should not differ from one description to another.

The adoption of a "standardised description of productivity" in which all the usual building jobs are arranged in a systematic sequence of items, in which a specific job is always classified under the same number and worded in the same way, is one of the major conditions for the achievement of organised work. It does away with doubts, inaccuracies and annoying hazards. Switzerland is preparing a standardised description of productivity for the building trade. It will be applied by all the main bodies responsible for the preparation of plans.

Proper arrangement and coordination of time allowed

Production can only be organised and, consequently, efficiency increased through a well planned, smooth work process, without idle periods or overloading. Arrangement and coordination of time allowed therefore play a prominent part.

Management should ensure that work within the firm is faultlessly organised. This implies that plans are made in due time and that productivity description is standardised. Proper internal organisation on the part of managers of firms contracting for building will make it possible to ensure coordination of time allowed for all contracts. That is the crucial point in respect of efficiency, according to the following equations:

Smooth work process = increased efficiency
Uneven work process = decreased efficiency

All things considered, arrangement and coordination of time allowed proceed from organised preparation of work. Such preparation aiming at ensuring the use of labour, machines, transport and equipment in adequate quantities, when and where required, leads inevitably to planning time allowed.

We have made investigations among contractors to try and ascertain the bearing a smooth work process or, on the contrary, an uneven work process had on productivity. In a number of building firms, a year of uneven work, i.e. made of a succession of periods of definite under- and over-employment has been compared with a year of smooth work, in which means of production were normally called upon. Such investigations showed that, in the same firm, production per net working hour in the case of an even work load was from 10 to 30% higher than in the case of an uneven work load.

Resorting to programmes has proved a useful practice for allotting time allowed to each operation. In comparison with time-allowed diagrams, they have the great advantage of allowing rapid amendments and forward and backward shifts by simply changing signs and marks, and also of providing a better and more condensed over-all picture.

Recent attempts have been made to organise building scheme planning according to the PERT or LESS arrangement network method. Technique has created fresh possibilities for arranging and coordinating time allowed, at any rate where large-scale projects are concerned. It would be premature to decide on the opportuneness of arrangement networks in the case of medium- or small size building schemes.

Organised control of efficiency

It is difficult to keep a check on work productivity on the site in the case of traditional building. The reason for this is that, failing ad hoc steps, there is no standard for measuring efficiency and control is rather a matter of non-objective estimation. Experience shows that little or no productivity control means lower productivity. It is therefore essential to organise planned control of efficiency on the building site. In this respect, two methods are available, namely, comparing expenditure with output efficiency in terms of money, and in terms of working hours.

The former method may be more accurate, but it is not so reliable when it is expected to provide information covering definite periods of building work, for instance, each month, and relative to the expenditure/output efficiency ratio.

This element of uncertainty comes from the fact that it is not possible to determine accurately the job performed, materials worked on, etc. in the monthly Profit & Loss account, so that estimations are resorted to which are always hypothetical. The second method is more practical and safer to apply. It consists in subdividing building work into stages or, for instance, according to the number of storeys and allowing for each stage or storey a specific number of working hours. By comparing, for each stage or storey, the number of working hours allowed with the number of actual working hours, it is possible to see whether output efficiency is normal or not. This method implies work preparation and real planning of time allowed, according to the comments made above; otherwise, it is not possible to determine with accuracy the number of working hours allowed to be applied as a measuring yard-stick.

Not before it is in a position to make a reliable measurement of productivity will management be able to accomplish better output efficiency on the building site.

Efficiency wages

In traditional building, a workman's genuine eagerness to be productive is a determining factor. It is therefore obviously a necessity to try and devise ways and means to give a worker a financial interest in productivity by paying him efficiency wages. Many systems to this effect are known; they may be considered however to fall into two main categories:

– Bonus is granted, as required; the amount and data of payment are decided by the management itself. This system may be quite simple, but its serious drawback lies in the conjectural way the manager calculates the bonus rate and also the non-objective way the workman appreciates it.

– Efficiency wages are granted following a carefully established scale. This does away, therefore, with the subjective element. But the method is more complex. Of general practice is the job or piece wage system, but it only applies to jobs that lend themselves to this procedure and therefore only affects a restricted number of workmen.

To create among workers an interest in output, it is necessary to establish a bonus system. Without going into all the details, let us say that the building site is then considered as a whole. Time allowed is worked out for each particular job. Over certain periods, work to be performed and, therefore, total working time allowed are accurately worked out; at the same time actual working hours are totalled. The ratio between total working time allowed and total actual working time provides a basis for working out the efficiency bonus.

The establishment of the efficiency wage system requires a first-class organisation of the firm and cannot be set afoot without adequate preparation. Efficiency wage practice has in some cases yielded remarkable results, with a 20 to 40% increase in production according to firms and the type of building.

Conclusions. Means suggested in this paper are but a limited choice. All things considered, it is always a matter of organising management to run a firm on efficient lines. Only in this way will it be possible to apply the methods outlined in this paper.

To ensure organised work it is essential that the preparation and carrying out of plans are, from the outset, suitable coordinated. Production will rise in ratio to the degree of cooperation between the two departments concerned. Comparisons made between similar firms in the building trade show a difference of 60 to 100% in hourly output between efficiently and inefficiently run firms.

This fact illustrates the enormous practical importance of able management. According to our own experience, a further approximate 10 to 20% increase in output may also be obtained as a result of close cooperation between the planning and the operating departments.

C 20

P. S. Slipchenko

Basic principles and experience of application of the flow-line production methods in construction

By P. S. Slipchenko (U.S.S.R.)

Technical and economical progress in almost all branches of modern economy, including construction (irrespective of the social, economical and political system of a country) is due to the industrialisation and organisation of the technological flowline.

The flow-line method in building production is a scientific system (tried and tested in practice) which provides high efficiency of a technological process of construction, the most rational utilization of productive capacity of building organizations and their resources (workers, technical personnel, mechanisms, transport, building materials, financial means and so on).

The flow-line method has been successfully evolved and has found wide application in the Soviet Union where a great stride has been made from the flow-line development of small settlements to the flow-line high-speed construction of many housing, industrial, power, hydrotechnical, transport and agricultural projects.

Following the example of the Soviet Union, the German Democratic Republic, Czechoslovakia and other countries are extensively developing the flow-line methods of construction.

The application of flow-line methods has been recommended by the Committee on Housing, Building and Planning of the Economic Commission for Europe (UNO) and by the Board of the Construction Industry of the Constant Construction Commission (Council of Economic Mutual Aid).

The basic principles of the flow-line method of building production are determined by two main features: continuity and smoothness. By this we mean an uninterrupted and smooth execution of a technological process of construction with the full and smooth utilization of the productive capacities of building organizations and their resources;

- an uninterrupted and smooth supply of necessary building materials, structures and units;
- an uninterrupted and even output of building production (buildings, installations or their parts).

This calls for the following measures:

- to break down the general process of building production into constituent component processes;
- to divide the realization of these processes among the executing agencies;
- to create a production rhythm;
- to co-ordinate the constituent processes in time and space.

Accordingly, the flow-line construction method may be regarded as one of continuous and uniform output based on a breakdown of the total production process, the division of labour, the coordination and rhythmical execution of the elementary building processes.

Flow-lines are classified according to duration as follows: short-term flow-lines, the objectives of which are houses, buildings or their complexes; and continuous (long-term) flow-lines the objective of which is the program of a building or assembly organization of a certain productive capacity.

As to structure, flow-lines are divided into:

- primary flow-lines which represent the successive accomplishment of a process on a series of working areas (parts of a house or a building);
- specialized flow-lines (a series of partial flow-lines) are those of which the output consists of identical structural elements for one building or of a series of buildings;
- whole-project flow-lines comprise groups of specialized flow-lines, the total output of which consists of complete construction projects or parts of such projects;
- complex flow-lines are a combination of organizationally related whole-project flow-lines for the output of buildings and installations of different types which form part of a single complex.

By the degree of development, flow-lines may be stabilized and non-stabilized, by degree of fragmentation they may be with partial or complete fragmentation of production processes (depending on whether an objective of the primary flow-line is a simple or a complex production process).

A system of flow-line parameters which characterizes the development of the flow-line in space and time is shown in Table 1.

TABLE 1 Basic parameters of a construction flow-line

Type of parameter	Symbol	Definition
Space parameters	m	Number of working areas
	F	Perimeter of operations
	L_3	Size of working area
	l	Size of plot
	a	Number of storeys
Technological parameters	n	Number of primary flow-lines
	p	Volume of work in primary flow-line
	P	Ditto construction flow-line
	S	Standard output
	q	Labour consumption in primary flow-line
	Q	Ditto construction flow-line
	i	Intensity of primary flow-line
	I	Ditto construction flow-line
Time parameters	k	Cycling module
	k_0	Spacing of flow-line

The following are the main parameters: a working area, an assembly area, a storey, number of primary flow-lines, intensity of a flow-line (volume of work accomplished in a unit of time), and the cycling module (duration of the primary flow-line on a working area).

Many years' experience of planning and organizing construction flow-lines has shown that such flow-lines are best represented graphically in the form of a cyclogram (Fig. 1) on which coordination of processes is shown not only in time but also in space. The characteristics of a primary construction flow-line are easily established by means of a cyclogram (Table 2).

TABLE 2. Characteristics of a construction flow-line

Indices	Single flow-line	Construction flow-line
Time	$t = mk$	$T = k(m + n - 1)$ $T = T_2 + k(m - 1)$
Intensity	$i = \frac{p}{t} = \frac{P}{mk}$	$I = \frac{P}{mk}$
Number of workers	$N = \frac{p}{ts} = \frac{p}{mks}$ $= \frac{q}{mk}$	$N = N_1 + N_2 + \dots N_n$ $= \sum_1^n N_n$
Technological cycle (period of development of flow-line)	$Time = (m - 1)k$	
Size of technological sector	$m_{time} = \frac{Time}{k}$ $= n - 1$	
Duration of building output	$T_{np} = mk$	
Production cycle	$T_z = nk$	
Number of completed working areas	$m = n$	

Peculiarities of continuous flow-lines have been revealed: they provide the most complete application of production capacities of building-and-assembly organizations.

Methods for the calculation and definition of a completed output have been developed; they allow for the effect of the volume of construction work, the duration of project construction, the schedule of their completion, etc., on the value of a completed output.

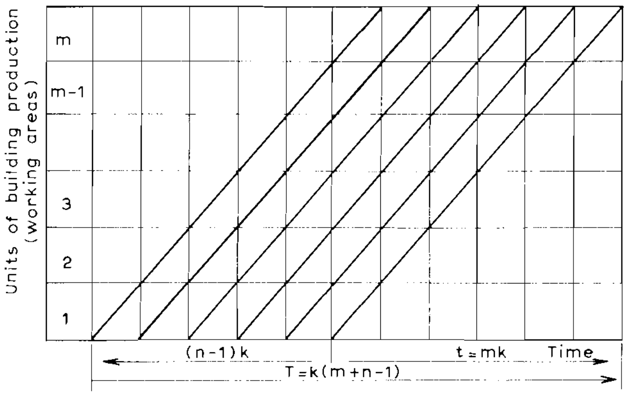

Fig. 1. Cyclogram of the construction flow-line.

Characteristics of various flow-lines for different branches of construction have been determined; they provide accurate calculations of the main parameters of a flow-line and, consequently, the designing of the flow-line organization of construction. Corresponding instructions and forms have been developed.

In housing construction, a complex flow-line of the development of settlements and housing estates is also used for all jobs connected with the engineering accomplishment of the territory. In using a whole-project flow-line we break down the process of construction of dwellings and public buildings into four or more technological stages (erection of the underground part of the buildings and above-ground structures, roofing, trimming and other operations).

In industrial and power construction the designing of the flow-line organization of work follows after choosing the starting lines. A complex flow-line for the construction of industrial enterprises may number up to 20 whole-project flow-lines used for constructing all the buildings, communication lines, and so on.

In the construction of hydro-power projects, a complex flow-line consists of a series of whole-project flow-lines used for constructing hydro-power houses, shipping structures, dams, and so on.

In the complex flow-line of canal construction the whole-project flow-line of the construction of a canal bed itself is a leading one. In designing a canal (for sections with a different technology of excavation and fleet of machines and mechanisms) we use parallel flow-lines executed by complex and mechanized teams of workers.

The complex flow of underground railway construction consists of a series of whole-project flow-lines providing the tunneling of vertical and slope shafts, distillation tunnels, the construction of stations, and so on. The passing through distillation tunnels is a leading flow-line, carried out with a complex and mechanized flow-line section.

Territorially-separated construction (for example, agricultural construction) is used for constructing projects at relatively small costs which are separated one from another at the distance of many kilometres. In this construction, for the flow-line execution of work new forms of building organizations and their subdivisions have been implemented (complex mobile detachments, columns, teams and the like).

The preparation of plans for flow-line construction and the organization of its execution are governed by regulations.

The State Committee on Building of the Council of Ministers of the Ukrainian SSR issued "Instructions for the organisation of the flow-line construction of housing developments" in 1961 and "Provisional Instructions for planning the flow-line construction of industrial enterprises" in 1963.

Provision is made for planning documents meeting the requirements of flow-line construction methods (irrespective of branches of construction) – standardised technological charts for building processes, standard technological specifications for unit building output and cyclograms showing the development of construction flow-lines in time and space.

The unique terminology has been worked out for flow-line construction methods and has been adopted both in the USSR and other countries. This terminology has been given to the Committee on Housing, Building and Planning of the Economic Commission for Europe (UNO) and to the Board of the Construction Industry of the Constant Construction Commission (Council of Economic Mutual Aid) for discussion and recommendation on their instruction, to all the countries concerned.

In the mass-sectors of construction (housing, industry, etc.), it is desirable to use the more efficient system of continuous flow-lines. House-building combines are playing an important part in the organization of house-building flow-lines extending over a number of years. Such combines make it possible to establish integral flow-lines beginning in building industry enterprises and ending at the building site with the commissioning of construction projects.

The special features of continuous flow-line production (long duration, selection of construction projects according to the predetermined production capacity of the building organization, series production, specialization, stability of complex material and technical supplies, high level of standardisation) determine the prospects for its future widespread use in construction.

At present the laws of the continuous flow-line are used as a technological basis for the application of mathematical methods and computer techniques in building with a view to finding the optimum solutions for problems of the statewide planning of construction. For example, the flow-line construction of a group of the greatest heat power stations in the Ukrainian SSR has been planned and is being executed.

In the organization of the flow-line construction, new ways of control for the construction progress with the help of electronic computer techniques and related network graphs are of great importance.

The efficiency of the flow-line method of construction is illustrated by several examples. Experience has shown that the time of housing construction carried out with the help of flow-line methods is reduced by 25–30 per cent, labour intensiveness is 1.5 2 times more than planned.

The Novokrivorozhye ore benefication combine in the Ukrainian SSR has been constructed in a period of 26 months (using flow-line methods) instead of 40 months (as per usual norms), which provided additional benefits in about 1 million tons of fine concentrate.

The flow-line construction of the Zhdanov 1700 MiU was completed in 15 months, i.e. 1.5 times faster than was planned.

The flow-line construction of the Kremenchug hydro-power station (625 thous. kw capacity) was completed 2 years earlier than the period stated in the plan.

The transition of the construction of the distillation tunnel of the Kiev subway to the flow-line method made it possible to complete its construction twice as fast.

The theory and practice of flow-line construction serves as a basis for the establishment and development of scientific research in building production.

The Research Institute of Building Production operating in Kiev deals with the elaboration of the flow-construction theory and its practical application in housing, industrial, rural and hydrotechnical construction. Working in this field also are the chairs of the Kiev, Kharkov, Novosibirsk, Rostov and other civil engineering institutes.

International co-operation, to which the Soviet Union, the Czechoslovak Socialist Republic and the German Democratic Republic are contributing, has already been established among scientists and practitioners concerned with flow-line construction methods.

In conclusion the author expresses the hope that the discussion of the problems raised in the paper will promote still better international co-operation in this field.

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Methods of organisation of investment enterprises on the basis of optimal system of functions

By W. Staniszkis (Poland)

This study deals with general rules for the organisation of investment enterprises based on the optimal set-up of functions. The notion "enterprise" comprises a set of elements of activity such as: the task and the decision of it's execution, active participants, place and time of action, methods, means and the objects which are the result of activity. The organizing consists of the integration of these elements in a way which would assure the success of the enterprise. By the investment process we understand the system of functions, which condition the erection of buildings which are the object of the investment proposal. The system of functions of the investment process is divided into three stages: (1) programming and planning, (2) designing, erection and assembly of machinery and investment appliances, and (3) starting. Each of the basic stages is preceded by the preparatory stage. The whole process ends with the receipt and accounting stage. The subjects active in the process are the participants of the enterprise.

A complicated system of functions, a numerous team of participants and long duration of investment processes point to the necessity of a theoretical study of foundation of organisation of these activities, in a way which would make possible the choice of an optimal solution. This choice can be done by the use of the method of determining chains of operations (MDC), consisting of the establishment of the set-up of functions of the process and of the mathematical analysis of such set-up, in order to adapt the system of functions to the lowest outlay and related shortest duration, or the duration necessary with the minimal rise of outlay.

General rules of organisation of investment enterprises

General rules of organisation of investment enterprises can be listed as follows: basic regularities, rules of the organisation of the system of functions and of the team of participants, and planning of the organisation of investment enterprises.

Basic regularities

In the given social and economical conditions and in view of the state of technique the effects of investment activity depend on the state of organisation of the investment enterprise and its participants. The analysis and evaluation of the organisation of investment enterprises proved that on organisational bodies and the conditions created by them depend: the way of taking decisions, the efficiency of activity and the degree of exploitation of means.

The organisation of the enterprises should be considered in the functional as well as institutional arrangement. The first aspect comprises: the determination of the set-up of functions, dependencies arising out of this set-up and disposal in time. The second deals with: active participants of the enterprise, the division of tasks, the way of cooperation and coordination, the setting in space and inputs of production means. In both aspects the rule that the elements are to co-assist in the execution of the investment program in the most economical fashion possible, is obligatory.

The efficient organisation of an investment enterprise is possible only if the whole arrangement of activities and the whole team of participants have been considered. Only when all the elements of activity and their interdependencies have been taken into account does the possibility exist of undertaking decisions based on appropriate criteria related to the purposeful and speedy execution of the investment program.

The basis of the organisation of the enterprise consists in the system of functions – a condition sufficient for the attainment of the planned investment aim. The system of functions in the investment process adapted to the aim and conditions of the enterprise and to the established methods and time of activity, constitutes the basis for the determination of the participants' tasks and the required means. As well as this, the set-up of functions can serve as basis for the establishment of the collected information and deliveries network within the system of the participants of the enterprise and among the departments in the participants' firms.

The organisation of the system of functions

The determination of functions which form the indispensable elements of the process, their succession, way of execution, time of duration and necessary means should be based on the technology of the considered process. The technology of each process determines the kind of basic and auxiliary functions necessary to obtain the product, which is the aim of the process and determines the conditions which make possible the execution of these functions in a purposeful and economical fashion.

The efficient course of the investment process requires that the execution stage should be properly prepared at the preparatory stage, that each phase of the process is forerun by the preparatory phase and that every function at the start is fully prepared for its execution. In the organised system of functions appear certain dependencies, which point to the double meaning of the aim attained by the execution of each function. One is the form of direct effect, the second being the preparation for consecutive functions. A considerate preparation of activity is to create conditions which would render possible and facilitate the execution of functions.

The decisions undertaken during the investment process should cover the full range of problems which will have to be solved at the appropriate stages of process. Erroneous, incomplete or delayed decisions cause later changes in the planned enterprise. These changes may create not only the necessity of new preparatory functions, adapted to altered conditions and requirements, but also cause a loss of time and outlays, owing to the waste of former preparations.

In the investment process appear the leading activities, which have the greatest influence on the consecutive parts of the process. In the course of leading activities the decisions steering the course of information and supplies are taken.

The course of steering decisions comprises:

- determination of investment aims;
- determination of the place and time of the execution of the investment;
- determination of the organisation of the investment enterprise;
- choice of technical solutions and the determination of the amount of means required;
- detailed determination of the course of the execution of the investment;
- basic working decisions in the course of the execution of the investment;
- receipt of the investment.

The course of the steering decisions, taken during the investment process sets up appropriate stages of the organisational cycle. Also the structure of each course of functions connected with the preparation and transmission, execution and control of the execution of each decision should tally with the organisational cycle.

The system of functions in the investment process should be adapted to the efficient course of dominant phases. The dominant phases in the investment process are those which in their course take up most of the investment outlays and the phases which influence the freezing of the outlays. The dominant phases comprise: the completion of the building, the supply and assembly of machinery and of investment appliances, and the start of the exploitation of the finished building.

The aim to execute the investment in the shortest feasible time, and parallel course of functions of the process, require precise coordination of functions in order to assure their working in an unhampered fashion. The attempts at shortening the time of duration of the investment process consist in a great measure in

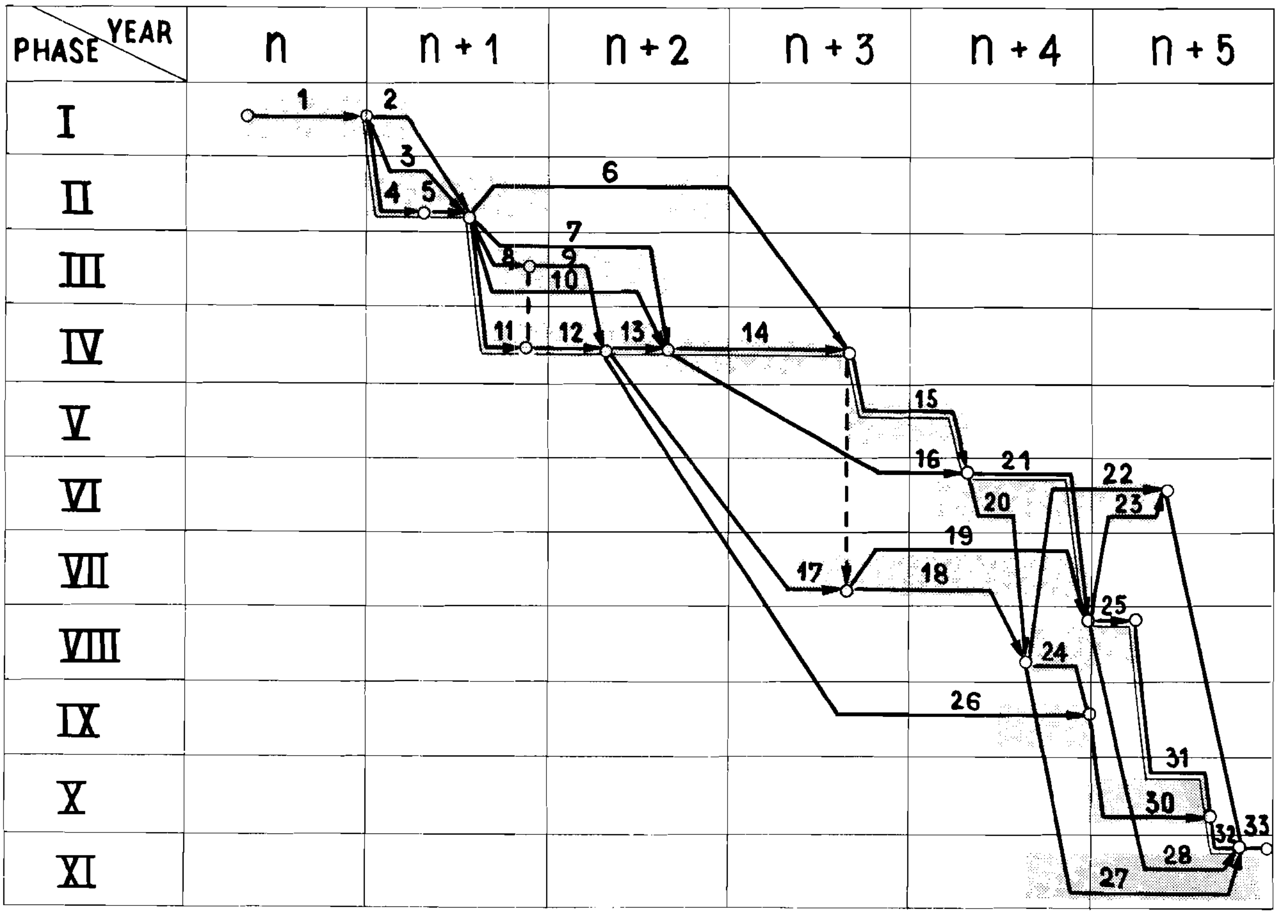

Fig. 1. The general network of functions and the timetable of the investment process of a factory hall /5000 m^2/

Phases of the investment process
- I preparation for programming
- II programming and planning
- III preparation for designing
- IV designing
- V preparation for building
- VI execution of building
- VII preparation of machinery setting
- VIII assemblage of machinery and appliances
- IX preparation of starting
- X starting
- XI receipt of investment

The list of main functions of the investment process
1. general decisions
2. set-up of investment services
3. detailed localization
4. working out of investment indices
5. acceptance of investment indices
6. investment and financial plans
7. establishment of investment overseeing
8. acquiring of geodesical plans of the site.
9. stocktaking on the site
10. acquisition of the site
11. preparatory functions of designing
12. primary technological design
13. primary building design, installations
14. basic design
15. preparing of building works in the firm
16. preparation of building site
17. plan of supplies of machinery and appliances
18. supply of machinery, part 1
19. supply of machinery, part 2
20. execution in the raw state, part 1
21. execution in the raw state, part 2
22. finishing works, part 1
23. finishing works, part 2
24. assemblage of machinery, part 1
25. assemblage of machinery, part 2
26. preparation of starting
27. part receipt of building works
28. part receipt of building works
29. final receipt of building works
30. starting, part 1
31. starting, part 2
32. starting of the plant
33. receipt of the investment

such disposal in time of phases and function, that the period of simultaneous course could take the longest part of duration — whenever technology admits it. Such solutions may cause disturbances in the course of the process if the preceding phase is too much delayed in the functions conditioning the execution of functions in the next phase.

The unhampered course of functions may be ensured by the application to the process' organisation of the method of the decisive course of functions enabling strict determination of dependencies in the system of functions.

The system of functions in the investment process should be coordinated to the course of conjugated and accompanying investments. The conjugated investments are those whose production conditions the exploitation of the investment being the subject of the enterprise, or that which is dependent on the exploitation of this investment. There are also the accompanying investments, by other investors, which influence the starting of the organised investment.

The basic importance of the functional approach to the organisation of an enterprise points to the necessity of choosing an optimal system of functions, of the investment process as to its costs as well as time of duration. The optimal set-up of functions can be determined by the mathematical analysis establishing the course of the process related, in the given conditions, to the lowest costs, shortest duration and to available means. Thanks to the method of deciding courses of functions (MDC) applied to the organisation of the optimal system of functions, one obtains precise criteria for choosing the most advantageous organisation of the enterprise.

The organisation of the team of participants

The organisation of the team of participants of the enterprise should be adapted to the tasks ensuing out of the system of functions of the investment process as well as to the conditions in which the investment is to be executed.

The adaptation of the institutional organisation to the optimal system of functions ensures the most advantageous course of investment activity. The division of tasks within the team of the enterprise's participants should take into account:

- the execution of each task by a properly specialised participant;
- the concentration of the execution of similar tasks in the hands of participants best suited for the purpose.

The execution of partial tasks by participants should be in harmony with the aim of the investment activity and within the team of participants. Economical effects of the specialisation of functions can be obtained only through efficient cooperation of participants of the enterprise, and coordination of their activity. The accepted system of functions of the process constitutes the basis for coordination of the course of activity. To ensure proper cooperation and coordination it is necessary to establish, within the team of participants, legal and physical bodies responsible for management and coordination of the whole process and of its parts.

The effects of the participants' activities depend on the degree of integration of people engaged in the investment, and in the building production, into a team conscious of the aim of the enterprise, and of partial tasks, and obeying the set order of activity. A common plan of work, laid out according to the system of functions, helps to raise output, better exploitation of tools and materials, and the standard of work. The managers have then the grounds for undertaking decisions with all the important elements taken into account.

The regular supply of the necessary means for the task is the condition for an efficient running of the enterprise.

The establishment of the system of functions helps to determine the plan of supply both with regard to kind of materials required and amounts as well as to the delivery dates. Besides, it becomes possible to coordinate the tasks to the supply possibilities. It is of particular importance for the organisation of a group of interprises executed by one firm or for a complex investment.

The planning of the organisation of investment enterprises

The attainment of efficient organisation of an enterprise necessitates the need of working out, at the programming stage, the basis for organisational decisions in the form of the proposal for the organisation of the enterprise. The plan should include the information necessary for undertaking the decisions such as:

- establishment of the system of functions;
- establishment of the team of participants;
- determination of the system of supplies;
- determination of the method of coordination of control of activities in the investment process.

The application of the method of organisation of enterprises based on the optimal system of functions should give the following economical results:

- raising of effectiveness of investment enterprises owing to a shortened time of execution and to lower costs of the investment;
- raising of productivity of participants owing to a shortened period of their engagement in the process, and lowering of prime costs;
- saving in the national economy through better exploitation of the investment owing to more efficient coordination of conjugated and accompanying investments, and to limiting of the investment, as far as possible.

Programming of building production

By O. Strádal (Czechoslovakia)

As one of the most effective means of finding the optimum solution in many branches of the national economy of numerous countries, production programming has undergone vast development in recent years.

Programming is a mathematical technique which selects from a number of possible solutions the one which represents, according to a certain criterion, the optimum solution under the given conditions. This criterion can be given, for example, in the form of a linear or non-linear function in accordance with which we can talk about linear or non-linear programming.

The purpose of this paper is to demonstrate several principal solutions, and their results, in the field of linear programming of building production in Czechoslovak construction. It contains descriptions of basic linear programming models on the one hand, and the results attained in experiments on the other hand.

The basic model of linear programming of building production can be defined as follows: for a given situation, a given production unit and a given period there are certain limits of resources which must not be exceeded. Such limits can be represented, for example, by the number of workers of a certain profession, or the capacity of mechanisms of a certain type (e.g. number of cranes) or even the quantity of certain building materials or products. Limiting of the quantities of building materials or products occurs particularly in the conditions of industrialized construction, the number of prefabricated components produced in industrial works being limited by the production capacity of the latter. It is the task of linear programming to ascertain the optimum solution under such restrictions. The criterion for the selection of the optimum solution is mostly the profit of the production unit. However, other criteria can also be used, such as minimum labour requirements on the site, etc.

The linear programming model of the building production of a production organization has its restrictions and a linear function determining the selection from the possible variants of the production programme. With regard to these variants of the production programme the following three possibilities can occur:

– a) The production organization has a completely free selection of its production programme. However, this possibility can actually concern only a part of the production programme, because there are always buildings or projects under construction which are covered by contracts and which must be consequently continued.

– b) The production organization has a fixed production programme regardless of whether it is due to the directions of its superior authority or to the previously concluded contracts. In this case it cannot select the desired types of buildings, but only the technologies of their construction. In this case the programme calls for a certain fixed number of flats, schools, etc. on the individual sites. The selection concerns the possible variants of their execution, i.e. determines the number of flats to be built by conventional methods (in brick masonry), to be assembled of prefabricated light-weight components, to be assembled of precast heavy units, etc.

– c) Current practice always represents a combination of both the above cases. Part of the capacity is free to be filled up with selected types of construction, the other part is fixed, affording only the possibility of selection of the most suitable method of execution or, as we say, the technological set which is most advantageous under the given restrictions.

The actual calculations can be carried out by the simplex method, programmes of sufficient extent being available for every medium-sized computer to enable the optimization of the building production of production units employing as many as 10,000 people.

It will be of interest to know for what period the solution of this problem can be applied. The linear programming model of building production can be solved, above all, for the following year or six months. Such a model selects, under the given restrictions, i.e. under the given limits of workers of the individual trades, quantities of materials or products available, or the capacity of mechanisms, the most suitable type of construction or the most suitable technological process of construction within the framework of the given organization. The production organization can mean the whole building corporation or one of its subordinate units, e.g. a regional production unit.

The linear programming model, however, can also be used for an analysis of perspective tasks and represents a very valuable instrument for the verification of hypotheses concerning the perspectives of construction and the required means of production. In such a case the model is prepared for one or several years to come, the limits of manpower, materials, products and mechanisms available being considered in several variants. After optimization of the individual variants the final selection can be made, for example, by means of graphic methods.

In the Czechoslovak building industry, several linear programming experiments were carried out for several building corporations as whole production unit enterprises, further for several of their subordinate units, and finally for a whole building trust employing some 10,000 people. The technical and economic characteristics of the requirements of the individual materials, products, capacities of mechanisms as well as the indices of manpower requirements of the individual trades in the construction of the individual types of buildings were taken over from the official collections of technical and economic indices of different building types. These collections incorporate the indices of some 500 representatives of various buildings and structures ascertained on actual sites. The indices include prices, production costs broken down according to various components (wages, materials, machines, overheads, etc.), the manpower requirements of the individual trades, the requirements of selected building materials and their weight for the whole building or structure and for its individual parts.

Experiments carried out in recent years have shown the advantages of production programming both on the level of a building corporation and its subordinate units, as well as on the level of a building trust both for the planning of building production in the coming year and for perspective planning. Simultaneously with these experiments, the combination of linear programming with the structural model of a building corporation was also tested.

In conclusion I should like to stress the economic importance of one of the features of linear programming, viz. the solution of the dual problem. As I have already mentioned a decisive role in the optimization of linear programming models will be played by the limits of the quantities of selected building materials, the number of workers of the individual trades, and the capacities of the mechanisms available. These limits represent the restrictions of the linear programming model, their value directly influencing the value of optimization criterion, i.e. the amount of profit or production costs. It must be realized that these limits are determined directly, arbitrarily, and often represent the bottlenecks of the whole production process. At the same time practice shows that they cannot always be unconditionally adhered to. If it were ascertained in time that such a limit represents a bottleneck of the production process, unconditionally influencing the economic results of the activities of the production unit, the management could take the necessary steps to eliminate it by, for example, procuring the deficient number of workers of a certain trade acquiring further mechanisms, contracting further quantities of materials, etc. Even in the case of a shortage of factory-made prefabricated components it would be possible to procure additional capacities by establishing temporary production lines on the sites, etc.

Of great value for ascertaining the extent to which these bottlenecks effect the results of optimization, e.g. the amount of profit, is the application of the dual problem

In the solution of problems by means of linear programming methods we also obtain the so-called dual variables. In our case of the optimization of profit these values reveal the "price" of the individual resources and bottlenecks for the corporation, i.e. how the procuring of another unit quantity of a certain resource, say an increase of the limit, will increase its profit. In the respective literature these prices are called "shadow prices" or "fictitious prices".

The economic interpretation of the dual problem has further consequences. In an optimum solution the excessive resources have no fictitious value. The fictitious prices thus afford information on the bottlenecks and excessive resources in the course of the optimization process, which is of great importance for their elimination by means of increasing the respective resources (limits).

We have experimented with the dual problem in the Czechoslovak building industry, and have attained promising results.

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C. Ugander

Integrated data processing for builders and general contractors

By C. Ugander (Sweden)

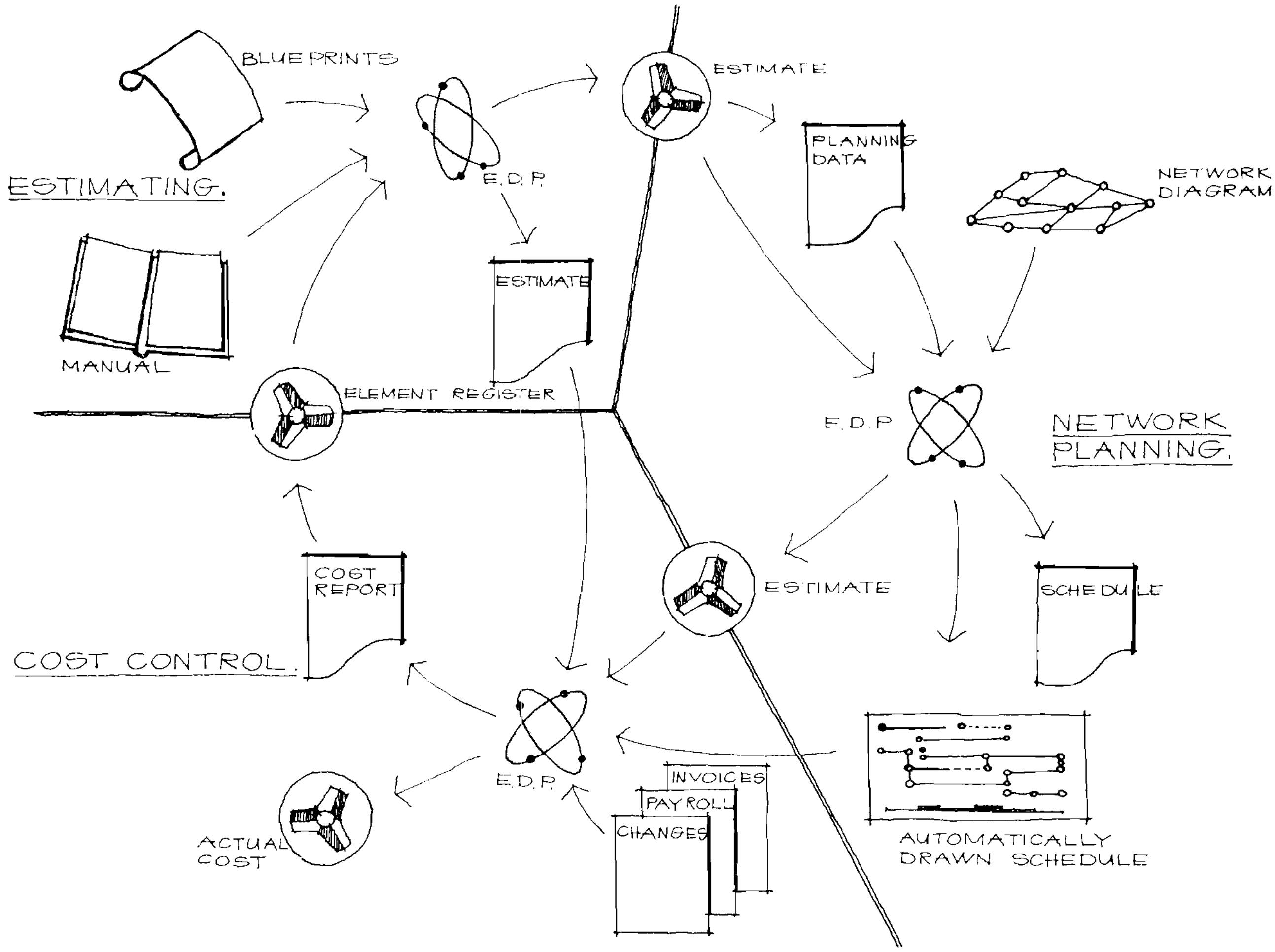

Fig. 1. Integrated data processing.

When a builder is going to prepare a bid he first has to find out the quantities involved in the project. These quantities must then be priced. This means that the builder has to go back to his own experience in order to get the correct prices. After having multiplied quantities and unit prices the builder has what could be called the production costs. To these he must add overhead costs and other expenses, and so he has his bid. If he later is awarded the contract he has to make some kind of schedule for the project. He maybe draws a network diagram and in order to estimate the time durations he must go back to the original quantities and for each activity estimate what resources he is going to use and then calculate the duration for the different activities. Later during the project the schedule has to be revised and the costs must be controlled. This means that the contractor once more must go back to the quantities or the different activities to find out how much of the estimated quantities has been produced at each reporting date. Finally when the project is completed the builder makes a cost analysis in order to find out how much time and what costs have been used for different activities. Once more, he then uses the very same quantities he has been using all the way during the project.

This description of the process a builder has to go through during a project is in no way unique. It is only meant to show that almost the same data are being used during the different phases of quantity surveying, cost estimating, planning and scheduling, cost control and cost analysis. Furthermore the volume of data that has to be handled is quite large. Therefore it is natural to try to co-ordinate all these routines with the help of a computer into one single integrated system.

This paper describes such a system for integrated data processing that has been developed in Sweden during 1963—64 by AB BYGG-ADB. For quantity surveying and cost estimating there has been developed a system called "DATAKALKYL". For network planning there has been developed in co-operation with AB Skånska Cementgjuteriet a system called "PLUFS". Finally for cost control and cost analysis another system, so far without a particular name, has also been developed.

DATAKALKYL

This is a system for quantity surveying and cost estimating primarily used for apartment houses. The basis for the system is what is called an element register consisting of a number of different elements. An element might be for instance a wall, a slab, a window bench, a hat shelf and so on.

The elements that are included in the element register are described on certain drawings. These drawings are put together in a manual. On each drawing is shown a code which gives the specific number that the element has in DATAKALKYL. On the drawing is also shown a subdivision of the element in what is called "skikt". This subdivision serves two purposes. First it is used to compose new elements. To cover every existing type of element would require a large number of elements. Thanks to this subdivision into "skikt" it is possible to compose new elements just by changing "skikt". Secondly the subdivision is used for network planning. Therefore the subdivision is done with regard to the different kinds of operations that have to take place in order to produce the element. It is possible to get the estimate specified on different kinds of operations, which is necessary for the network planning.

When the take off is carried out for a certain project the builder is working with the blueprints and the manual with the element drawings. On the blueprints the elements which have to be measured are shown. For each element the quantity surveyor looks in the manual in order to find the number of the appropriate element. This number is filled in on a special form. Then the measurements are taken off the blueprints and also filled into the form. In order to prepare for network planning it is possible to specify the quantities in what is called planning units. This means that it is possible to divide the project into different planning units each given a specific number. A planning unit might for instance be a floor or a complete building, depending on how detailed the planning is going to be. All data that has been filled into the form is then transformed to punched cards which are fed into the computer. There the measurements for each element are multiplied with each other. The result is a list showing calculated quantities for each element specified on the different planning units.

In the computer is also calculated required quantities of material and labour. On a magnetic tape there is stored data about how much material and labour is required per unit of each element. These figures are multiplied with the calculated quantity for each element. When all the elements have been processed in the computer there is stored data about all the material and labour that is required for the whole project. These figures are printed on a list including all the material required and for each material the quantities. The list also includes all crafts required and for each craft the required number of working hours. On this list the builder can fill in the material prices and labour wages that are going to be used for the project. When the lists have been filled in they are returned to the computer in which the quantities are multiplied with the prices. The result is the costs for each material and labour craft, and the sum is the production cost for the whole project. These figures are printed on a list which will be the basis for the contractors bid. However, the figures are also stored on a magnetic tape so that they can be used later for planning purposes if the builder is awarded the contract.

Network planning

If the builder is awarded the contract and he wishes to do network planning he must prepare a network diagram. With this diagram, he estimates the quantities for the different activities. If the project earlier has been processed with DATAKALKYL the quantities are already taken off and stored on a magnetic tape. All that is needed is to sort the data on "skikt" and print a list showing for the different activities the quantities and also the required time for different crafts. This means a rather simple way of getting the planning data, a thing that otherwise is rather difficult and time consuming.

When the network diagram is complete and the time duration for the different activities is decided upon, the next step is to calculate the time for the whole project and to sum up how much labour is needed. For these calculations a special computer program called PLUFS is used. Therefore certain data about each activity has to be filled into a certain form. From this form, cards are punched and then fed into the computer in which the calculations are taking place in accordance with the critical path method. So far the results always have been presented in lists, but when this report is being written the first tests with automatically drawn diagrams have been produced. This means that the results are not taken out of the computer but they are stored on a magnetic tape, which then is moved to the automatic lineplotter which automatically draws the complete diagram.

This diagram is only regarded as a preliminary plan, used as a basis for very detailed discussions together with the foremen on the building site. As a rule it is always necessary to try to shorten the building time, and some other changes are usually also required for instance because of an uneven labour diagram. Very often these changes can be done manually. However, when manpower levelling is required it is necessary to feed into the computer data about how this levelling shall be carried out. The computer then makes the calculations and the results are presented in the form of an automatically drawn diagram which, after the approval of the foremen, is drawn as a final schedule. The network planning stage is then finished.

Cost control and cost analysis

When the network diagram is drawn and the activities are defined, it is possible to begin the work with re-arranging the estimate. If the estimate is going to be used for an effective cost control, it must be changed, so that it comes in accordance with the network diagram. This means that the quantities in the estimate must be subdivided into activity quantities. When this is done, the changed estimate is filed onto certain forms from which cards are punched. The cards are fed into the computer and the estimate is stored on a magnetic tape. The computer also prints a list showing the rearranged estimate. This estimate is then used during the project as a basis for the cost control.

In order to get actual costs, material and labour must be fed into the computer. For this purpose a special form is used on the building site. On these forms, data about time distribution payrolls and invoices are filled in. Also data about changes in the original estimate are filled in. To collect all these data on the building site a routine is developed for which one of the clerks is responsible. The forms are sent to the data centre, once a week and there the punching is done. The punched cards are fed into the computer and the data are stored on a magnetic tape.

Whenever anybody so wants, it is possible to get a cost report for the project. If such a report is wanted, the data centre is asked to produce a special list on which the produced quantities shall be reported. This means that from the computer is printed a list showing for each activity what quantities have to be produced according to the estimate and also how much was produced according to the last report. On this list there is a blank column to be filled in, with data about how much is produced at the reporting date. On the building site it must also be decided how much material remains to be billed and also if there is any material that has not yet been built. These figures together with the list with produced quantities is sent back to the data centre and is there fed into the computer which then prints the cost report. This report shows what costs should be committed according to the estimate, and what costs have actually been committed. In connection with these cost reports is also made a revision of the schedule for the project. If the deviations from the original schedule are large this might lead to part of the network diagram being rescheduled.

In this way the cost control is carried out during the construction period. When the project is completed it is possible to get a cost analysis for the project. This cost analysis includes data about production rates for each activity. On the basis of this data it is possible to go back to DATAKALKYL and change the data that has been used there for production rates. In this way the circle is closed and from one project is collected data which can be used for future projects.

Computer requirements

Two kinds of computers are being used for the integrated system. For DATAKALKYL and the cost control is used an IBM 1401 with 4 magnetic tape stations and 8192 positions. For the network planning is used an IBM 7090. The calculations in connection with network planning are more complicated and require a larger memory. This is especially true for the manpower levelling. The equipment that is used for the automatic drawing of the diagrams is a lineplotter called Calcomp 570 equipped with magnetic tape.

Practical experience

The different systems for quantity surveying, cost estimating, network planning, cost control and cost analysis have been developed without any connections with each other. First the program for network planning was completed in September 1963. The programs for DATAKALKYL and cost control were completed in June 1964 and were tested during the summer and in September 1964. The first real projects were run with these systems. This means that when this report was written there is only considerable practical experience from the system for network planning. The systems for DATAKALKYL and cost control have just recently been put into practical operation.

As for network planning, it is our experience that even if the computer is helpful for the pure time calculations, a large job still remains to be done manually. This is especially true with the drawing of the preliminary and the final plan. Therefore the possibility to get the preliminary plan automatically drawn will be quite difficult. When it comes to the question of manpower levelling the computer has proved to be superior to the human being, because the computer can try a much larger number of combinations than is possible with manual methods. Therefore if the computer is used in such a way that it produces complete diagrams as well as manpower diagrams, then the machine is really an effective tool. In addition to this the integrated system makes it easier to decide the time durations for the different activities. Today this estimate of time duration must be done very approximately. But with planning data prepared directly from DATAKALKYL this obstacle is eliminated.

When it comes to the system of DATAKALKYL the experience from the test projects has shown that, when the element register is complete, the advantages with this system will be speed and increased accuracy. The costs turn out to be about the same, or maybe slightly less than the costs with manual methods. Finally when it comes to the system for cost control, the advantages will be that there is a regular routine and that the time consuming calculations can be done on a computer, and also that it is possible to get reports to the building sites very fast.

Future developments

Today all three systems are operating satisfactorily. It is quite obvious that each system in itself can compete with traditional methods. Therefore these new systems will lead to increased productivity and lower costs.

However what is most important and desirable for the future is to connect the different systems more closely together. For instance it should be possible to use the magnetic tapes from DATAKALKYL directly for cost control and cost analysis. This is in no way an unsolvable problem, it is only a question of hard work. However, it should be pointed out that all future solutions to these problems would be very much helped if some common coding rules and common principles for estimating and cost control could be agreed. Today it is unfortunately so that the estimate is being done in accordance with certain principles, but the planning and cost control is done in accordance with quite other principles. If the same principles could be used for the whole process, the development within this area would be much easier to carry through.

Finally, it should be added that what is described in this report only deals with the builder's and general contractor's problem. However, the building process starts long before the contractor comes into the picture. Therefore the future development must aim at going back to the architect, because it is there that the project is originally born. To go that far is in no way impossible. But then the question about common codes and principles is even more important. If, however, these problems can be solved, then we have already come some steps on the way towards a truly integrated data processing system for the building process.

Group D
Regulations

Final report from the group rapporteur J. Nadal, Director of the "Instituto Eduardo Torroja de la Construcción y del Cemento", Spain.

The papers submitted to the general subject of "Regulations" are 7 papers, printed for consideration in advance, and 5 other papers, which we have received later.

The 12 papers constitute a significantly important contribution to the study and understanding of the evolution of Regulations. Indeed they show close agreement with regard to rapid evolution of materials, techniques and actual construction itself.

Hence all the papers received have a common thought behind them; I would even say more, they have a common purpose. This is the attainment of methods of formulating building regulations in such a manner that the regulations shall be useful for the future development of industrialised construction. This common purpose is not, on the contrary, the enunciation of restrictive documents, which would impede the introduction of new products into construction, as Mr. Legget has stated in his report.

It can be noticed that there is a growing tendency towards the substitution of restrictive conditions, in greater or smaller measure, by others which stimulate the use and development of new materials, more advanced techniques... But this evolution of regulations, none the less, is not as rapid as might be desired.

An international collaboration might appear to be necessary to clarify and complete certain concepts and also to establish bases from which future regulations can develop authentic means to control and to aid the most rapid possible evolution of construction. In this respect, the communication of Mr. Christensen (D.2) could really serve as starting point for the setting up of precise definitions, and as an aim for the future construction specifications.

In my view the papers by Mr. Blachère (D.1) and Mr. Saillard (D.6) are also important contributions, taking into account that they bring forward the points of view of the research centres and of an international organisation. This is complementary to the concept of regulations which are exclusively concerned with present day legislation, as discussed by Mr. Christensen.

Basic Principles

To establish what we might term basic principles, or perhaps the philosophy of specifications, the communication of Mr. Christensen and that of Mr. Blachère are extremely interesting. In addition to the contributions submitted to group "D", the document H3, devoted to general considerations on the matter of construction specifications, is also of interest.

These three communications, as well as that of Mr. Legget, have emphasized the need to do away with old conventions, and go back again to the fundamentals. This means that the human being should be taken as the initial reference, together with his requirements, or else to define the behaviour requirements of the building as a whole (according to Mr. Bergvall); or the behaviour requirements of its essential components, such as the structure, roof, etc. (Mr. Legget).

By taking as one possibility the human requirements as the basis of regulations, four categories can be established, according to Mr. Blachère. These correspond to physiological, psychological, sociological and economic circumstances.

From this initial principle, or system, a method should be chosen to attain precise regulations, which are specific for building, and have consequently an immediate effectiveness for the architects, contractors, building authorities, and, in general, for all those who take part directly in the process of building.

Regulations based on functional requirements or regulations based on specific needs, prescribing the use of given materials or construction methods

Human requirements, enunciated as such, are practically never directly applicable as technological specifications.

The human and functional requirements must be suitably correlated. The application of functional needs, as a basis for positive action by the legal authorities has the advantage that such needs may be formulated without reference to materials, structures or techniques of the future. Hence the field of applicability of these is vast; its validity in time would be very long.

These advantages would help industrialisation, technological advancement, and also international cooperation.

But the method has also disadvantages. We might add, it has weak points. In my view these points are, on the one hand, the need to know very well, and in a very detailed manner, all the possible loading conditions, even the ecological ones, and also all the permissible limits of error, or tolerances.

Furthermore it is necessary to establish standardised testing methods, to establish with reasonable accuracy and reproducibility the value of each variable, or of the parameters, which define the functional behaviour during the permissible period of service.

The science of construction is not yet sufficiently advanced to meet these two conditions in all possible cases, and it is in this context that technical research, applied to building, has its most urgent and primary function.

The system in contrast to the one we have just described consists in formulating the regulations in the form of specific requirements, which demand the use of certain materials, structures, or construction procedures.

This type of regulation is mostly the traditional one. Its requirements are almost exclusively based on the experience derived from practice, extending over several years.

Obviously this system has the disadvantage that such specifications are only valid for materials, structures, techniques and methods already in existence; so it becomes necessary to revise the specifications each time that technological advances lead to new methods, new materials or new construction systems.

This type of regulations, moreover, does not constitute always a truly positive measure, in the sense that it favours the development and evolution of the construction industry. Sometimes it can become a real barrier, holding up for a considerable time the evolution of a given material or technique. One can even state that in some cases these regulations can act as an insurmountable customs barrier, preventing certain constructive procedures from entering a particular country. But this system has also its advantages, among which one is of great importance: the very simple and well known manner of checking the quality, by following certain tests and methods, and using a type of technical equipment and facilities that are available at most of the control laboratories.

This does not imply that in all cases the correlation between the results of tests and the behaviour of the construction itself is totally satisfactory. But in general, and in the normal practice of what we might call traditional building and traditional materials and applications, the traditional methods of testing are still valid.

After having referred to the two systems, it should be emphasized that it is practically impossible to formulate all regulations following only one of these two procedures. It should be well understood that these regulations are almost always based partly on functional requirements, and partly on traditional practices.

But there is still another variable of great importance. This derives from the fact that the application of a series of descriptive rules leads to obtaining, or not obtaining a construction permit. This may lead to the favouring of traditional methods as opposed to new construction procedures.

This disadvantage may be avoided – according to Mr. Blachère – by formulating instructions that are applicable to the regulations, and which would operate on the quality specifications in the same manner as the regulations themselves refer to the human needs and requirements.

These instructions would consider the various construction procedures, and building conceptions, viewed as a whole, and referred to a particular case. They would do so as if there did not yet exist any normal regulations for building, and would seek to define the solution that would meet the human requirements for that particular case.

International cooperation and unification of regulations

If building construction is to evolve in the direction of a much greater productivity through standardisation of methods and mechanization, and in general terms, in the direction of the other contemporary industries, then we agree with Mr. Bergvall and Mr. Alexandre that it is essential to expand the markets, to attain production on a truly industrial scale, in the modern sense of this term.

It is therefore requisite to obtain unified rules, applicable to the largest possible regions, well beyond the national limits, and opening up the possibility of exploiting international markets. From the point of view of meeting human needs and even technico-economical ones, the problem is not impossible to solve. In some cases it has already been solved, at least in partial aspects.

Even in the most advanced aspects, such as the definition of functional requirements with precise limits of variation, satisfactory solutions have been achieved within the field of activity of the Union Europèenne pour l'Agrément Technique dans la Construction. This includes Belgium, Spain, France, Holland, Italy and Portugal, and is represented by research centres which, in the realm of evaluation of new materials, systems and non traditional construction units, have agreed to unify the functional requirements, the judgement criteria and even the conditions under which the agrément documents should be provided.

As you all know, the Agrément Technique opens the door, certainly a most necessary step, to the introduction of new materials, and techniques, which because of their novelty cannot be included in existing regulations, since these regulations are still the written expression of an experience acquired in the course of time.

The paper by Mr. Essunger (D.3) is another very interesting example, and a very encouraging one, of the collaboration and uniformity which has been guaranteed by the regulations which are at present in force in Scandinavia.

The Swedish document involves an interesting programme of work, which can be taken as an example of coordination in the development of specifications, and which makes evident the usefulness of dividing matters into administrative and technical aspects.

I regret most sincerely that lack of space makes it impossible for me to comment on the original paper of Mr. Saillard. It deals with the standard 1964 recommendations of the European Concrete Committee, for the design and construction of reinforced concrete.

This is a modern specification based on our present-day knowledge of reinforced concrete, and elaborated by a considerable number of specialists of more than twenty countries. Its present influence on the national specifications, which are in the course of revision or bringing up to date, is considerable and very important. It constitutes an initial step towards the unification of criteria in the design and construction of reinforced concrete works. This should be complemented at later dates by the results of systematic research also undertaken at the international level.

Modular coordination

To wind up this reference to international cooperation and unification of regulations, a point should be added, which is most important in our view, namely *dimensional coordination*.

Without the achievement of a dimensional standardisation, or even better, systems of modular standardisation, valid for a large number of countries, and applicable to the largest possible geographical regions, it is impossible to think of a true international coordination, and an efficient unification of regulations.

We shall refer here to the decisions taken by the Economic Commission for Europe of the United Nations, during its Geneva meeting of November 1964, with a view to the development and stimulation of modular coordination. These measures led to letters being addressed by the executive secretary of the Economic Commission for Europe to the Ministers of Foreign Affairs of the various member countries, in which it was requested that measures should be adopted in their respective countries to attain rapidly and effectively the dimensional coordination of building elements, as a necessary basis for the industrialisation of building.

It is to be hoped that future Spanish specifications, based on this document, will be coordinated internationally, with consequent advantage to the development of mass production in building.

In connection with dimensional coordination, we feel we should mention the significance of document E3, of Mr. Burgess, entitled "Installation of prefabricated partitioning in traditionally constructed buildings". Mention should also be made of the activities of Commission W24, of the C.I.B.

Methods of calculation and control

Among the conditions which the integrated specifications of the future must take into account, one is the factor of safety, and others are the methods of calculation and of control.

If specifications are to be useful as indexes of comparison, factors of safety should be defined clearly and precisely, and should be based on uniform scientific principles.

In the case of reinforced concrete, the practical recommendations, which were the object of a communication by Mr. Saillard, have laid down highly interesting criteria, partly probabilistic in nature.

Regarding the regulations which apply to the use of large panels in construction, we should not overlook the existence and the activities of Commissions C.I.B. W19 and W23. According to the information provided by the work done by Mr. Streletsky, Mr. Tal and Mr. Otstavnov, (D.7) Commission W23 has also considered the ultimate conditions of stability of structures, which reduce the margins of the factor of safety for the design of structures.

As to methods of calculation, needless to say, thanks to the introduction of electronic calculation, these methods have initiated a rapid evolution towards the attainment of solutions which are more representative and closer to the exact ones than was ever possible previously. So much so, that in many instances it is more convenient and even easier, to seek directly the precise solution, based on the principles of elasticity, or even on the elastoplastic behaviour, than to undertake the usual approximate calculation. This was described by Mr. Brancio during the sessions and Mr. Saillard has dealt with this question in his report.

The communication of Mr. Kositsyn (D.4.) constitutes an important synthesis of the new construction concepts and methods of mass production on a large scale which are being developed in Russia. It contains highly interesting references to calculation hypotheses, and to conditions of spatial rigidity of building made with prefabricated units. This makes it possible to study the effect of a three dimensional set of forces acting on the structures.

Finally, it is necessary to develop, in accordance with Mr. Legget's view (D.5), a standardised method of testing. It should be as simple as possible, and ensure that reproducible results can be obtained. Once such methods have been unified and accepted at the international level, it will also be necessary to integrate the specifications themselves. Indeed, we emphasize our hope that building specifications will be accepted in the near future as a vital aspect of the construction process, and that the close collaboration of the legislative bodies, the professionals and the research centres of various countries will lead to the unification and standardisation of testing methods, which in turn will add rapidly to the efficiency of the building regulations.

With regard to the discussions that took place in Group D, Regulations, the communications were directed towards the formulation of future regulations, seeking to arrive at flexible formulations, so that the regulations may evolve along with the technology. Hence, such regulations would be useful in their application to future industrialisation of building and would never be a hindrance that might impede the development of new materials, techniques, or methods.

In general none of the papers which we received expressed complete satisfaction with existing specifications. There is a tendency to replace the rules based on more or less restrictive principles by others, capable of stimulating the use and development of new construction practices.

As a point of departure, it seemed very clear that it will be necessary to approach the problem in its fundamental aspect, by founding all regulations on the human requirements. Beyond that, it will be necessary to find the means of establishing such requirements in the form of specific, precise, concrete conditions, and so that they are applicable to the normal constructional practice, and can be interpreted by all those who have a direct role in the constructional process.

This procedure was well defined by various speakers, and we can state that it involves necessarily the definition of the functional requirements. In the opinion of several speakers, these requirements should be enunciated and defined by committees of experts from the C.I.B.

To make this method of procedure feasible and systematic, linking up the initial human requirements with the final specifications (and even with the quantitative specifications and methods of specifying quality etc.), it is necessary to stimulate as much as possible the scientific and technological research activity in all fields connected with construction, especially so with regard to the aspects of security, durability and economy.

In the case of many problems, it is still impossible to attain, or at least to reach as rapidly as we should wish to, the enunciation of regulations based on scientific criteria; on the lines we have previously indicated. In such cases we are still obliged to adopt regulations based on restrictive principles, and on the use of certain techniques and materials of a traditional nature. Even in this case, it would be useful to undertake a systematic revision of the regulations, by committees including a large variety of specialists and also non specialists. Their aim should be to render these regulations as flexible and open as possible, to facilitate the adoption of new tendencies, materials, and constructional methods.

At the same time, in certain cases and in some countries, it would be advantageous to establish a parallel set of detailed specifications, meant for the architects and engineers. This would be a kind of code of practice, very simple and easy to follow, meant specially for the contractors of small projects, for the inspectors, and in some cases for the owners themselves. This latter fact would be a good thing, since in some countries some buildings are made without the aid of professional technicians.

In the matter of international cooperation, a tendency was observed towards "supernational" regulations. These would favour international trade of building materials, and would give the building industries the same possibilities of developing their markets as are enjoyed by other modern industries.

None the less, some speakers showed a measure of reserve on the matter of unifying regulations, and as an initial step they proposed the exchange of information, the setting up of international committees of professionals—architects and engineers—and other steps, that would be more suitable within the immediate future.

On the question of international cooperation, we should also mention that it was accepted, in general, that it would be convenient to establish on an international level the basic pattern of building regulations. That is to say, the functional requirements, the methods of calculation, the concepts of factor of safety, and dimensional coordination should all be unified.

As regards reinforced and prestressed concrete techniques, international cooperation is more advanced than it is in other constructional domains. This is due to the European Concrete Committee, which has developed a unified set of specifications: this will undoubtedly have an important influence on the specifications of a large number of countries. In order to supplement the specifications of the C.E.B., within the field of constructional industrialisation, it is still necessary to undertake work and research at the international level, and also to take account of the new regulations of some countries, among which mention should be made of Great Britain.

Finally, it became evident in the course of the discussions that it is essential to establish testing methods that will enable one to check the functional properties of constructional elements. These testing methods should be unified, accepted by countries of the largest possible geographical ambit, and should also be the most simple ones, giving results that are reproducible in all the control laboratories.

Such testing methods are also necessary for the unification of the regulations themselves, and without them the efficiency of the regulations would be doubtful, or even useless in several instances.

Other aspects of regulations were also discussed, such as the administrative, and sometimes political, aspect of them, and even the influence that derives from the type of property of the soil on which it is being built. Such aspects of the problem should be studied by committees of experts.

To conclude, we should point out that the method of Agrément Technique in construction was considered favourably by several speakers, since this special arrangement makes it possible for non- traditional materials, techniques and systems to be included within the technical regulations by way of a favourable evaluation by the experts, after having compared the properties of these new materials, techniques and systems with the present circumstances of the building industry.

Proposed legislation based on human requirements for the construction of dwellings

By G. Blachère (France)

The problem is periodically posed of investigating the feasibility of drawing together and possibly unifying the regulations existing in different countries and sometimes even in different localities, and whose aim is to secure health, safety and, in the latest legislation, comfort for the occupants of a dwelling. It is generally taken for granted that it is necessary to approach this problem by making a large survey of all existing regulations. In practice however it proved almost impossible to achieve this, and furthermore even to undertake a synthesis of the texts. And that is fortunate, for not only is the job truly impossible, but even if possible it would be quite useless.

What actually are the present regulations? Hybrid texts indeed in which, along with general and vague recommendations such as "ventilation shall be adequate", there are to be formed very precise prescriptions, without any possibility of finding out justifications for such prescriptions. Essentially, therefore, these regulations consist of descriptive texts containing arbitrarily chosen prescriptions that are applicable to the works proper. Logically speaking, therefore, this legislation is unsatisfactory. We propose to show that it can no longer be considered adequate, for it is today possible to draft a set of rules that would not only be logically satisfactory but also virtually *universal*. Tbese rules would no longer set forth arbitrarily chosen solutions, but would express goals to be achieved, these goals being to satisfy the various requirements of the *occupant* of the dwelling. In what follows we shall use the word *"requirements rules"* to indicate that the new rules would be governed by *human requirements*, as opposed to descriptive texts relating to the works themselves.

Now we are all familiar with the requirements of the people living in a home: indeed we had to take careful stock of them in order to be able to correctly set out the problem to which the building project is to be the solution on paper and to which the building itself will be the real answer. The known data in this problem are, in fact, the human requirements and the external data, both natural (climate, soil, etc.) and artificial (noise, pollution, etc.). The means for solving the problem are, of course, the building sciences from which can be deduced the quality rules applying to the various parts composing the building.

These human requirements can be divided into four categories, according to the standpoint from which the requirements are viewed:

Man as a physical being: physiological requirements
Man as a thinking being: psychological requirements
Man as a social being and member of the family group: sociological requirements
Homo economicus: economic requirements.

Some of these requirements, particularly among the physiological ones, are absolute ones: their level is provided by science. Other requirements are contingent: they depend upon the climate, on education, way of life and economic levels. They vary from one country to another but are nevertheless similar in many vast regions such as the Mediterranean, northwest Europe, or the Caribbean. A proposed draft set of "requirements rules" is given below, cut down to fit into this paper but sufficient, to show its underlying spirit. Those parts of the text which must be adapted to suit local conditions are marked in the margin.

In this text, the statement of the requirements of the people occupying the dwelling is followed by a similar account of the requirements imposed in the interests of the surrounding population: in order that every building may provide a solution to the problem confronting the potential builder of a safe, healthy and comfortable dwelling, it is necessary that the artificial climate created by the whole of the buildings in a built-up area be maintained within certain limits and that the harmfulness of each building as an individual be limited.

On the surface, it is easy to apply a set of descriptive rules: a check is made that the planned structures meet the explicit prescriptions, and if they do not, permission to build is withheld. But we all know that such regulations can hinder very much the development of new technical systems: if one is to apply the rules to the letter, then no innovations are permissible, and if one turns one's back on this situation, then one is deprived of any line of conduct. In the case of a set of "requirements rules", one may expect the reverse situation: any new solution will be accepted indeed provided it satisfies the requirements set forth in the regulations; in other words, such a set of rules would not restrain progress.

But how is one to check that these requirements are met each time permission to build is requested? This could be done if a set of *instructions* is prepared for applying the regulations. These instructions would be to the quality control rules mentioned before what the regulations themselves are to the human requirements. But would not such instructions recreate the same "descriptive framework" we are so anxious to avoid? Not at all, for the quality control rules, like the instructions, are established to cover the different construction methods used for the building parts and the different possible conceptions of the building as a whole. And when an entirely new system or a new building concept is involved, for which no instructions can obviously have been prepared as yet, then the answer will be to make a direct check to ensure that the requirements, i.e. the regulations, are satisfied.

In short, the "requirements regulations" are universal and will allow innovations to be introduced. Lastly, they will require to be amended only when the habits or the economic level of the country have altered.

Here now is an extract from a draft set of "requirements regulations" for the construction of dwellings. (The letter "M" indicates that the requirement is not absolute but can be modified to suit local conditions)

Item 1: ...

Item 2: ...

Subject to being used and maintained in the normal way, dwellings must offer their occupants living conditions meeting their physiological, psychological, sociological and economic requirements, these requirements being established by the present text, or set forth on the basis of established scientific facts in the case of absolute requirements. The existence or the use of these buildings must not have harmful effects for the built-up area in which they are located, beyond the limit fixed by the present text.

Items 3.4.5.: ...

List of human requirements.

Item 6: Acoustic requirements:

Dwellings must be such that with their windows closed, and with the other premises or items of equipment located in the same building or in adjacent buildings used normally, ..., the noise level in dwelling rooms does not exceed the following limits:

Middle frequency octave: cycles-per-second.: 63, 125, 250, 500, 1000, 2000, 4000

dB: 55, 44, 35, 29, 25, 22, 19

By "normal use of a dwelling", it should be understood that:
- the aerial noise level produced in such a dwelling does not exceed 75 dB per band of an octave, and
- the adult occupants walk about and the children run around; also, smallish objects may occasionally fall on the floor.

"M" Item 7: Vibration requirements: ...

"M" Item 8: Thermal requirements: ...

a) Cold season requirements

... during cold spells, when the outside temperature drops to 3 °C below the average minimum annual temperatures for the locality, the following requirements must be met:

A temperature of at least 22 °C must be obtainable in each room...

In the event of non-operation of the space heating system, if common to several rooms, the requirement above can be met in one room at least in each dwelling, other than the kitchen, through recourse to an emergency system.

b) Hot season requirements ...

Item 9: Dampness requirements:

The building and its space heating and ventilation systems must be such that there be no condensation on the walls of the rooms...

The building must be such that the inner faces of the outside walls never become damp from the soil.

Item 10: Air purity requirements:

The building and its ventilation system must be such that any harmful gases liable to be produced never reach the critical concentration level above which indispositions occur, ...

"M" Item 11: Lighting requirements:

The building and its artificial lighting equipment must be such that it be possible to read or to carry out delicate manual tasks at any time of the day or night in all the rooms of the dwelling, ... Under cloudy conditions, when the illumination on an outdoor horizontal surface is 5000 lux, an illumination of 25 lux must be attained without artificial lighting over two-fifths of the useful area of the dwelling...

Item 12: Suitability of the indoor spaces and their aspect:

The internal dimensions of the dwelling rooms must not give the occupants a disagreeable sensation because of their absolute values or their ratios ...

The useful area of the dwelling must measure at least fourteen square metres per nominal occupant.

Item 13: Requirement about contact with outside world:

The building must be such that its occupants enjoy suitable contact with the outside world: ...

Item 14: Safety requirements:

a) The building must be such that it cannot collapse either wholly or in part under its own weight, under the effect of extreme climatic loads, under the effect of overloads associated to normal utilization or to foreseeable abnormal overloads, ...

b) The building must be such that its occupants be protected from maleficent human or animal intrusions.

c) The building and its equipment must be such that risks of pathological infection be reduced to a minimum:

d) The flooring must be such that it entails no specific danger of falling through slides or irregularities.

e) The building and its equipment must be such that the risks of collisions with obstacles when walking, of explosions, of electrocution, of asphyxiation, of injury from machinery, be null.

f) The building and its equipment must be such that in the event of a foreseeable earthquake, a fire, or the striking of lightning, the occupants suffer no bodily injury.

"M" Item 15: Requirements regarding ease of access from the public thoroughfare

"M" Item 16: Requirement about adaptation of the dwellings to the way of life of its occupants:

The dwelling must be adapted to the habits and needs of its occupants:

By virtue of its layout it must both allow the family gathering and safeguard the privacy of each of its members.

The dwelling must:

1) Be provided with running drinking and palatable water;
2) Include at least one special room for toilet purposes;
3) Be provided with a private lavatory with a flushing system;
4) Include a room specially equipped for preparing meals and cooking food, i.e. a kitchen;
5) Include a location and a washing device, together with facilities permitting efficient year-round drying;
6) 7) 8) 9)

10) By the number of rooms, their area, their layout and their connections, make possible the remainder of the activities of the individual members of the family, examples being meals, work and relaxation for adults and children, as well as installing the necessary furniture and equipment.

11) ...

Item 17: Durability requirements:

The building must be such that it satisfies all the foregoing requirements for a period acceptably related to the building cost. A building cost greater than one hundred times the SMIG*) per useful square meter of living space means that the durability of the essential elements of the construction should cover a 50 year period, under proper maintenance conditions and normal conditions of use.

Item 18: Requirements about ease of maintenance: ...

List of requirements laid down in the interests of the surrounding inhabitants.

Item 19: Limitation of noise emission: ...

Item 20: Limitation of the emission of polluted water into the air:

Item 21: Control of removal of waste water: ...

Item 22: Control of removal of refuse: ...

Items 23, 24: ....

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* SMIG stands for "Salaire minimum legal" (legal minimum salary).

Rationalisation of building regulations

Rationalisation, simplification of administration, regional collaboration

By K. Christensen (Denmark)

The aims and development of building regulations

Originally building regulations were established by the community with the simple aim to safeguard man.

In the beginning the prescribed safety measures were only concerned with the erection and the construction of buildings, but in the course of time, and as a result of technical development, the legislation has been extended so as to comprise detailed provisions aiming at fire protection, hygiene, protection of workers, air raid precautions, and planning, including slum clearance and preservation of buildings.

Until the end of the second World War it was considered sufficient if the building regulations took into account the abovementioned aspects, but on account of the beginning industrialisation of building and new commercial conditions with greatly increased market areas, it has become desirable that building regulations should cover as large geographical areas as possible, so as to provide sufficiently large markets for industrially produced building components—with the consequent possibilities of standardisation and reduction of the cost of the components.

As an example it may be mentioned that the production of dwellings in Scandinavia is at present ranging from 30—75,000 units per annum in the different countries, while the production for the whole of Scandinavia is around 175,000 units, a figure which is expected to increase to about 200,000 in the near future.

It is evident that a manufacturer of building products will have a better chance of supplying a high-quality product at a low price when his market comprises 200,000 dwellings annually than when differences in the building regulations of individual countries reduce his market to about 30,000 dwellings annually.

The authorities concerned with building regulations must therefore realize that the character of their tasks has altered completely. While previously their task was that of regulating and controlling the quality of the buildings, they now have to assist at the birth of the industrialisation of building by creating a progressive legislation which will provide the best possible conditions for an industrial production of dwellings.

It is natural, as well as necessary, that for this purpose the authorities should work in close collaboration with the researchers. On the part of researchers it is often maintained that one of the great problems of building research is to transmit the research results to the members of the building trades. It may be said in this connection that one of the ways in which such results may be disseminated most rapidly is via the building legislation.

Definitions

A classification according to subjects, of the existing legal provisions with regard to building, may roughly be performed as follows:

A. Regulating provisions, e.g. legislation on measures of productivity, distribution of labour, leases, country planning, district planning, etc.

B. Economic provisions, e.g. legislation on financing of building, economic control measures, insurance, taxation, etc.

C. Building technical provisions, e.g. legislation on the interrelationship between buildings and their environments, on safety precautions, with a view e.g. to structural and fire hazards, and provisions concerned with hygiene. Aesthetic requirements are usually expressed in terms of technical requirements with regard to choice of materials, types of buildings, heights of buildings, etc.

From an administrative point of view, the three groups are equally important, and each group influences the others. In the present connection, however, the interest will concentrate on group C. With regard to the two former groups, conditions in the individual countries differ so much and change so much that a co-ordination appears to be impossible and—presumably—superfluous, while with regard to group C it will—as already mentioned—be of the greatest importance to attain a certain rationalisation.

It should be noted, moreover, that the term building regulations as used in the present paper refers only to regulations based on actual legislation and not to provisions or recommendations issued by standard organisations, professional organisations, research institutions, or the like.

A classification of building regulations according to the issuing authority will be as follows:

- a. Acts passed by the legislature of the country concerned.
- b. Administrative notifications issued by national or local authorities, based on legislation.
- c. Building directions issued by standard organisations, professional organisations, research institutions, etc., which have obtained an official status by the fact that they are referred to in acts or notifications.

The formulation of building regulations

In principle building regulations may be formulated either as functional requirements, or as specified requirements prescribing the use of certain building materials, structures or working methods.

The application of functional requirements as basis for provisions by legal authorities, involves the advantage that exact requirements may be specified without any reference to existing or future building materials, structures or working methods. Thus functional requirements may be more readily applied within larger geographical areas—a fact the importance of which for the industrialisation of building has previously been emphasized.

The other way of formulating building regulations is one which has been used generally hitherto, viz. a series of requirements based on experience which prescribes the use of specified materials, equipment and structures of specified dimensions and constructed according to specified methods.

This method of formulation has the drawback that rules can be laid down for existing materials, structures and methods only, so that it is necessary continuously to revise existing regulations as the technical development produces new materials and methods. In addition, by being closely connected to local building practice, this method applies to limited areas only and thus does not tend to further exports and productivity.

It is evident that the traditional formulation of building regulations is not in accordance with the rapid technical development through which building is at present passing in many countries, but at the same time we must realize that if we attempt to draw up the necessary functional requirements which building regulations should contain to-day, we should find that we were quite unable to illustrate our requirements by means of exact concepts. For this purpose research of such a magnitude would be required that it would not be within the scope of any single country. It must therefore be considered to be impossible at present to base building regulations wholly on functional requirements.

The conclusion to be drawn from these considerations is that, as matters stand to-day, building regulations must consist in part of functional requirements, within the spheres in which research results are available, and in part of traditional requirements based on experience. Consequently building regulations must be formulated with the end in view that traditional requirements should in the course of time be replaced by functional requirements gradually as research expands our knowledge within the individual fields.

Regional collaboration

In the Scandinavian countries the central governments cooperate with a view to the establishment of uniform building regulations based on the same principles, the final aim being to have identical building regulations throughout Scandinavia. To attain this object it is at present being endeavoured to work out a framework for such common building regulations in order, right from the start, to determine the extent of the field within which inter-Scandinavian regulations may be established and also, through the systematics evolved, to be able to guide the working groups who will have to fill in the individual sections of the framework, so as to make clear for these groups the extension of the individual subjects and their places within the whole. A brief description of the methods applied in this work will be given here, i.a. to provide an impression of the great extent of the work required, particularly within the field of research, and as a consequence of which it is necesssary that the resources of all the participating countries should be concentrated on the task.

1. For each of the countries a survey is prepared of the existing building regulations, presenting the subjects covered and the ministries under which they belong, to obtain a view of the fields which are covered by the legislation of the individual countries. In addition a survey is prepared for each country showing the technical directions which is either given in connection with the building regulations or has been given the status of building regulations.

2. On the basis of these surveys guidance must be given, to show the subjects which the building regulations must comprise. Investigations to determine the subjects with which building regulations should be concerned is at present needed, and so is a definition of which parts of a building should be subject to regulation. At this stage of the work it will also be necessary clearly to define the ultimate aims of building regulations, and how far-reaching the requirements made may be and ought to be.

3. Next a systematic list should be drawn up of the subjects with which building regulations should, according to the above-mentioned considerations, be concerned, and the principles according to which the subjects may naturally be classified should likwise be considered. There is much to be said in favour of a division into two main groups:

A. Regulations concerned with the planning and erection of new buildings.

B. Regulations for the inspection and maintenance of existing buildings.

Within each of the two main groups it is logic to subdivide into subjects showing how the various problems materialize, partly for the builder as the construction work advances, and partly for the owner along with the ageing of the building.

A. Regulations concerned with the planning and erection of new buildings

– *a. Physiological and hygienic requirements as to quality to ensure the comfort of the occupants of the building.*

– *b. Requirements concerned with the interrelationship of the building and its environments.*

– *c. Requirements concerned with the utilization of the site.*

– *d. Requirements concerned with the function of the building.*

– *e. Requirements concerned with the function of the rooms.*

– *f. Requirements concerned with the construction of the building.*

– *g. Requirements concerned with service installations.*

– *h. Requirements concerned with building products.*

– *i. Requirements concerned with building materials.*

– *k. Requirements concerned with building operations.*

– *l. Requirements concerned with the administration.*

B. Regulations for the inspection and maintenance of existing building

– *a. Physiological and hygienic requirements as to quality to ensure the comfort of the occupants of the building.*

– *b. Requirements concerned with the maintenance of the building.*

– *c. Requirements concerned with the inspection of the function of the building.*

– *d. Requirements concerned with alterations in the original function of the building.*

– *e. Requirements concerned with conversion and modernization of older buildings.*

– *f. Requirements concerned with the preservation of buildings.*

– *g. Requirements concerned with slum clearance.*

– *h. Requirements concerned with the administration of a permanent building inspection.*

4. For each of the individual groups of requirements a thorough specification should be prepared, providing a complete survey of all the individual fields within which requirements may be formulated. As an example it may be mentioned that with respect to items under group A a specification of building types is aready available based on a decimal classification system and comprising 69 main groups each of which is again subdivided into many sub-groups.

5. In order subsequently to be able to formulate the specified requirements as unambiguously and accurately as possible it will be necessary to tabularize them, so as to obtain a view of the fields which have already been made the object of advanced research and those of which our knowledge is still insufficient.

6. On the basis of such tables it will be possible to draw up a list of priority for the fields in which further research is required and for those in which research should be initiated.

It appears, therefore, that close collaboration between researchers and legislative authorities is of the greatest importance, since the latter from their work with the building regulations will learn of our lack of knowledge of certain problems and will thereby be enabled to place "orders" for research work. At the same time the extent of the tasks waiting to be done will no doubt show that it will serve such intensified research best to be placed at the highest possible Scandinavian level—partly to ensure the necessary financial grants and partly to be able to utilize the resources of each individual country.

7. At this stage it must be settled which of the requirements should be incorporated directly into the building regulations and which may be satisfied by reference to standard specifications or other directions prepared by professional organisations or research institutions.

8. It is only when the subdivision of the entire material has been performed, so as to provide a view of the individual components of the complex, that a more specified classification may be made. It must be decided whether a special classification system covering all the subjects within this vast field should be worked out, or whether any of the existing classification systems may be used supplemented with extensions for the subjects which are not covered.

Simplification of the administration of building regulations

In connection with the rationalisation of building regulations the question of their administration by the public authorities will inevitably arise. How is it carried into effect with the least trouble for both parties: those who have to see that the regulations are observed and those who have to plan the buildings so that they conform to the regulations? Here it is only possible briefly to mention certain suggestions, which must of course all be subjected to a close consideration.

Decentralization of the public administration of building projects should be supported and furthered by the central administration by keeping the local authorities informed about new developments and the views held by the central administration on such developments, so as to ensure uniformity of decisions. Permanent courses should be run for local civil servants to enable the latter to keep abreast of the technical development and the policy planned by the central administration.

The public administration of each new building project should preferably be based on an effective control of the different phases of planning, while the responsibility for the building process itself should rest with the technicians and the contractor. If necessary, an authorisation may be granted to members of these professions.

It is a question whether the inspection by the authorities on the site during the building process should not be completely abolished and replaced by a system of registration combined with the insurance and financing procedures as that used for motor cars. The civil servants charged with the inspection of motor vehicles do not walk around motor car factories to see that the cars are properly constructed!

The administration of the different provisions of the building regulations moreover frequently devolves upon different public offices. It would be reasonable to try to find out how many of these are necessary for the administration of the legislation. At the same time it must be borne in mind that even if a simplification is brought about, the development everywhere tends towards more legislation gradually as the demand for measures of control increases. It will thus be seen that the need for rationalisation will be ever present within the profuse growth of the legislation and its administration.

With regard to existing regulations it may be pointed out that the responsibility which rests with the authorities has a further aim than that of seeing that the provisions are observed. It is also their responsibility that regulations which are no longer in agreement with modern building methods and materials are revised as soon as revision is warrantable, so that the regulations do not at any time delay the development.

Finally, it should be endeavoured to simplify the forms and documents applied. Of course it is impossible to avoid a certain amount of paper in the administration of building regulations since it must be ensured that the required information reaches those in need of it, but we must make certain that the authorities do not ask superfluous questions, and that different offices do not ask the same questions.

D 3

G. Essunger

Co-ordination of technical building regulations in Scandinavia

By G. Essunger (Sweden)

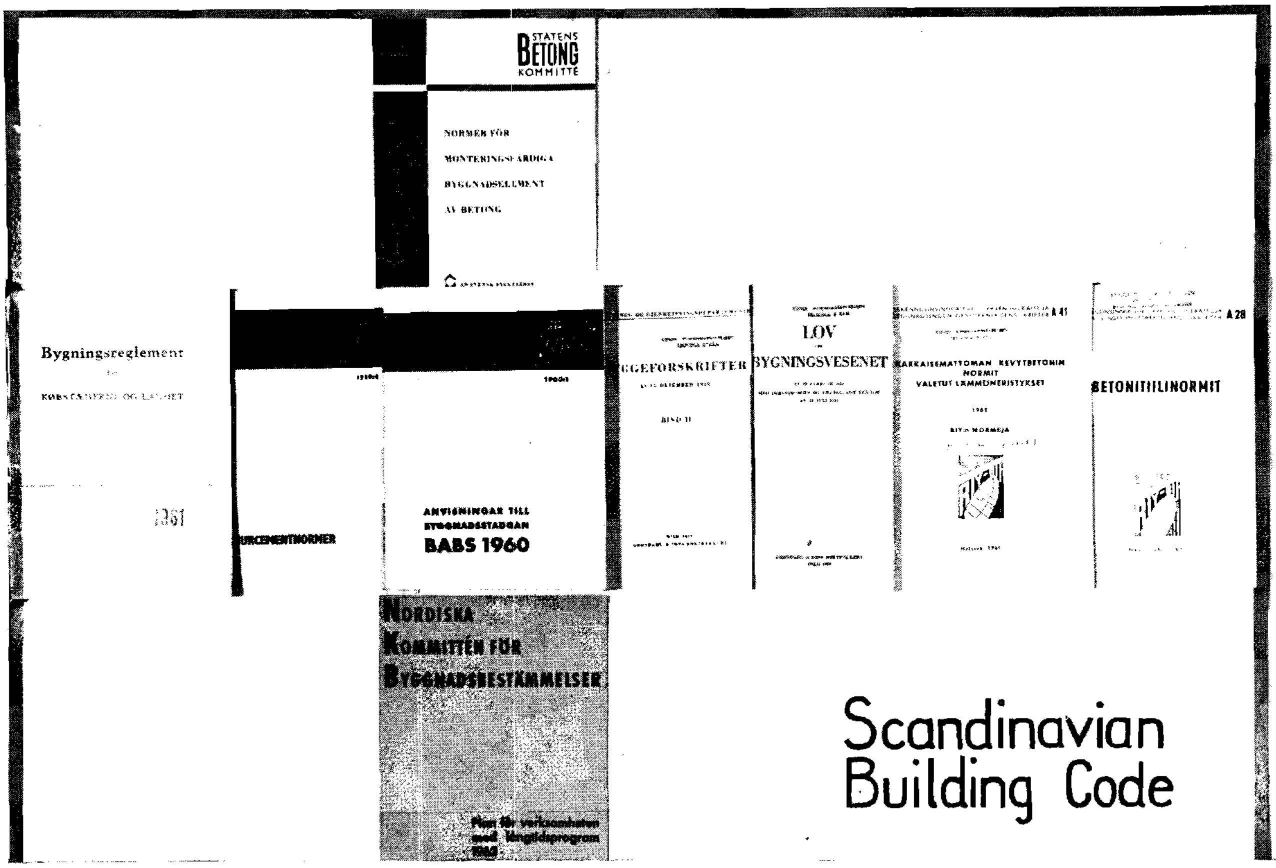

Fig. 1. In the Scandinavian countries the building regulations have been revised during the last few years in order to make the requirements unitary in the different countries. At the same time a collaboration committee, Scandinavian Building Regulations Council, has drawn up a common Scandinavian Building Code to fill the purpose mentioned.

Within the building-trade there is proceeding a considerable technical development characterized first and foremost by the following facts:

Projection according to scientifically shaped principles of calculation and dimensioning
Use of high test building materials
Industrial manufacture of building units
A further number of technical installations in the buildings
Mechanization of building work

To support technical development and industrialize building production it is necessary that the projection as well as the building work are made according to unitary regulations and norms. These ought to be continuously adapted to experiences obtained and shaped as universal functional requirements.

The climate conditions are rather similar in the Scandinavian countries. On the whole also the same kind of building materials are used. The building practice also corresponds to a great extent in these countries. The conditions for co-operation between the Scandinavian countries as regards preparing building regulations are therefore good.

Through co-operation, work resources and knowledge available can be exploited in a rational way. This is the case especially for the results of the investigation. A consequence of the co-operation is that it may stimulate further investigation into problems which can be solved in common. Regulations and norms of a similar or common kind facilitate commercial dealing in materials and prefabricated building units between the Scandinavian countries and with other countries. This is also the case, when it is a question of manufacture of constructions under licence. Also the exploitation of technical working-power in the form of consultation is assisted in this way.

Building regulations are drawn up and fixed in different ways in the different Scandinavian countries. A common feature is that the fundamental regulations have been established by the parliament, but rules of application are made out by the government or some other state organ. The technical regulations were earlier often locally fixed, but in these times a great effort is made in all the Scandinavian countries to make all the building regulations uniform for the whole country. This is applied under the condition that the regulations are made out and centrally established by a state authority.

Through the development sketched above natural conditions have been shaped for a collaboration between the controlling house building authorities in the Scandinavian countries. This collaboration between the central house building authorities in the Scandinavian countries is applied in "Nordiska Kommittén för Byggnadsbestämmelser", NKB. In NKB there are representatives for:

Board of Housing Boligministeriet, Denmark
Byggnadsstyrelsen, Finland
Skipulagsstjórinn, Iceland
Kommunal- og Arbeidsdepartement, Norway
Kungl byggnadsstyrelsen, Sweden

The aim activity of NKB is coordinated through working committees—at present ten committees—which put together their proposals in reports. On the basis of these reports the committee passes resolutions regarding the measures required, which may usually refer to one or several of the following points.

Lines of direction for regulations are established and recommended for application in the country in question by the institution which makes out or fixes the regulations.

In the cases when there are no such trial methods required for the application of the regulations, the official trial institutions or other convenient bodies are proposing to make trial methods common for the Scandinavian countries.

When the basis of knowledge for the regulations is considered to be defective, proposals for investigations or research missions are handed over to the organizations for building research. If it is found possible, these proposals may be completed with outlines for a research programme.

The questions which ought to be dealt with by some other Scandinavian organization of collaboration, are submitted to such an organization, for instance the building-technical organizations for collaboration between the union of engineers and Nordiska Betongförbundet, to be carried on there, possibly in collaboration with the committee.

In the programme of the work the matters have been divided into two head-groups, viz. administrative questions and technical questions with the following division:

1. Administrative questions

Formation of the functional requirements based on the basic principles affecting safety and health which ought to underlie the regulations. In this connection it also ought to be made clear how a Scandinavian "Building Code" should be drawn up. Co-ordination of the running administrative detail of building matters.

Co-ordination of the rules to judge and accept or classify materials and constructions (order of approval).

Co-ordination of the rules for official control (for instance in the form of production control) of materials and industrially produced building units (order of control).

Elucidation of the conditions for the co-ordination of testing methods for materials and constructions.

2. Technical matters

Questions concerning supporting constructions.

General building technical questions about hygiene and fire.

Questions regarding structural materials and particular building units and buildings.

Technical questions concerning installation.

On the table given below there have been placed together as examples running tasks, actual ones as well as those which ought to be taken up when the resources required are available. For the tasks stated in groups, a programme of details should be drawn up.

As development within the buildingline is rapidly increasing, it has not been considered convenient to bind the work within NKB to a programme too detailed, which may soon become out of date. The programme ought to be flexibly adapted to the requirements accentuated first of all by the running industrialization and the trade in building materials and manufactured building units. Thus we have aimed at having a so-called "rolling" working programme.

In order to pursue the work already begun without too great a waste of time or make it possible to take up new tasks to the extent desired, it is necessary that the resources required are placed at the disposal by the state. Every country answers for the money required for secretariate, administrators and publication etc.

In this connection it may be pointed out that the means required may be considered as very modest in relation to the importance for rationalization within the housebuilding line in the Scandinavian countries that the activity intensified within NKB may cause. Also it ought to be noted that the work carried out within the committees of NKB is to a great extent of such a kind that under all circumstances it should be carried out within the countries in question.

The Scandinavian collaboration ought to be connected with an international collaboration between different public institutions. In certain branches, for instance concerning concrete constructions and steel constructions, a certain collaboration has already been established and can be exploited in this connection. Co-operation also within CIB and ISO can serve the same purpose to co-ordinate building regulations in the different countries. First of all one ought to take up safety matters and principles for the approval and control of materials, constructions, and methods. Also questions of principle concerning general formation of building regulations and systems for such regulations ought to be discussed on a wider international basis.

LIST OF TASKS WITHIN NKB

Administrative matters	Technical matters			
	Supporting constructions	General building technics	Building materials, building units, and buildings	Installation technics
Order of approval	Wood constructions	Insulation of heat	Chimneys	Ventilation
Order of control	Load conditions	Sound insulation	Light non-bearing external walls (curtain walls)	Lifts
Co-ordination of testing methods	Concrete constructions (Nordiska Betongförbundet)	Fire protection		Water- and drainage installations
Principles for the formation of regulations and norms	Safety matters	Damp insulation	Covering materials	Oil cisterns in buildings
	Ground constructions	Drainage of water	Floor Materials	Fire places
Scandinavian Building Code	Steel constructions	Lighting	Roofs	Electric installations
Requirements as to drawings	Brickwork constructions		Rubbish shutes	
Responsible preobjector	Light metals constructions		Measures required of different building units	
Responsible organizor of works			Requirements as to buildings (hotels, schools, offices, hospitals, industries, etc.)	

Peculiarities of design of fully prefabricated structures in industrialised construction

By B. A. Kositsyn (U.S.S.R.)

Industrialised methods of construction become more and more predominant in permanent construction in the U.S.S.R. An unprecedented rate of building construction has been reached in this country due to the use of precast large-panelled building construction. In addition to a great reduction in the period of construction the industrialised method increases safety and provides a longer life for structures, since it becomes possible to achieve a uniform strength due to shop fabrication and to better quality control. The number of industrial operations in-situ which require careful quality control is being significantly reduced due to precast construction. The number of these depends mainly on the number of joints of load-bearing structures.

As precast construction experience has shown, in many structures not all the working reinforcement of reinforced concrete structures should be spliced, e.g. in walls of large-panelled buildings, in roofs of prefabricated shells. There appeared a new type of structures, the design of which was beyond the frame of classical requirements for designing reinforced concrete structures. It then became necessary to consider the above peculiarities of structural systems in the methods of design of structures made of such structural units.

The present paper is concerned with design peculiarities of fully prefabricated structures taking as an example large-panelled buildings. It is supposed that these peculiarities apply equally to other types of fully prefabricated structures.

Peculiarities of structural designs

Large-panelled buildings differ from traditional masonry buildings in the following ways:

Precast structure of walls which consist of separate panels of one-two room dimension; material of wall panels which is presumably stronger than brick masonry; smaller thickness of walls as a result of application of higher-strength material; strong connection of wall panels with one another and with adjacent structures of the building. (Panel structures and connections, as a rule, can resist tension and shear).

Large-panelled buildings approximate to thin-wall spatial systems in which the effect of the three-dimensional stressed state becomes evident while structures of brick construction (walls) belong to massive ones. Every element in a spatial system resists a local load transmitting it to "nodes" of the system (floors resist bending out of plane with transmission of the load to walls, transverse loaded walls resist compression with transmission of the load to foundation and longitudinal walls, etc.) and it participates in the three-dimensional stressed state of the whole system, the stressed state under the local load not always prevailing. This is the main difference between the stressed state of structures of large-panelled buildings and masonry buildings, since in the latter the first type of stressed state prevails.

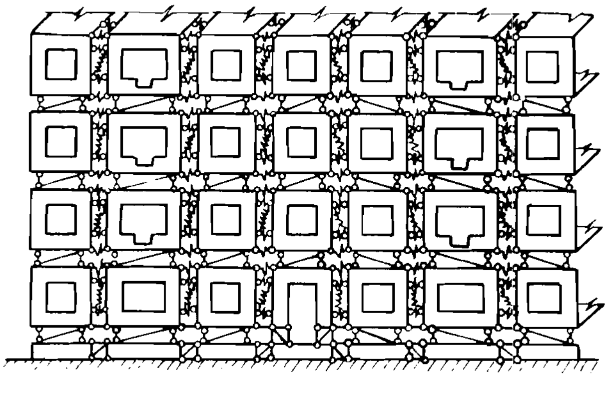

Fig. 1. Design diagram of an outer wall of a large-panelled building at bending in plane.

With their structural designs and type of bearing, large-panelled buildings are complex statically indeterminate systems (composite structure of walls, presence of window and door apertures, ground foundation).

Approximate design methods should be found which will permit to take into account the effect of three-dimensional stressed state of structures and the effect of adjacent elements in designs for local load. At the same time these methods must guarantee the reliability of design at least within the exactness of definition of initial effects on the building (active load, degree of heterogeneity of compressible soils in basis, etc.).

Comparison of results of the experimental investigation of the stressed state of large-panelled buildings or of their models in field conditions, with the results on the design of buildings (models), may serve as a criterion for estimating the exactness of the design method.

Design schemes of building elements

Walls. To adopt sufficiently exact design schemes of walls of large-panelled buildings it is necessary to analyse their structural designs under two conditions of stress: under bending in the plane of a wall and at compression due to the vertical (local) load with probable out-of-plane deformations. We shall start the analysis with the first type of stressed state.

It was stated by design practice in large-panelled buildings that it is not always necessary to achieve equally strong connections of wall panels along the whole length of joints but that it is sufficient to fix the panels at some points to ensure unchangeability of structures. Therefore in most large-panelled buildings point-connection of panels is provided. With this way of joining at points of panel joints the continuity of material is broken as an in-situ concrete laid in channels of vertical joints and the mortar layer in horizontal joints cannot function as a binding material without splicing the reinforcement and should be regarded as a "lining" between separate panel structures. A plate composed of separate panels should be adopted as a design scheme of an outer wall at its bending in plane, rigidity of braces in the design scheme being equal to the rigidity of panel connections. For further simplification it is possible "to transmit" panel rigidity into bracing and regard them as absolutely rigid plates in their plane. In the design scheme of load-bearing and self-bearing walls the shear ties in horizontal joints may be accepted as rigid, since panel shears in the planes of joints are resisted, besides the mortar bonding forces, also by the friction forces. However the rigidity and strength of horizontal joints is insufficient to consider as a whole single member, those parts of a panel which are located above and under the window. When a plinth band is used the design scheme of load-bearing and self-supporting outer walls may be presented as a combined system composed of "rigid band" and separate plates connected with one another by rigid and pliable braces (see fig. 1).

Joined reinforcement of floor areas adjoining outer walls should also be taken into account in the design scheme as additional longitudinal bracing. In the design diagram of transverse walls at bending in plane, it is obligatory to take into account the effect of floors, considering them as linear elastic bracing between separate "pilasters" of wall panels (fig. 2).

Rigidity of linear bracing in the design diagram may be regarded equal in all floors, making the problem at once statically indeterminate (with rigid pilasters).

In analysis of the second type of stressed state due to vertical (local) load with probable out-of-plane deformations, panel structures are, usually, designed on eccentric compression, regarding the floors as linear braces fixing the structures and preventing the wall losing general stability. This design is well justified for medium-height buildings (up to 8–9 storeys), since minimum sectional dimensions of inner and outer walls are as a rule restricted by requirements for providing heat- and sound insulation. However with higher loads (in high-storey buildings) such a simplified design diagram may lead to superfluous thickness of walls according to strength design. In these cases it is necessary

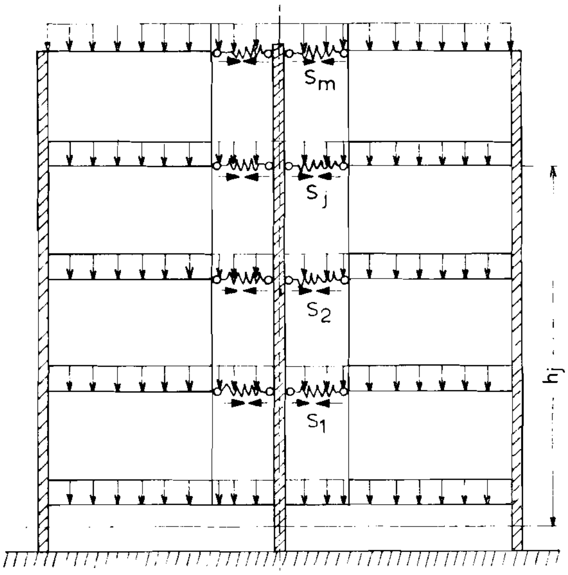

Fig. 2. Design diagram of an inner transverse wall of a large-panelled building at bending in plane.

to consider the advantageous influence of adjacent elements, in particular, panel structures of walls embedded in floors. The latter, acting as linear bracing, interfere at the same time with free rotation of end planes of panels within horizontal joints. This allows the reduction both of the free length of panels while checking its stability and of the value of accidental and non-accidental eccentricities of vertical load application in checking the strength.

A design diagram of panels of load-bearing walls with joints of platform type (fig. 3a) with consideration of floor effect is represented by fig. 3b. The rigidity of elastic embeddment of panels "C1" and "C2" in a design diagram is estimated in the usual way as the resistance of conventionally cut elements of the joint to unit rotation.

Floors. A design diagram of floors depends on the character of support and when supported along the contour, it depends upon the ratio of main dimensions of slabs. In designs of floor slabs of large-panelled buildings, forces occurring due to participation in joint work with other structures should also be taken into consideration, such as the bracing in design diagrams of inner transverse and longitudinal walls at window openings, or composite members in floor disc-diaphragms in design taking into account the effect of wind, as elements securing the elastic embedment of wall panels in horizontal joints of platform type. In addition, a check on the strength of floors and their connections for forces appearing in them in a three-dimensional stressed state of the building body during non-uniform settlements is needed.

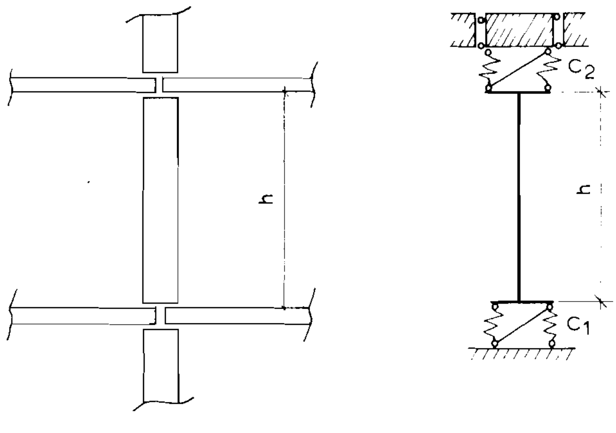

Fig. 3. Joint of a platform type of inner wall panels and design diagram of a panel at deformations out of plane.

Three-dimensional rigidity of buildings

The term "rigidity" in building mechanics has a clear physical sense: rigidity of a structure is a quantitative parameter characterizing the resistance of the structure to certain types of deformations.

In the analysis of structural designs, rigidity, as a qualitative value, should also be tied up with the ability of the building to resist deformations. Spatially rigid buildings are those in which free reciprocal displacements of adjacent elements (longitudinal walls in regard to transverse ones, floors in regard to walls, etc.) are impossible.

When neglecting elastic deformations of connections of adjacent elements of buildings, most types of large-panelled buildings may be referred to as rigid. It should be noted that to provide for the required rigidity in the structural design of a building it is not necessary to provide connection of all panels along the height of walls with shear bracing. Requirements for the way of creating a three-dimensional system depend upon the type of forces acting on the building. Analysis of structural designs of large-panelled buildings is also needed when selecting design diagrams for estimation of summarized forces due to non-uniform settlements of foundations. The design of a building is accomplished with or without allowance for spatial behaviour of the structure depending on its structural design, and other simplifications are also introduced.

Code of practice for design of large-panelled buildings in the U.S.S.R.

"Instructions for designing large-panelled buildings" published in the U.S.S.R. give recommendations for designing buildings up to 9 storeys for mass construction under usual conditions. In addition to the existing Building Code of Practice of the U.S.S.R. the Instructions recommend for the first time that a control computation of structures and connections on the strength and crack resistance under possible non-uniform settlements due to compression of heterogeneous soils along the length of the building, should be undertaken. This control design is aimed at providing the necessary crack resistance of connections and structures and is done for a particular combination of the dead load, part of the live service load and non-uniform settlements of soils of standardized heterogeneity defined as a ratio of the maximum possible value of deformation modulus to the minimum possible value of the same category. An average rigidity characteristic of the foundation is defined as a ratio of the load to the average settlements of the foundation. Since this calculation is applied to check structures of standard design, which may be constructed in future under various conditions, several design gradations of the degree of foundation homogeneity are adopted. While adjusting the standard design to local conditions the designer may compare the design parameters given in the design with the actual parameters of ground and he may, under unfavourable conditions of construction, choose either a strengthened type of foundation which varies in standard designs, or design an artificial foundation (on piles or replacing very compressible grounds by less compressible grounds).

The Instructions give recommendations on the consideration of spatial behaviour of structures; summarized forces should be estimated by taking into account the actual rigidity of building elements. Similar design codes are being prepared for large-panelled buildings constructed in complex geological conditions: over worked-out mines in coalbearing regions and on compressible soils.

For those who are interested in more detailed study of the design method of large-panelled buildings the following may be recommended: works of Kucherenko Central Scientific Research Institute of Building Structures "Statical design of large-panelled buildings" Moscow, Gosstroyisdat, 1963 and "The Instructions for designing large-panelled buildings".

Conclusions. The industrialised method of erecting buildings and structures has contributed to creating new structural elements differing qualitatively from traditional in-situ structures. Residential buildings assembled of prefabricated elements have greater spatial rigidity which permits the consideration in designs of the effect of a spatial stressed state of structures. Recommendations of the Code of Practice for designing large panel buildings in the U.S.S.R. allow to check by calculation the strength and crack resistance of panel structures and joint connections under different conditions of construction.

Building codes, test methods, and industrialised building

By R. F. Legget (Canada)

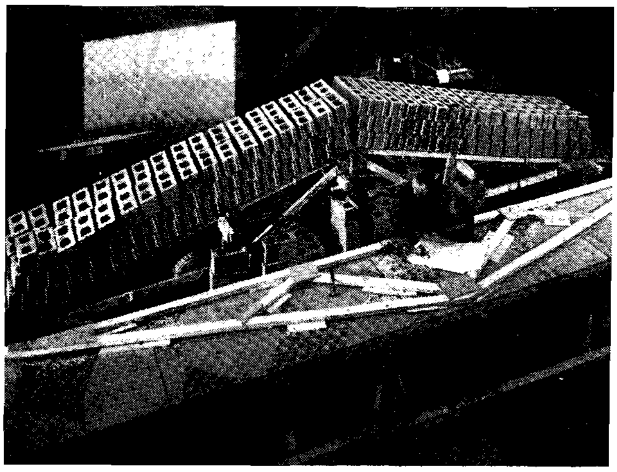

Fig. 1. Load test on a prefabricated timber roof truss for use in house construction being carried out at the Building Research Centre of the National Research Council in Ottawa, Canada.

Public regulation of the design and construction of buildings is today a generally accepted part of the over-all building process. It must, therefore, be considered in any review of the trend towards industrialised building, a trend that is now world-wide and which, as this Congress will probably show, may be expected to dominate construction in the more developed countries in the relatively near future. There are those who regard all such regulations as a brake upon progress, a statement such as that "all regulations increase costs" being a common misconception. On the other hand, there are those who are apprehensive of any departure from accepted methods of building and so have some vague idea that regulations should be "tightened up" for all buildings or components not constructed on the building site. Consideration of building regulations therefore appears to be an appropriate part of the broad review of industrialised building that this Congress will assemble.

From their inception, building regulations have been designed to protect the public. Initially, in North America, they related to fire hazards. These early building bylaws were naturally restrictive in an attempt to eliminate the dangers created by fire in relation to the simple wooden houses of the early settlers. Quite naturally, but rather unfortunately, the extension of building regulations to matters other than fire followed the same restrictive pattern, but not always in the same way. In consequence there grew up all over North America a heterogeneous assortment of local municipal building ordinances that followed no consistent order, differed in many matters of detail and were in general so specific in their restrictions that the introduction of new products or methods of building was made extremely difficult. And this despite the fact that the regulations were essentially for the protection of the public and not for any intentional limitation of building progress.

The same situation may possibly have existed in other countries; it certainly was the case in Canada. As the technology of building has advanced, despite such restrictions, and as public funds in many countries have been channelled into house construction, there has had to be in many parts of the world a reconsideration of building regulations. Canadian experience may be summarized, not as representing any ideal solution, but since it points at least to the way ahead and does take cognizance of the special needs of industrialised building.

It was decided in 1937 that the government of Canada, through its National Research Council and Department of Finance, should prepare a "model" building code that would be published as an advisory document, available to anyone at cost, but so prepared that it could be adopted or enacted by any municipality in Canada as its own building bylaw by passage of the necessary local enabling legislation. The first edition was published in 1941. The National Research Council assumed full responsibility for the Code in 1948, charging a special Associate Committee on the National Building Code with the task of keeping the Code up to date, and in keeping with advances in building technology. Further editions have been published in 1953, 1960 and 1965. It is planned to issue new editions hereafter at five-yearly intervals. Today, this national set of building regulations is in use in one way or another, by voluntary local adoption, by over two thirds of the population of Canada. There is, therefore, even today reasonable uniformity in building bylaws from coast to coast, despite differences in climate and local custom. If present progress continues, it will not be too long before the regulation of almost all building throughout Canada will be based on the same fundamental document.

Basic to the preparation of the National Building Code has been the protection of the public in its use of buildings with respect to structural sufficiency, fire prevention, and health hazards, these being the three "foundation stones" of the entire document. Measures for the elimination of health hazards, and for the prevention of fire hazards in buildings, can be seen to be but little affected by the way in which a building is constructed, on the site, or in a factory and then erected on the building site. But it became clear about ten years ago that there were questions that could be raised regarding structural regulations that were influenced by the method of construction.

The matter was first raised in relation to prefabricated housing. Why, it was asked, should factory-made houses have to adhere to the same regulations as were applied to houses built by traditional methods on the building site. The obvious reply was "Why not?". This exchange of views led to the formulation of what was really an obvious policy, once the basis of the Code (the protection of the public) was remembered. The requirements must be the same for any structural component or system, whether prefabricated or not, since it is called upon to perform the same function in the finished structure.

Development of the policy was easy as compared with its implementation. Consider house roofs, for example. Roof construction in timber frame houses, the normal type of single-family dwelling used in Canada, had followed a traditional form developed in practice, but not designed according to any structural theory. Roof construction using prefabricated wooden trusses had to meet the same performance requirements. The strength of traditional house roofs was not known and so an extensive research program was initiated jointly by the NRC Division of Building Research and the Canadian Forest Products Laboratories. From this has been developed a set of design criteria for roof trusses, and correspondingly an acceptable test method for house roofs. The *performance* of house roofs can now be specified, leaving quite free the choice as to the type of roof to be used to meet this requirement, either built on the job in the old style, or at least partially prefabricated in a factory.

This relatively simple example illustrates two main developments that appear to be essential if building regulations are to be ready for the great advance in the volume of industrialised building that is bound to occur in the near future. In the first place, building regulations must get away from the old specification type of document and trend much more in the direction of being performance codes. This will give new building systems that are developed with increased industrialisation an equal chance to compete with well accepted methods. The change will be a gradual process since many elements of building design, such as those with regard to exit requirements, must still be quite specific to be effective. Structural requirements, however, can well become much more flexible by the introduction of the concept of *performance*, rather than adherence to a specific structural type or design method.

The process of adaptation is more easily described than actually achieved. Reduced to bare essentials, a performance structural code could require merely that all structures shall be structurally sufficient for the loads to be imposed upon them. This would be absurd, but the statement does point to the absolute necessity of an adequate and accurate knowledge of the loads that may be imposed on structures of different functional types, if performance is to be adequately assessed. Performance of different structural components will have to be described, even in the simplest of performance codes, and this involves the establishment of appropriate performance criteria, such as maximum permissible deflections under design loads. If such criteria are to be meaningful, and useful for comparative purposes, then the testing of structural components to see if they do conform to performance requirements must be carried out with standard and readily reproducible methods. The development, and wide acceptance, of such standard test methods is the second main development that must take place if building regulations are not to impede the inevitable wide use of industrialised building methods.

A start has been made in each of these directions but progress must be greatly accelerated if building regulations are even to keep pace with the growth of the industrialisation of building. Many national building codes, and the more advanced locally developed codes, do take cognizance of performance requirements even though they may still contain, of necessity, many specific design requirements. One means of avoiding any untoward restriction of new building methods is for regulations to contain also what is popularly called an "escape clause". In the Canadian Code, for example, there is a clause that says, in effect, that the owner of a proposed building may submit (naturally at his expense) to the authority having jurisdiction over his building sufficient evidence in the form of test reports or other proofs that the innovation he is proposing meets the performance requirements of the Code. In this way no really sound new development in building need be restricted, but its acceptance obviously depends upon the availability of standard test methods, the result of which will enable the building official to compare the performance of the new development with the known performance of the material component or system that it is designed to replace. Again, therefore, the need for an adequate set of standard test methods for building constructions will be obvious.

The relevance to CIB of what has so far been said will be clear, since performance requirements for buildings, the loads to which buildings are subjected, and the test methods by which building constructions and materials can be tested are not peculiar to any one country, nor affected by political boundaries. They are truly international. A fine start has been made by CIB Working Commission W23 in its work on developing a set of standards *Loads on Buildings*. Other Working Commissions are making a start at some aspects of performance requirements. Little has yet been done, at the international level, with regard to standard test methods. Work of the American Society for Testing and Materials in this field may therefore be mentioned, since ASTM is in many ways an international body, despite its name. It has an active technical committee developing standard test methods for building constructions, about twelve of which have now been published.

Looking ahead, therefore, it may be said that building regulations must be accepted as a vital part of the building process; that every effort should be made to have these necessary, and usually local, legal documents of the performance rather than of the specification type; that the sooner international agreement can be reached regarding standard loads for building design the better; that corresponding accord with regard to performance criteria is similarly desirable even though it may be more difficult to achieve; and that all these developments necessitate adequate, and internationally accepted, standard test methods for building constructions. Here is the greatest need, if the progress of industrialised building is not to be impeded, and here is the greatest lack. If for no other reason than this, the existence of a body such as CIB is vitally necessary. It will require the united efforts of building experts from all developed countries in meeting the demands of their own and of the newly developing countries in the years that lie ahead, as the "building explosion" rapidly develops, to ensure the necessary and proper regulation of this vast world-wide building program in the interests of public safety, good building practice and sound economy. This is but one of the challenges that now faces CIB.

Towards an international code of practice for the reinforced concrete industry

By Y. Saillard (France)

This paper discusses the Standard Recommendations (1964) of the European Concrete Committee (C.E.B.) for the design and construction of reinforced concrete.

The constructors and clients of all countries are now convinced that one of the prime conditions of industrialised building construction is to modernise the design and construction regulations, to unify them, and to make them easily adaptable to the constant progress of our knowledge and techniques. It is evident that no construction process, however ingenious it may be, will have any practical effect, if the building manufacturers cannot make the best possible use of it, from view-points both of security and economy.

Principles of the recommendations of the European Concrete Committee

It is well recognized that older regulations, even though they have often made possible, in the past, the construction of important and even exceptional structures, are hardly adaptable, in spite of their value, to the high physical and mechanical quality of the present materials, to the perfection of the construction procedures, to the efficiency of the controls of fabrication, and also to the appearance and development of new techniques like prestressed, precast or lightweight concrete, synthetic materials concrete, etc.... To remedy this deficiency, a modern regulation must enable the actual behaviour of the structures to be followed as closely as possible. In other words a reinforced concrete regulation must be based on the experimental knowledge of the actual evolution of the combination of concrete and steel conceived as forming a single whole, in the various stages of the physical and mechanical behaviour of a structure: elastic stage, cracked stage, plastic stage, ultimate stage. The corresponding laws must reproduce, as accurately as possible, the various observed phenomena, not merely at one particular section, but more generally in the whole structure, whether statically determinate members or statically indeterminate structures are considered. Those laws must then lead to practical design methods, based on the consideration, not only of the elastic calculation, but also of the phenomena of cracking and hysteresis, of the effects of creep and shrinkage, of the development and of the importance of the plastic adaptation and, finally of the more or less serious consequences of an eventual rupture.

Thus have progressively been defined, during the last twelve years of the work of the C.E.B., two fundamental concepts:

The concept of "limit states", according to which a structure may be considered as well designed if the probability of it becoming unfit for use (through rupture, excessive cracking or deformations, buckling or displacement of the whole structure) is low enough, and;

The "semi-probability" method for the assessment of safety, taking into account the practically available statistical information, enabling the appropriate safety for each limit state to be defined, thanks to the concepts of "characteristic values" and "design values" of the strengths and of the loadings.

The thorough study of those concepts has been the subject of a close collaboration between the European Concrete Committee (C.E.B.) and Commission W 23 of the International Council for Building Research Studies and Documentation (CIB), which led to identical conclusions, (see report by Dr. F. G. Thomas "Basic parameters and terminology in the consideration of structural safety"; CIB Bulletin no. 3, 1964; pp. 4 – 12). The bases of those conclusions have also been adopted by Technical Committee 98 "Bases of the design of structures" of the International Standards Organisation. The Standard Recommendations of the European Concrete Committee develop the application of those fundamental principles, while supplying the constructors with the essentials of the present knowledge and of the new theories of reinforced concrete. Of course, those Standard Recommendations are a document which should be progressively improved and completed as the studies and techniques will develop.

International coordination projects of the European Concrete Committee

It became apparent, as the work of preparation of the Standard Recommendations went on, that in many chapters of reinforced concrete, a sustained work of theoretical and experimental research was still necessary, even for apparently well known problems. That work does require an intensive international cooperation of all interested national or internatioanl technical bodies, not only in Europe but also in all the other countries with which the European Concrete Committee develops a close collaboration, such as: the United States, Latin America, Japan, the Middle-East. This spirit of international cooperation has a close relation with the objectives of the U.N.E.S.C.O., as concerns particularly the preparation of standard "Construction manuals" for the benefit of countries in the process of development. This community of objectives is presently materialising effectively through the direct collaboration of the European Concrete Committee in the preparation, under the patronage of the U.N.E.S.C.O., of a Regulation for the design and construction of concrete structures for the Middle-East.

Among the urgent problems which require international cooperative programs of systematic studies and research, the C.E.B. work Commissions have noted especially:

– The analysis of the phenomena of bond and anchorage, with the definition of a limit-state theory.

– The evolution of cracking and deformations in linear members and in plane structures, taking into account the type, the duration and the eventual repetition of loadings. As concerns more particularly the definition of the permissible limit-deformations, the C.E.B. has decided to refer to the prescriptions being prepared by CIB Commission W 23.

– The theoretical and experimental study of the behaviour of structures in shear and torsion, taking into account the fundamental rules for "connectors" of reinforced concrete.

– The determination of the elasto-plastic behaviour of the statically-indeterminate structures and its application to the practical design of structures, taking particularly into account the present possibilities of computer programming.

Extension of the scope of the recommendations

The European Concrete Committee has also considered extending the scope of its Recommendations to the new techniques which have appeared most significant in the development of the concrete constructions:

Prestressed concrete, with full or partial prestress, is studied within a Joint F.I.P./C.E.B. Committee, created in 1962, in collaboration with the International Federation of Prestressing (F.I.P.). The work of this Joint Committee is directed towards the preparation of International Recommendations for the design of Prestressed Concrete structures, along the same principles as the Recommendations of the European Concrete Committee. The determination of the safety in the different phases of construction and operation, the verification of serviceability, the design with respect to shear, the various problems concerning prestressing reinforcement, have already been the subject of several resolutions, which should lead to a first draft proposal of an international code of practice, during the fifth Congress on Prestressed Concrete, in the spring of 1966.

Panel structures: During the plenary session at Ankara, in September 1964, the European Concrete Committee decided to complete its present Recommendations, by developing the chapter on "panel structures" which had been temporarily left out. A work Commission was created to that effect, in direct connection with C.I.B. Commission W 23 A and with the UEAtc.

Lightweight concretes: The C.E.B. has also started to study the extension of its Recommendations to structures of reinforced lightweight concrete, whose practical development proves to be ever more interesting, particularly in prefabricating techniques.

Conclusions. These projects confirm the fundamental objective of the European Concrete Committee which is to prepare Recommendations for an International Code of Practice, in close connection with all directly interested Associations and, particularly, in the field of building, with the C.I.B. The common work of the C.E.B. and the C.I.B. corresponds with the major concern of both international organisations to promote industrialised construction by all available means, and, particularly, by preparing regulations well adapted to the modern evolution of constructions and techniques.

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Deformations	no. 16, 20, 24
Shear	no. 25, 26, 33, 37, 40, 41, 42
Safety	no. 4, 39
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T Beams	no. 8, 18, 25, 32
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Improvement of the design of building structures and the industrialisation of construction

By N. Streletsky, K. Tal and V. Otstavnov (U.S.S.R.)

Industrialisation of construction is characterised by a combination of mechanised shop fabrication of components and mechanised erection of buildings and structures with prefabricated components. Shop fabrication of structural elements is profitable with a limited nomenclature of elements. In this way industrialisation of construction results in the reduction of the number of standard types of elements fabricated at a given shop and used in the structure, and thus leads to unification and standardisation of structural elements.

A move towards a reduction in construction costs, necessity of transportation (sometimes over long distances) of building materials and then of precast elements, reasonable restriction of lifting capacity of erecting cranes, etc. leads to the necessity of a maximum reduction of the weight of structural elements, and, therefore of the dimensions of their sections.

The reduction of the weight of buildings and structures may be done at present by using, in every possible way, high-strength materials in construction and by reducing safety margins of structures. This in its turn requires a profound knowledge of behaviour of structures at all stages and an ability to define by design more exactly the actual behaviour of structures.

Structural design based on more exact and comprehensive consideration of factors defining the behaviour of a structure during its life makes it possible not only to achieve the minimum weight of building structures but also to modify actively a number of production factors and to increase the quality of building structures.

At present the limit state design method is given a more detailed development and is being widely applied. This has significant advantages in comparison with the method which takes into consideration allowable stresses and failure loads. There are now favourable requirements for international unification of designs based on this method. Characteristic features of the limit state design method, the introduction of which into design practice has been going on since 1954, when the U.S.S.R. first used it, have two aspects:

a. designing in terms of a number of situations which would be non-allowable and dangerous for the building. These states have been classified till now into three categories:

1. a state of ultimate load-bearing capacity
2. a state of non-allowable deformations
3. a state of local damages.

The major requirement is to ensure a certain degree of guarantee not to achieve any of these limit states at any stage of fabrication, transportation, erection and life of the building.

b. The above guarantee is ensured by considering in the design deviations of variable parameters (load, strength characteristics of materials, dimensions of sections, etc.) from their nominal values. These are considered by introduction of independent coefficients which may be regarded as partial safety factors (overloading factor, reduction factor for nominal strength of materials and some other factors). Variability of most parameters is of a casual nature and may be estimated statistically. However the available statistical data are rather insufficient for well founded consideration of this variability in design; therefore some coefficients are established on the basis of yet insufficient statistical data or on the basis of general judgements.

The limit state design method being developed in the work of CIB Commission W23 has at least two safety parameters on a statistical basis, they are: load-increase factor (overloading factor) and strength-reduction factor (homogeneity factor). Other variable parameters are being considered now on the basis of acquired experience in design and maintenance of buildings and structures. Independent consideration of variability of strength characteristics of materials allows the respective parameters (factors) of safety to be brought closer to the conditions of fabrication of materials and control over them. In the same way consideration of load variability closely binds up safety with service conditions. Thus, for instance, for concrete fabricated at special shops with automatic devices and improved ways of control reducing dispersion of its strength, it appears possible to have lower values of strength-reduction factors and thereby to achieve actual economy of materials.

Further work in the field of improving design methods

The work on improvement of design methods to obtain a final harmonious system must go on continuously and will require some more efforts for producing statistical material needed for a more founded design method.

Different service conditions and the effect of these on the probability of reaching the limit states should be widely studied, and this would need much work by many organizations and specialists in all countries of the world. It would be advisable to conduct investigations in regard to the known limit states as well as to those which may be found during the progress of the work. Besides its main aim this work will also promote the development of unified rules of maintenance of buildings and constructions the creation of which will be of great importance for industrialisation of construction. Investigations will help to find combinations of accidental unfavourable service conditions, guaranteed elimination of which leads both to significant reduction of considered safety factors and considerable economy. At the same time appears the task of establishing organizational and structural measures not allowing for the occurrence of unfavourable service conditions. CIB Commission W23 has already adopted unified values of loads for civil buildings; this work, however, on unification of certain loads should be further extended to allow considerable increase in nomenclature of interchangeable structures and reduction of general nomenclature of elements. Development of economically advisable unified gradation of safety factors will also promote further industrialisation of construction. The nomenclature of interchangeable elements will increase, the number of standard type elements will be reduced and, thus, their shop fabrication will be made easier. Structures having different design factors of safety might also be used in one and the same buildings and structures by replacing materials of certain characteristics by others. Unification of requirements for fabrication of materials and quality control is of vital importance for industrialisation of construction. These problems naturally follow from the need to improve design methods. The possible reduction in dispersion of strength characteristics, and more steady qualities of materials, also promotes the increase of quality, safety and reduction in material expenditure and cost. One of the most important conditions for further development of design methods is the development of a unified system of design and production rules and a system of allowable deviations from standards (a system of allowances). This will permit the rationalisation of the system of safety factots and avoid conservative designs.

Group E
Modular Standardisation

Final report from the group rapporteur R. F. Legget, Director, Division of Building Research, National Research Council, Canada.

The industrialisation of the building process can only be achieved with a high degree of standardisation. This must inevitably include a reasonable degree of uniformity in the system of measurement adopted, with at least an approach to the reduction of random dimensions. "Modular coordination" is the name that has been almost universally adopted for an internationally agreed system of uniform dimensioning in the building process, whether this is industrialised or not. It is fitting, therefore, that one of the groups of papers at this Congress should have been devoted to this subject. The name given to the "E" group of papers is a happy combination of the concept of the module with the necessity for standardisation.

Modular coordination, however, is the term that must be used in discussion since it has become well recognised, even though it may not be semantically accurate. It is certainly not a term of euphony. In some quarters, it has even become, in itself, an obstacle to rational discussion of the potential of the system it describes. One may wonder how many other cases there are in the building field when semasiological impediments add to existing technical difficulties. For there are technical difficulties, even with such a simple concept as the use of modular dimensions, and this fact is reflected in the papers of Group "E".

In case there are some readers who have not yet had direct contact with modular coordination, it may be helpful to make a brief explanation of the concept at the outset. Modern thinking in this matter was stimulated by the studies and writing of Alfred Farwell Bemis, an American civil engineer, who in the nineteen thirties published a three-volume work on rational house design. Among the ideas he then presented was a simplification of dimensioning by the use of a single "module" (a term used in Roman days), either in multiple or fractional form. He suggested a four-inch module. After much international study, this has been almost universally adopted as the basis for modular dimensioning–four inches in the "pound-inch" countries, and ten centimetres in metric countries, the two dimensions being fortunately almost identical.

Design dimensions - Component dimensions

Some confusion is caused by the use of the one term to describe what are really two separate and distinct building concepts–the use of the module to determine the dimensions of planning grids for the three-dimensional design of structures (a four-foot system of grid lines, for example, being widely used); and the use of the module for determining the dimensions of building components, such as bricks, that are mass produced, and that can be used in buildings that may, or may not, be laid out on a modular grid system. As thus stated, the whole idea must appear to the uninitiated to be so simple that it could be described (as I have described it in the title of a paper) as "Common Sense in Building". This is not an inaccurate description but, as all readers will know, common sense is often conspicuous by its rarity.

Review of papers presented

Eleven papers were grouped together under the "E" designation. Ten merit immediate attention, the eleventh (E.5) being an interesting introduction to a presentation that its author, Sr. Leoz de la Fuenta of Spain, says can "only be adequately explained by a very full verbal exposition accompanied by some three hundred colour slides." Sr. de la Fuente has some provocative things to say about architecture, and also about engineers. Since I am only an engineer, I must refrain from even questioning some of his statements, especially as they are only by way of introduction to his thesis on the division and organization of architectonic space, a presentation of which many would like to hear on some more suitable occasion.

It is fitting that the opening paper should be by Mr. Lennart Bergvall of Sweden, especially since he is the present Chairman of the CIB Working Commission on Modular Coordination which is, at the same time, the International Modular Group. Tribute must be paid to what this Group, under Mr. Bergvall's inspired leadership, has done to develop careful thinking in many countries about the use of the modular system. Mr. Bergvall gives a clear overall explanation of what the modular system is.

By way of illustration, he mentions the automobile industry - at least one other paper does so too - with the interesting analogy of the supply to the main automobile manufacturer of many components, for inclusion in the finished structure, made in separate subcontracting plants, and so not dissimilar to the supply of building components to a building site. In a companion paper (F2) written with Mr. E. Dahlberg, Mr. Bergvall shows how the modular system is applied in Sweden in the successful manufacture of the "Element House System" and, on an experimental basis as yet, to the manufacture of lightweight concrete slabs for use in apartment house construction.

The fact that we are dealing with what is actually a very old idea is delightfully demonstrated by the illustration at the head of the second paper, by Mr. Blach of Denmark, (E.2) on rules for modular design practice. The drawing shows a reconstruction of the arsenal at Piraeus, of the year 328 B.C., and shows very clearly the idea of a planning grid set out to a large module, in this case generally four feet. Another interesting historical reference is to be found in the later paper by Herr Schmidt (E.7) in which he shows how Sir Joseph Paxton when designing the Crystal Palace in London, in 1850, used prefabricated components that were quite obviously dimensioned on a modular basis. It is a sobering experience to realise that ideas considered at the Conference as possible aids to the industrialisation of building were in active use, admittedly by pioneers of genius but still in very practical use, so many years ago.

The rules set out so clearly by Mr. Blach make the distinction between the use of planning grids and modularly dimensioned components quite clear. Other papers do not emphasize the distinction in the same way but it is one that should be kept in mind in all discussions. Mr. Blach's four points provide a good basis for clarity in thinking. The papers by Herr Paulich (E.6) and Herr Schmidt, (E.7) both of East Germany, show well how modular coordination is being used in the large-scale manufacture of precast concrete units. The extensive use of such units in East Germany is illustrated in a companion paper by Herr Schuttauf (A9) wherein it is stated that, in 1963, 77.2 percent of all East German flats were of prefabricated construction, showing how effectively modular coordination is being used in that country.

Herr Schmidt also emphasizes the two aspects of modular dimensioning, and discusses frankly and constructively the main objections raised to the use of modular dimensioning. It is to be hoped that future discussion of the impediments to the use of modular coordination will build upon the foundation so well presented in this stimulating paper. Mr. Silvennoinen of Finland also discusses the problems of using modular coordination in prefabrication with similarly helpful comments. Messrs. Senstad and Slettebo of Norway (E.8) give an interesting description of the techniques they have developed to check the actual, as compared with the theoretical, dimensions of prefabricated concrete elements, the paper being a good indication of the extra attention that has to be devoted to detailed dimensions as soon as the building process becomes industrialised.

All who have the privilege of knowing India will appreciate the broad sweep of the review presented by Shri Visvesvaraya in his paper (E.10) on the industrialisation of building through standardisation. His use of the size of bricks as an illustration of the need for standardisation is of special significance when it is remembered that India has several thousand brick-making plants, brick being the almost universal building material in India for simple dwellings when these are made from any sort of finished material. That brick sizes have been standardised in India is an advance of real potential, and shows great courage on the part of those responsible.

Those who have read only popular and superficial accounts of the "free-enterprise" economy of North America may be surprised to see in Mr. Zerbe's paper (E.11) the record of a splendid application of modular coordination to individual house building, the UNICOM system of house framing developed by the National Lumber Manufacturers' Association of the United States. This system has been well publicised by its proponents in most attractive, simple, and useful publications. Its use is spreading in North America. The savings in lumber and in man-hours are appreciable and yet nothing is lost in flexibility of design. A companion paper from Canada by Mr. R. A. Orr (F.24) describes one of Canada's most successful house-prefabrication operations. Again, all dimensions are modular and Mr. Orr makes clear that only by this careful attention to detailed dimensioning can he achieve the fine results that his paper indicates.

Two papers have been left for final comment. Mr. R. A. Burgess of the United Kingdom (E.3) describes in his unusually valuable paper a detailed field study of the problems encountered with the installation of prefabricated partitions in traditionally constructed buildings. If more records of this sort, obtained by detailed observation on the job, were available, progress in the use of modular would benefit immeasurably. It is not at all a "success story". It shows how many factors other than the theory of design affect the success of using modularly dimensioned components. The coordination of the different specialist trades on the job, for example, will determine the ease with which prefabricated elements can be installed quickly and without loss of time. The architect in charge of the largest building yet constructed in Canada to modular dimensions has said what Mr. Burgess says about this in these cryptic words - "The man that gets there first is the man that's right", when it comes to fitting different components and building elements together.

Manufacturers also come in for comment by Mr. Burgess. Of the partitions he measured, 40 percent did not conform with the acceptable tolerance in dimension of one eighth of an inch. Only 34 percent of the manufacturers even stated any tolerance for the dimensions of their products. Serious as this might seem to be, it faded into insignificance when the "tolerances" on the job were considered. So bad was this aspect of one job that not one of the prefabricated partitions could be used without some adjustment. Admittedly, this was an unusual combination - prefabricated units going into "traditional" buildings - but the emphasis that Mr. Burgess places upon the absolute necessity of good inspection on the job, close tolerances for job dimensions and most accurate setting out, points to what must be imperatives as the industrialisation of building extends.

It may be worth mentioning, if only by way of contrast, that on the large Canadian job just mentioned, all setting out was to a modular planning grid. A structural steel strike occurred during the construction period. Most of the time lost through this strike was regained by the structural steel erector re-starting his work at several different locations, instead of at one place only for the traditional single line of progress. Correspondingly, the masonry work that followed was started at a number of different locations. Today one can inspect the masonry in the building without being able to detect any sign of unusual junctions anywhere at all. An account of this most successful operation has been published.*

I have deliberately left until the end the paper by Dr. N. B. Hutcheon and Professor S. R. Kent, (E.4) since I was privileged to participate in the discussions that preceded the writing of the paper. While admitting that "some system of modular coordination becomes highly desirable in order to provide a firm basis for the coordination of dimensions both in design and manufacture", these authors raise, quite constructively, some pointed questions about the true or actual economies that can be realised by the imposition of standardisation. They, too, mention the automobile industry, but rather in contrast to building, since buildings at present rarely have more than a 60 percent on-site labour cost. The paper is condensed in presentation and does not really yield to summary; may I commend it as a useful basis upon which to frame critical questions. The final reference in this paper to joints, however, must be stressed. Mr. Burgess shows how actual connections can be very troublesome on the job, in an extreme case. The success, or at least the economy, of using modular prefabricated building components on any wide scale will ultimately depend upon solution of the practical problems of handling the problem of joints.

The Secretary General kindly noted several papers in other Groups that appeared to have some reference to our subject grouping. I have mentioned three of these appreciatively. Some of them in fact described operations in which non-modular dimensions were being used. This expression can be used in view of the official adoption by ISO, and by many countries of the world, of the four-inch ten-centimetre module as the basis of dimensional standardisation in building. In view of this apparent neglect at so representative a gathering as this, can we be sure that we are on the right track in advocating, as I personally do, the universal use of modular coordination as an essential to the future of international building, if we are to keep pace with the demands for new building that almost all countries of the world are already experiencing?

Is use of modular coordination essential?

This was one of the questions with which the summary report on this Group of papers at the Congress meeting was concluded. It was also pointed out that it was indeed surprising that eleven papers only were submitted under the "E" category, despite the fact that without some agreement upon uniformity in dimensions, advance towards industrialisation of building will be limited indeed. Discussors were asked if modular coordination was in use in their countries, and whether it had proved to be a practical working "tool" in advancing efficiency in building. A good general answer was provided by the fact that, alone among the Groups, discussion of the "E" papers occupied two sessions, a specially adjourned discussion period having to be arranged to take care of all who wished to speak.

It was made quite clear that modular coordination is being used in many countries, and not only for the dimensioning of factory-produced building elements. Interesting examples were given from Great Britain, Canada, and Spain of actual field applications. The Canadian example was unusual in that the speaker showed how the modular principle was applied to a large and complex building even though the basic grid dimension had to be 25 feet 1 inch, due to the spacing of the railroad tracks which the building foundations had to "straddle". Multiples and fractions of this odd dimension had been successfully used in planning the building and its associated services, and in setting it out in the field. With more simple dimensions, and especially the internationally agreed system of four-inch ten-centimetre modules, the same efficiency should be more easily attainable.

The discussion showed clearly that, quite apart from the simplicity introduced by the modular principle, its use will have an indirect benefit necessitated by its actual application on the job, in that a new appreciation of tolerances in building is essential. Not only must manufacturers be ready to guarantee specified tolerances for their factory-produced materials and components, tolerances that must be stated in all product literature relating to modular items, but the setting out on building jobs must be carried out to the most exacting standards of accuracy, and the actual field inspection of building operations must become a much more rigid control. Improved standards of job inspection were shown to be an essential complement of the use of the modular system but as an advantage rather than the reverse, since it will inevitably lead to better standards of finished building while facilitating the proper application of the standardisation that the use of the modular system promotes.

The many problems presented by joints between building elements were not overlooked or minimised in the discussions, but it was recognised that these are not peculiar to modularly designed structures. It was evident that, as the idea of standard sets of dimensions comes to be generally accepted, so also will there have to be increased attention to joint design, joint installation, and joint inspection in the field. Again, however, this added discipline to the building process will not be a disadvantage but will also assist in the development of better building practice.

The remarkable international character of the Copenhagen Congress naturally directed attention to the international aspects of modular coordination, as did also visits

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* Modular Coordination, Proceedings of Conferences held in Toronto and Montreal, April 1963. National Research Council, Division of Building Research, Ottawa. October 1965, 51 pp. NRC 8655. Price $ 1.00.

paid to Danish factories in which prefabricated concrete elements were being produced for export. The only way in which such international trade can be expected fruitfully to develop will be with steadily increasing, and eventual universal use of standard dimensions. The modular system provides the ready-made answer to this aspect of industrialised building which, in itself, provides one of the strongest of all arguments in favour of the system, despite the attendant problems which nobody would wish to minimize.

The developing countries

The challenge faced throughout the world by reason of the phenomenal demand for buildings, and especially housing, means that inevitably there will be an increasing amount of international trade in factorymade building components. Especially will this be true of the younger and developing countries. At the same time, they cannot depend on imports from more developed countries for any permanent solution of their own building needs but must integrate imported building components with their own products as their own building industries gradually develop. This linked the discussions of the Group "E" papers with the all-pervading appreciation of the special needs and problems of the developing countries, with which all the activity of CIB is so directly concerned. It is not improbable that some of those who came to Copenhagen with doubts as to the real validity of the utility of the modular system had their doubts removed when they came to appreciate what an internationally agreed-upon system of building dimensions can mean to world development of building. And the internationally agreed modular system, now being steadily refined, provides a sound answer to this challenging problem.

Quite the most significant contribution to the entire modular discussion came from a country from which it might have been least expected, the Republic of Eire, or Ireland if the old and still commonly used name may be used for convenience. The Congress was advised of a careful study made within the building industry of this small country, which now faces unparalleled industrial expansion, of what a complete conversion to modular dimensions would mean. No real objections were encountered from the design professions. Some manufacturers could convert their production to modular dimensions without any difficulty or extra costs. Those that would face extra costs thought, in general, that the increased production which they might anticipate would enable them readily to absorb the increased costs within a reasonably short time. A recommendation that the entire country "go modular" is therefore currently under official consideration. The eyes of the building world will indeed be on Ireland in the months ahead and if she does embark upon this bold approach to her building challenge, the experience she gains will be a major contribution to international building progress.

Modular coordination and freedom in design

There was in the discussions the inevitable undercurrent of objection to the modular system on the grounds that it restricts or inhibits the alleged "freedom of the architect". It was clear that only through the educational process can this objection really be eliminated since it can so easily be shown to be completely invalid. Fortunately, some of the speakers who showed how the modular system had been successfully used in their countries were architects, thus providing personal answers to the old objection. The Congress was told of successful educational methods used in North America, both in the United States and Canada, for introducing the modular approach to architectural undergraduates, as also to practising architects and architectural draftsmen through the medium of office seminars and of Extension Courses of lectures, arranged in cooperation with universities. North American experience in this direction can be used by any country, since all the major publications used as teaching aids are listed in the new Canadian publication to which reference was made in a footnote on page 201.

A more philosophical approach was suggested in an eloquent contribution to the discussion by a speaker from Israel who pointed out that the modular system can be regarded as a grammar, to be associated with the language of design. He pointed out that the greatest writers, the poets and the artists in prose, all have to use language to express their ideas and in so doing are guided by the basic requirements of grammar, with no loss in the beauty they are able to achieve. So also, he said, can it and should it be in building, as designers recognise and appreciate the discipline that the modular system provides without in any way impeding the flexibility of sound design and with no limitation upon possibilities for aesthetic achievement.

Similar support for the modular system, and an equally sound answer to those who complain about assumed restraints so introduced into design, comes from the sister art of music. An English friend of mine first pointed out to me that prior to the time of Johann Sebastian Bach, composers wrote music just as they wished with no agreed-upon system of arranging notes on paper. Bach, in addition to all his other contributions, was one of those who assisted in the development of the now universal five-stave system of recording music on paper. Historical records show that there were violent protests from musicians of the time about the restriction of their "freedom" in composing. And yet within relatively few years the immortal music of Beethoven was being written for the world's enjoyment, within the "constraint" of the five stave system. So may it be with building, as the use of the modular system steadily extends — giving increased efficiency in building, greater flexibility for the interchange (even internationally) of building components, and all the freedom that the designers of the future need as they combine aesthetic appeal with that functional soundness that must characterize all buildings of the future.

Dimensional coordination as a tool for industrialisation

By L. Bergvall (Sweden)

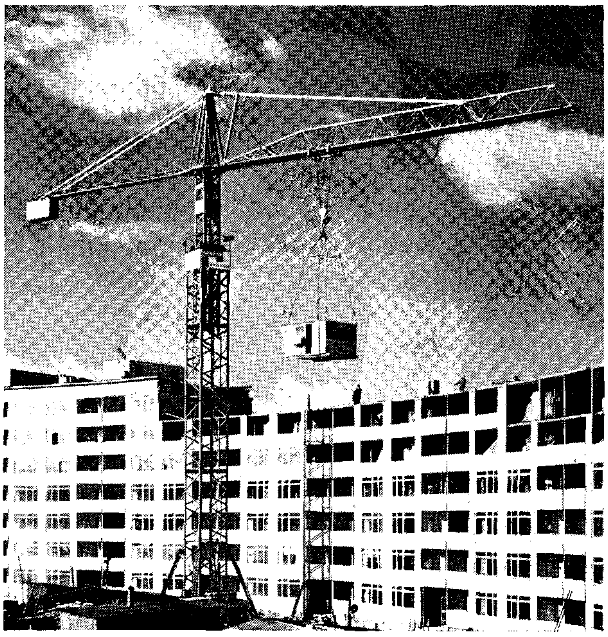

Fig. 1. Modular coordination becomes a necessity as industrialisation becomes a reality.

In the building industry the last decade has been characterized by a steadily growing interest in various methods for industrial building. Although it was established in many quarters already before the war, that building must be industrialised just like other fields of production, it is only as most countries are nowadays faced with a serious shortage of skilled labour, compared with the goals set for the building industry, that this process of industrialisation has really become significant.

It is well established nowadays that the rapid rise in living standards in the industrialised parts of the world is mainly the effect of the enormous increase in productivity, which goes with industrial production and particularly so with industrial mass production. If such an increase in productivity is to be obtained also in the building industry, that industry too must be converted to industrial production and mass production.

Standardisation as an industrial tool

Now the industrial experience from other branches of industry shows, that the full benefits of industrial production methods can be achieved only through production in sufficiently long runs or even in continuous mass production. Such production methods usually imply production for stock and sale, not to order. All these features of modern industrial production, as shown by experience, call very strongly for standardisation as an indispensable tool by which the consumer's natural demand for variety is balanced against the manufacturers' equally natural desire to omit variants. This tool, properly handled, will usually, through a systematic study of the real needs for variety in combination with a systematic selection of the variants, bring about solutions, which satisfy all reasonable needs for variety at the same time as a drastic reduction of variants is obtained.

Standardisation in the building industry. Modular coordination

The building industry, however, is in many ways different from most other industrial branches, even regardless of the obvious fact that a certain part of the production of a building must always be carried out on the building site, subject more or less directly to weather conditions and affected very substantially by such local conditions as topography, soil conditions etc. Characteristic for building production is that it consists basically in putting together on the building site a great number of different components. These components may arrive at the building site more or less prefabricated. As long as most of these components were produced particularly for each specific project or could be adjusted on site, the dimensional coordination of these components did not offer any substantial problems.

If standardised, industrially manufactured components are to be used, which are not easily adjusted on site, the problem of a dimensional coordination of all the components, which are to meet in the building, becomes, however, of paramount importance. Without any kind of systematic dimensional coordination any more extensive use of standardised, mass produced components is rendered impossible. If, however, all those dimensions of the various components, which are important for their coordination with other components are whole multiples of one basic dimensional unit, the module, such a systematic dimensional coordination will be possible. This is the basic idea behind what is called modular coordination. The size of this basic module, M, is internationally established as 10 cm for metric countries and 4″ for foot-inch countries.

Already this basic modular coordination, keeping all coordinating dimensions at multiples of M, means a considerable simplification of the number of possible sizes of many components. For some products, however, even this simplification is not sufficient; a selection of preferred modular sizes must be made. As such preferred sizes so far, whole multiples of 3 M and 6 M are established. Thus 3 M and 6 M serve as multimodules. Similarly it might be necessary to consider for some components dimensional increment steps, which are smaller than the basic module. In such cases the coordinating dimensions must be multiples of a submodule, being a whole fraction of the basic module. As such a submodule M/4 (2.5 cm respectively 1″) is established. This does not prevent the necessary simplification of the number of sizes as long as it is observed that the basic module, M, is the smallest module to be used for the overall planning, determining room sizes etc., i.e. the smallest permitted planning module.

Now, industrialisation of the building industry is a very wide term, which usually means industrialisation of the building industry proper, as well as the industry of building components and materials. Modular coordination is a tool for both, but in different ways.

Modular coordination and the building industry

When the industrialisation of the building industry is discussed, comparisons are often made with the automobile industry with its automatic or semiautomatic production and assembly lines. These comparisons, however, often overlook the fact, mentioned above, that part of the building work, the "assembly", at least, must be carried out on the building site.

There is, however, a production method also used extensively in the automobile industry, which might well serve as a model for the building industry, the use of subcontractors, by which most of the components necessary for the assembly are delivered from factories outside the assembly plant. Just as the automobile industry simply could not exist without being backed up by such supply industries, this will probably be the only way by which the production of building components can ever reach the drastically cost saving mass production stage. But here again a distinction must be made between the automobile and the building industries. Even if buildings as such may, in the future, be standardized to a much higher degree than to-day, there will always be a need for much more variety of the final products of the building industry than of the automobile industry. This means that building components must be flexible, adaptable to many different buildings, where they meet with other components in a great number of different combinations, which might even not be foreseeable in advance. Thus modular coordination, which coordinates those dimensions of all building components, which are of importance for their coordination with other components, will be an indispensable tool for the industrialisation or increased mechanisation of the industry of all types of building components. And just as in the automobile industry, a condition for such a use of subcontractors is that not only the nominal, but also the actual, dimensions of the various components fit together. And, also as in the automobile industry, this means that the inevitable dimensional deviations in manufacture and assembly must be controlled by an adequate system of tolerances.

This conversion of the building component industry to mass production of a limited number of standardised variants might in the first stage mean a fairly rigid limitation of the freedom of design, but on the other hand the difference in price between standard products and specials made to order, will, at this stage, not be such as to prevent completely the use of such specials in cases where there is a sufficiently strong reason for it; this will hold true particularly for very large projects.

We can, however, already now forsee that after this "paleo-automatic" era will follow a real automation of the component industry. In that more developed stage of automatized production lines, combined with electronic control of the whole process from order to shipping, we might again be able to afford an almost unlimited number of various sizes, finishes etc., which can be achieved without extra cost, because of the enormous capacity of these electronic devices in handling variants. But this flexibility must be kept absolutely within the limits of standardised, foreseen variations. We will thus, in this era of real automation, have a very great freedom within the wide framework of standardisation, but will only very rarely be able to afford products outside this standardisation, as the automation will cause a cost difference between standard products and specials, which is almost prohibitive for the latter. In this era of advanced industrialisation, modular coordination will, as a means of dimensional coordination, be of even greater importance than to-day.

Modular coordination and the building work

To the same extent to which a real industrialisation of the component industry takes place, the use of prefabricated components will increase and at the end of this evolution we can foresee a stage, where building on site is completely reduced to assembly of ready made parts. This might include methods where a very limited number of components, complete with finish and built in service installations etc., are used on the site, as well as methods using a larger number of components, by which components for structure, installations and finish may arrive unassembled to the site, and, of course, in all sorts of intermediate forms. Common for them all will be, however, that all parts fit together without adjustment on site, and also here modular coordination, in combination with an adequate system of tolerances, is the indispensable tool.

It is an established experience that for building with prefabricated components an adequate setting out of the building on site is of paramount importance; as a matter of fact success or failure with a prefab system may depend on the skill with which this problem is solved. Modular coordination will serve as a tool also for this by providing a continuous reference grid for the whole building but also through the great simplification of the nominal dimensions that goes with it. Within the framework of modular coordination, all nominal sizes are simple numbers representing multiples of the basic module, M, and for the assembly of prefabricated components it is usually only these modular, nominal sizes that are of importance. Further, modular coordination simplifies also design and planning of site operations through rationalization of the system of dimensioning and through establishing in a lucid way the positions of all components in relation to each other and to the building. Finally modular coordination will promote that close cooperation between designers of various kinds, manufacturers, surveyors and contractors, which is an essential in an integrated, industrial building process, by providing them with a common dimensional language.

Thus modular coordination stands out as an indispensable tool for the industrialisation of the building industry, in the component factory as well as on the building site. It is also significant that in the present stage of development of the building industry, marked by the gradual conversion to various methods for industrial building, the interest in modular coordination is rapidly increasing.

Rules for modular design practice

By K. Blach (Denmark)

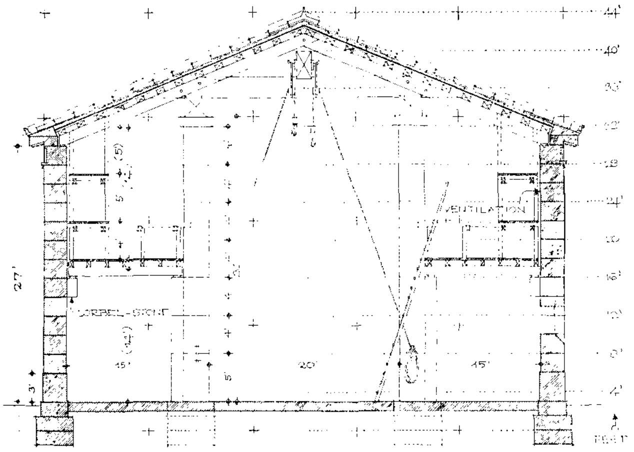

Fig. 1. Co-ordination of measurements. Year 328 B. C. The arsenal at Piraeus. (Reconstruction by Eivind Lorenzen)

In Denmark, the second phase of modular co-ordination in building—that of practical application—is being speeded up by requirements in the Danish building law. Simultaneously, some changes in the philosophy and scope of modular co-ordination in building have occurred. Formerly it was held, that any component created according to modular rules would be generally applicable. Thus industrialised production methods could be utilized, and modular components could be cataloged as stock items.

Now a more encompassing scope is being set forth: to achieve some kind of simple order in building again, so that modern, complicated components can be as easily handled as the simple ones of yesterday—thus leaving the designer the time and energy to concentrate upon the truly creative side of building. As a secondary result of modular co-ordination it is noted, that co-ordination of measurements automatically will provide the basis for industrialised production.

It is also acknowledged, that modular components will—as a rule—only be applicable for the kind of use for which they were created. And during the creation process, the "module" can never be given a preference as against functional requirements, statics, laws guiding the use of materials and production methods.

Modular design—how is it to be done?

The procedure when planning on the basis of rules for modular design practice varies according to the nature of the job on hand:

Planning	... with components	... of modular dimensions	1
		... of non-modular dimensions	2
	... of components	... which must have modular dimensions	3
		... which need not have modular dimensions	4

Among the above mentioned cases the following will be of the greatest interest; 1: Planning with modular components; 1 + 2: Adaptation of non-modular components; and 3: Planning of modular components.

1. Planning with modular components

For economic or production-technical reasons a manufacturer will often design his modular components so that they are applicable only at typical, frequently occurring design details. Even in cases when information about the field of application of the modular component is given by the manufacturer, it will usually be necessary that the architect, already for the purpose of the preliminary sketch, checks whether satisfactory solutions for all design details in the job on hand may be obtained by means of the modular components which it is the intention to use. Such checking may be performed for instance by comparing the modular components with available systematic surveys of design details, erection methods etc.

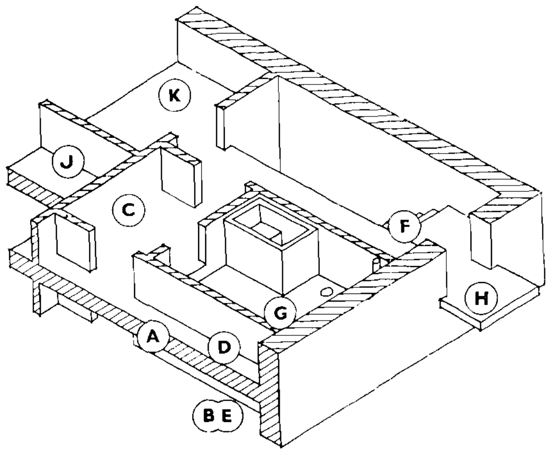

Fig. 2. The Danish Building Manual "Byggebogen" contains systematic surveys of design details in connection with walls, partitions, floors, flooring, roofing etc.

1. and 2. Adaptation of non-modular components

A modular design job which requires the adaptation of non-modular components, should start with a special study of the larger, structural components (especially floors, walls, beams, and columns) because they are often used as a basis for subsequent steps of planning and erection, as e.g. marking out of measurements for finishing processes. If such a study shows that the examined components may be used directly in the form in which they are available, subsequent steps in the planning may be based on such use. If the components examined cannot be used satisfactorily for all the design details required, the possibility of solving the problems by using special components to a certain extent should be studied. Special components may be different dimensionally ("connecting units", "adapters", etc.) or structurally (concrete components with special reinforcement, calculated brickwork, etc.). In this connection considerations of economic or production-technical nature will often determine the extent to which special components may be used.

The procedure described with regard to the load-bearing components may be applied also to the adaptation of non-modular components at a later stage of the planning.

3. Designing of modular components

The dimensions and details of modular components must be based on a thorough consideration of all the design details in which they may have to be used. The amount of work required for the proper consideration of a modular component depends on the number of design details which it is considered reasonable to include. It is therefore necessary in each individual case to judge whether the number of possible applications bear any reasonable relation to the amount of work required.

For the design of new modular components which are to a reasonable extent generally applicable the working procedure described in the following may be used:

Step 1. Choice of component

The components which are of particular importance are generally those which occur in great numbers (are "repeated" frequently).

In blocks of flats it will usually be the components of the normal storey which are repeated particularly frequently and which should therefore serve as basis for modular dimensioning of individual components.

Step 2. Determination of "range of applicability"

Since the amount of work required for the dimensioning of a modular component generally increases with an increase in the range of applicability of the component, it is necessary to define the desired "range of applicability". Such a definition, which may subsequently be applied for the description of the purposes for which the finished modular component may be used, may be formulated on the basis of the following items:

a) The types of buildings for which the component must be applicable (E.g. dwellings, office buildings, schools or hospitals) This item will often be of particular significance to certain of the load-bearing components. It will, for instance, influence spans and consequently the dimensions of trusses, floors, etc.

b) The complexity of the plan of the building for which the component must be applicable (e.g. applicable only for simple, rectangular buildings on level sites or, in addition, to buildings of more complicated types). This choice will be of particular significance to the degree of general applicability which the component may be given.

c) The height of the buildings for which the component must be applicable (e.g. in connection with housing the component may have to be applicable only for 1-storey houses or, in addition, also for houses of up to three storeys, seven storeys, etc.). The chief significance of this choice will be the information with regard to various loads (including wind pressures) with a view to which the component in question should be dimensioned.

d) The structural principles in connection with which the component must be applicable (e.g. in structures based on a bearing system of columns and girders or on load-bearing cross-walls). The choice with regard to this item refers first and foremost to the design of the load-bearing components, but may also influence the design of details of the components to be used in the finishing processes.

e) The materials from which the component should be made (e.g. stone, ceramics, wood, metal, glass, plastics. If required several materials combined). This choice plays a significant role in connection with the control of dimensional deviations and determination of tolerances and manufacture dimensions.

Step 3. Determination of the nominal modular dimensions of the component

On the basis of the choices made in connection with steps 1 and 2 it is possible to give a description of the component to be designed (e.g. that it is a storey-high component of concrete to be used as a load-bearing cross-wall in a block of flats). If required, a rough sketch may be drawn at the same time which illustrates the approximate dimensioning of the component.

Subsequently it is endeavoured through further sketches and, if required, calculations, etc. to arrive at a proper detailing of the component. This work must be based on all the known and relevant functional requirements which may be derived from information in the form of e.g. dwelling research, statics, knowledge of materials, and production methods. When the dimensions of the component have been determined on the basis of functional requirements, or when it has been established that the functional requirements do not exert any direct influence on these dimensions, it is possible to determine its nominal modular dimensions by inscribing the component in the smallest possible 'box" of modular dimensions. The nominal modular dimensions of a component must always be larger than or equal to the dimensions it should have according to the functional requirements.

Step 4. Determination of design details including joints

When the over-all modular dimensions of the component have been established, its details must be determined, based on functional requirements with regard to joints, supplemented with knowledge of deviations of measurements and tolerances in connection with production and assembly. In this connection it will usually be of special interest to endeavour to achieve a proper detailing of the following four typical ways of joining components:

a) The adjoining component contributes by a "joint part" equal to half of the joint normally occurring in connection with the component for which the modular dimensions are being determined (e.g.: the assembly of uniform, light-weight façade-elements).

b) The adjoining component contributes by a "joint part" equal to more than half of the joint normally occurring in connection with the component for which the modular dimensions are being determined (e.g.: the above-mentioned light-weight façade-elements inserted in brickwork of standard bricks).

c) The adjoining component contributes by a "joint part" equal to less than half of the joint normally occurring in connection with the component for which the modular dimensions are being determined (e.g.: light-weight façade-elements inserted in a wall of light-weight concrete blocks joined by means of adhesive).

d) The adjoining component does not contribute by any "joint part" and may possibly penetrate into the modular space of the component for which the modular dimensions are being determined (e.g.: light-weight façade-elements embedded in concrete).

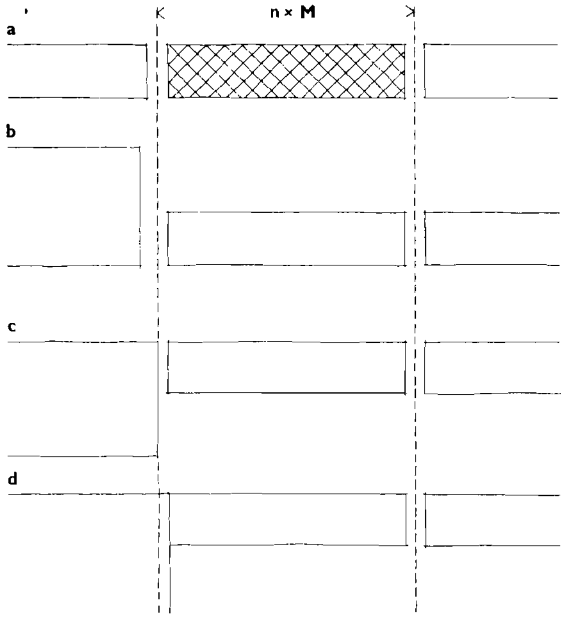

Fig. 3. It must generally be possible to join any component to other components of different types—always by means of a suitable joint—and this requirement may influence the detailing of the component.

The installation of prefabricated partitioning in traditionally constructed buildings

By R. A. Burgess (U.K.)

This paper has been developed from a research project into non load bearing internal partitioning systems which was carried out at the Department of Building of Manchester College of Science and Technology on behalf of the Building Research Board. Its object is to form certain fundamental principles related to the incorporation of these and other prefabricated components in traditionally constructed buildings.

The main portion of the research involved detailed studies of 12 sites with the object of establishing the factors which influenced the progress of partitioning erection, and the sites were chosen to represent each of the main design types, with the exception of cellular cored plasterboard. Each Contract was studied for a period of at least three hours on each working day, and the resulting data, when tested by interpolation was found to be accurate within a limit of ± 5%.

Complementary to this work, surveys were made of 42 offices throughout England, where partitioning had been in use for at least two years, with the object of discovering the reasons for the selection of a particular system and also the degree of satisfaction which it had given to the user.

As all the buildings studied were constructed by traditional methods and of traditional materials, they afforded a good opportunity for examining the problems of the integration of factory-made components with enclosing surfaces provided by traditional on-site finishing techniques. The factors of integration which emerged as most influential upon the effective completion of site operations and the consequent performance of the installations will be examined under the following heads: —

1. The stage of the building programme at which the components were introduced.
2. The limits imposed by allowable tolerances.
3. User requirements related to selection and flexibility.

Time scale

The problems of installation varied between one site and another according to the amount of traditional contractor's work which was completed before the prefabricated components were delivered to site and installed. The later their position in the building programme, the more alien were they in character and the more drastic was the effect of their imposition upon the site organisation. For example, a timber framed partition clad in some form of plaster board or straw board introduced less problems of erection, than a fully finished partition brought onto the site at a later stage. Certain factory-made components, such as standard windows, have been well established for many years, and their incorporation in the processes of building has been accepted and both the designer's detailing and the tradesman's training are related to their characteristics which are closely associated with traditional processes: they are very rarely self-finished, usually requiring site decoration and are built-in during the earlier stages of the contract. Whilst lightweight block or slab internal walls may be considered in this category, demountable partitioning is erected in the closing stages of the work, usually under pressure of an imminent completion date, and has many characteristics of furniture: indeed, in England, cases exist where it has been included in this classification for purposes of taxation and thus qualify for more advantageous allowances as a running cost.

In order to ensure a smooth flow of work during installation, it is important that the adjacent wall surfaces should be at least ready for decoration, the ceiling tiles hung and the floor finish laid, as any additional work required to be done after this point will add to the risk of surface damage. Although the use is increasing of a temporary protective covering of stout paper or other similar sheets, it is still difficult to prevent marking factory-finished surfaces once they have been installed, and any lengthy site storage prior to erection will also increase the risk of damage.

Thus the sub-contractor installing the partitioning is dependent upon the prior completion of their work by several finishing trades and services engineers, creating the need for a full understanding of the quality standards required of preceding trades if prefinished modular components are to be fitted satisfactorily with the minimum of adjustment or damage to the surrounding surfaces. The manufacturer whether he is responsible for the fixing or not, will be foolish if he relies upon agreed dimensions and proceeds with fabrication without checking the actual measurements on the site. Thus he is unable to complete manufacture until the controlling dimensions are established after the surrounding surfaces are completed. At present, his only means of avoiding this delay is to incorporate a method of make up panels which can be adjusted on site, although it is hoped that in the future, more reliable dimensions will be obtainable at an earlier stage by means of improved site inspection procedures and the development of dry finishes.

Frequently the sub-contractor responsible for the partitioning installation is under pressure from the main contractor to start work on the programmed date, even when the site as a whole is behind schedule. Whenever he agrees to this, as instanced in several of the sites studied, he risks finding himself both in organisational difficulties due to the overlapping of several finishing trades operations in a confined area, and also of working at a reduced efficiency and for a reduced profit. The ensuing frustration has usually led to a loss of the initial goodwill and a rapid deterioration of relations between the parties involved. Nevertheless, it needs an influential or courageous sub-contractor to ignore the general contractor's request and to refuse to start before everything is ready for him. One case was observed where a sub-contractor started erecting with a gang of four men one month before the site — which was running four months behind schedule — was ready for him. The result was that the gang left the site four times before the work was completed due to the slow progress of the floor layers, and interference from the five other trades also working in that area. This was clearly an unprofitable operation, emphasising the fact that partitioning can only be erected efficiently where the area is free from other trade operations.

Acceptable tolerances

On the majority of sites, 80% of the completion trades usually involve traditional materials and a system of tolerances which relies largely upon the following trade overcoming any errors which have been made, the additional work involved being accepted as almost inevitable. Thus the later a trade arrives on site, the more accumulated errors it is likely to encounter. It is frequently no one individual's job to check the requirements for acceptance of prefabricated components which, therefore, become involved in unsatisfactory fixing conditions, arising from their dependence upon the accuracy of preceding trades, and on ignorance of the order of the allowable tolerances: unfortunately, the complexity of installations in modern buildings is such that the supervisor cannot usually rely upon personal experience for guidance, but must depend upon comprehensive instructions from the various specialist trades. Where these are inadequate, the efficiency of the operation must inevitably be impaired: on only two of the sites studied, had the main contractor a satisfactory understanding of the partitioning erectors' detailed requirements. Nevertheless, care must be taken to avoid the situation on one recent site where the contractor paid such attention to the specific requirements involved in the many prefabricated components that he failed to supervise adequately the more normal operation of erecting the single storey steel frame, a lapse which ultimately resulted in the loss of several weeks' progress.

In the case of a partitioning installation, tolerances should be considered, related to component manufacture, and to site conditions. The former are partly covered by the appropriate British Standard Specifications. In a recent survey of three examples from each of ten components the dimensional variations which were measured were found to be as follows. Whereas a manufacturing variation of plus or minus one eighth of an inch is acceptable, it is significant that 40% of the samples measured fell outside that limit in either a horizontal or vertical direction. Over long runs of partitioning, such as office corridors, an accumulating variation of this proportion can prove highly disconcerting, involving the erector in additional site cutting of make up pieces. If inaccuracies such as these exist in the manufacturing process, a specific tolerance of ⅛″ on site dimensions should be treated with the utmost caution and considered to be unrealistic. Whilst only 34% of the manufacturers stated in their literature the allowable fixing tolerances of their system, it can be generally assumed that 2″ can be accommodated by using jacks, or wedges, with cover strips, and telescopic wall plates, which can cover up to 12″.

In reality, site conditions are the controlling influence, and may often make a mockery of any such small tolerance as ⅛″. This was well illustrated on one site where factory-glazed timber partitions were used. Make up sizes were specified to the nearest eight of an inch on measurements taken from the drawings, without any site checking. Several of the walls proved to be off-square and the in-situ concrete columns slightly off set, so that none of the make up panels sent from the factory could be used. Had this system followed its usual procedure of fabricating on the site all the make up panels of less than 12″ in width, these costly errors would have been avoided. As the only site work required prior to erection was the framing of panels by half posts, the cutting of mitres for floor and head pieces, and the work on the infill panels, the usual erection process was economical and speedy, and made adequate allowances for the irregularities of the adjoining surfaces.

Fixing to floor and ceiling is done by a jacking action at head and foot, or by means of sole plates at floor and head with wedges for rigidity, and cover strips and skirtings to secure the panels and to overcome the problems of uneven floors.

Where there is a suspended ceiling it will be necessary to continue the main framing posts to the soffit of the floor slab or beams, or to provide a secondary framework above the ceiling to ensure the rigidity of the partition. Where the posts are jacked or wedged, it should normally be possible to precut them to lengths, although the use of powered hand tools have made this a simple site operation. It is, however, most undesirable that the panel units should also be cut, and a great advantage is to be gained by relating the finished floor to ceiling height to that of a standard partition. On one of the new office blocks which was studied in detail, the standard height of the chosen particular partition was 3″ greater than the floor to suspended ceiling, which involved the sub-contractor on site in cutting 3″ off every standard unit. This case was the more extraordinary as the building had been designed and erected for the parent company of the partitioning manufacturer.

Where the difference between the standard partition height and the soffit of the ceiling exceeds the tolerance allowed for by the usual cover plates, infilling panels become necessary. These are frequently of another material which is easily worked on site and adjusted to the partition: this additional work, whilst solving the problems of vertical tolerances, introduces a further element of site work, which may occupy up to 50% of the overall erection time. The ease of demountability and the degree of re-use is also diminished. This must be the price which is paid for the lack of standardisation of ceiling heights.

If prefabricated components are to be readily fixed into the type of traditional building under discussion, a more careful quality inspection technique must be introduced onto the site. The essence of effective inspection is in good planning, implying a sense of purpose and active participation by all those involved in the site operations. A detailed study of this has been made by G. E. Bone, a research student of the Department of Building who laid down techniques of inspection and proposed a purposeful inspection procedure for site work, including the use of master inspection programmes and check lists, in contrast to the present haphazard approach. This would also require the training of all supervising personnel in the techniques of good supervision and the establishment of departments to deal specifically with the co-ordination of quality control, particularly related to specialists' and sub-contractors' work.

Applied to partitioning, rigorous dimensional checks are necessary at the structural stage to ensure subsequent fit, and a clear instruction should be issued of the number and position of measurements necessary for specified layout, probably allowing a ¼″ tolerance for fit. The simpler the surface finish, the greater is the risk that its inspection will be neglected and such elementary measurement as that overall between two plaster faces is overlooked, or checked inaccurately. The development and use of measuring instruments which reduce possible errors is to be encouraged. The order of errors which research has brought to light are 2″ in finished floor to ceiling height over a run of 20′0″ and 2⅜″ over a run of 80′0″ of brickwork punctuated by windows. Both of these cases could cause extremely difficult problems of partition installation, in the one case of vertical tolerances and visual acceptability, and in the other of aligning junctions with brick piers. In another case errors in a line of precast concrete columns between the internal faces of which metal windows were to be fitted varied between —¼″ and + 5/32″ and were generally of a minus value: as the allowable gap was + ¼″ these would produce several very narrow openings for fitting in the windows. A preplanned inspection procedure would have avoided this. The use of templates by partitioning sub-contractors was observed on two of the sites studies and these facilitated erection procedures. However, if they are to be used most advantageously, they should be supplied to the general contractor during the early stages of work on site and when setting out. An intelligent application of this principle is well worth further consideration.

Selection and flexibility

In the survey carried out on 42 office partitioning installations, the principal factors influencing selection, once the use of demountable partitioning had been accepted ,were, in order of importance:—

Degree of flexibility	20 cases
Sound insulation value	17 cases.
Initial low cost.	17 cases.
Acceptability of appearance	16 cases.

From this it is clear that little consideration had been given to relating the choice of system to the conditions existing in the enclosure and in very few cases had the use of prefabrication of partitioning influenced the design of the building as a whole. Out of the 12 detailed studies, two buildings showed some evidence of this by the use of lighting and ceiling grids, the regulation of service runs and a modular fenestration, making possible full flexibility of the internal layout within a predetermined module. In both these cases the erection process was efficiently completed within the programmed period.

A sound reduction value of 40 dbs. can now be expected from a 4″ thick partition if the edges are adequately sealed, provided that there are no holes cut for the passage of pipes or ducts and any doorways are of an equal insulation value. The more complex the surrounding planes, with beam soffits protruding, or columns projecting, the more difficult will be the sealing problem.

A recent survey showed that there are at least 64 systems of demountable partitioning marketed in the United Kingdom, which must be the inevitable result of a competitive society where contracts are usually obtained by tender. The range of modular or 'standard' sizes is consequently very large as a manufacturer will normally wish that his product may serve as wide a field as possible. Laterally this flexibility is achieved either by cutting one standard panel to provide a make up panel in each run as in the case of three of the 12 sites studied in detail, or by manufacturing the whole run in the factory to special predetermined sizes, demanding a precision in measurement which is difficult to achieve. Any module which is used should relate to the economical manufacturing size of the basic components as any cutting of these at the factory must be wasteful, and the designer in selecting his module should bear this in mind.

In the 42 offices visited in the survey, 10 reported less flexibility than had been anticipated and a higher wastage factor on removal and re-erection. Various factors contributed to this, not least the confusion which often exists between the measuring of the phrases, demountability, flexibility and interchangeability.

Any wall is theoretically demountable provided it does not act as a structural member, but it is generally assumed that such walls will be dry finished and so designed that they can be rebuilt with the minimum wastage of material and disturbance to adjacent planes and integrated services. The degree of flexibility provided by a system depends not only upon its design but also upon the limiting factors imposed by the design of the enclosure Thus heating pipes or ducts which require holes to be cut in panels, varying ceiling heights, different surface textures and colours, sound barriers above ceiling tiles and discontinuous floor finishes are typical of the factors which may reduce the flexibility. Interchangeability relates to the individual units, and implies that, for example, a single solid unit can be easily replaced by a door frame and opening. A close examination of many systems will reveal that door frame sections are not always related to the framing posts, and therefore, are not always directly interchangeable.

All these factors have a bearing on the satisfaction which a user will derive from a selected system. In office building, a reasonable amount of readjustment may be anticipated and in the user survey the following pattern was found; alteration had been made as follows:—

Estimated over 50%	8 cases
Estimated 25–50%	5 cases
Estimated 10–25%	3 cases
Estimated less than 10%	16 cases
None altered	10 cases

These figures show that in 62% of the cases less than 10% had been moved and in only 20% had more than 50% been moved. These are cautionary figures when one considers that a demountable partition may cost from 30% to 200% more than a solid block wall. This means many users are paying for a property of flexibility which they may seldom use in reality. Also they may have to accept a lower sound insulation performance. However, there is some advantage to be gained from the prestige value of their appearance, from ease of maintenance and speed of erection. Where the building is designed in a similar idiom, the prefabricated demountable partition has many advantages, and with increased emphasis upon modularity it may well become the only acceptable internal wall for office buildings.

In many cases a change in the position of partitions was confined to cross walls between offices and where the fenestration is related to adequate single office dimensions, this is very logical. Problems of aligning junction posts with window divisions may arise where new walls are introduced into partitioning runs which are not related to the module of the main structure. This emphasises the fact that the full benefit of prefabricated partitioning cannot be felt unless there is modular co-ordination throughout the design.

Conclusions From this research the following points of a general nature emerge, each forming a fundamental principle which should be observed if the various problems outlined are to be avoided.

1. The later a prefabricated component is introduced into a traditionally constructed building, the greater is the need for some means of compensation for dimensional errors on the part of other trades: in partitioning, this can be provided by vertical and lateral make up pieces cut on the site.
2. The need for a more careful quality inspection technique for finishing trades becomes apparent. It should be based on measurement, and the establishment of a vertical and horizontal datum in each enclosure is desirable, together with the clear delegation of responsibility for accuracy.
3. The necessity for plan analysis in order to impose logical limitations on partitioning layout based on the conditions of the surroundings and likely usage.
4. The imposition of a modular discipline embracing structure, services and finishings provides a greater flexibility within its modular limitations than is otherwise possible.
5. Careful consideration must be given initially to the anticipated need for future re-arrangements, as increased costs and lower performance standards may have been accepted unnecessarily.

Acknowledgement

Appreciation must be recorded to Professor Denis Harper, Professor of Building at Manchester College of Science and Technology for the advice and encouragement which he has so readily given in the course of this research, and also to Mr. J. C. W. Roberts and Mr. D. C. Lane, whose painstaking work as research assistants made the compilation of the data upon which this paper has been based possible.

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Influence of size, function and design on the standardisation of components

By N. B. Hutcheon and S. R. Kent (Canada)

The principal objective of industrialisation of building is to increase productivity, or in other words to reduce the cost of building. Since almost all the materials and components assembled on the building site under present methods are already produced in factories of one kind or another, it becomes necessary in justifying an extension of industrialisation to assume that a further transfer of operations from the site to the factory will result in overall savings. This must mean in general that larger and more complex assemblies must be made in factories and transported and erected on the building site. The ideal of complete factory assembly such as is achieved in the case of automobiles will seldom be achieved except in the case of very small buildings.

Since components and sub-assemblies must always be fitted together they must inevitably be made to controlled dimensions. Clearly, if these dimensions are standardised, and if designs of buildings are carried out so as to employ components of these standard dimensions there exists the possibility of establishing requirements for larger numbers of identical units. Conversely, since successful industrialisation of building depends upon just such a demand, the greatest possible degree of standardisation would appear to be essential. Some system of modular coordination becomes highly desirable in order to provide a firm basis for the coordination of dimensions both in design and manufacture.

Modular coordination is in the first instance a discipline in the establishment of dimensions. Thus it provides a rational basis for standardising and coordinating them. But standardisation of external or overall dimensions is only a part of the standardisation of a component or assembly for purposes of facilitating either mass production or subsequent use. Repetitive production results in identical products, having identical functional capabilities as well as dimensions. From a manufacturing point of view it may be just as costly to provide a range of functional capabilities within a fixed set of dimensions as to provide some choice of dimensions within a given number of units.

The development of industrialisation in building will depend very largely on the extent to which it is possible to develop and extend repetitive production and to employ this production economically in the construction of buildings. Thus, the role of standardisation, of which dimensional standardisation is only a part, can only be assessed realistically in terms of the effects it will have upon the design and economics of buildings constructed from standardised components.

Size of units

Transfer of more of the building operation to the factory inevitably means making larger units or sub-assemblies to be transported and assembled at the building site. This increase in the size of units, coupled with the need for standardisation and reduction in the variety of units offered in the interests of economical factory production inevitably introduces a certain rigidity in design. As an example the selection of a wall panel 20 ft (6 m) by 10 ft (3 m) may predetermine certain basic dimensions, and thus influence the division of space into rooms for various purposes. Alternatively, a requirement for variation in the width of rooms or in the spacing and width of windows may indicate the appropriateness of panels of different widths. The forcing of dimensions to conform to the minimum number of standard sizes may be wasteful in the matching of the space provided to the requirements, while an increase in the variations in sizes of components may increase the cost. This problem is not peculiar to buildings constructed of large factory-made units, but is likely to be more acute as units and sub-assemblies become larger under the pressure of exploiting the economies of factory production. A gain in one direction may be offset in part by a loss in another.

The increase in size of units will reduce the number required for any one building, and will tend to reduce the number of applications which can be found for them through reduced flexibility in application. Increased size and weight will require changed transportation and handling facilities, while the requirement to develop a use for the largest possible number of units from any one factory will make it desirable to ship units as far as possible. All of the added costs involved will have to be offset by the reduced cost of factory production.

Function and design

An increase in size and complexity of components and sub-assemblies tends to make them less versatile, so that fewer uses for them can be found. This might be offset in part by over-designing as to functional capability in order to maintain the widest possible range of application for them. Structural elements such as beams and columns provide the more obvious but by no means the only cases. Attempts to encompass a wide range of structural capabilities in identical units can only mean that such units will always be overdesigned for any specific application. The added cost of materials inevitably involved will have to be offset by savings resulting from increased production.

Exterior wall panels represent an extreme case of multiplicity of functions. Walls may be constructed in situ from a variety of materials selected to satisfy the various functional requirements to the degrees required by the particular application. A "standard" exterior wall panel may have to be overdesigned in respect of structure, fire and acoustics as well as for the control of heat, moisture, air and rain in order to encompass a wider range of applications. To these functional complications there may be added those of size, fenestration and aesthetic flexibility, all of which are in opposition to a high degree of standardisation.

Open versus closed systems

Industrialised building systems which envisage the construction of various kinds and sizes of buildings from selected factory-made components conforming to the system are commonly referred to as "open". Those which are based on a particular set of components, complete and coordinated within themselves, not necessarily interchangeable but often capable of some rearrangement to offer some variation in size and shape of building are referred to as closed systems.

It is the open systems, obviously, which offer the greatest scope, in principle, for the extensive development of industrialisation. The requirement for complete standardisation and interchangeability as between components from different sources is a very demanding one and one which has seldom if ever yet been achieved in the case of any other manufactured products consisting of closely assembled units and of appreciable size and complexity. This slow development of standardisation on an "open system" basis for other manufactured goods is most significant and deserves the most serious consideration. It may be argued that buildings, because of size, must always be assembled from parts on site and this favours standardisation. On the other hand the parts must always be assembled in close physical association and often become highly integrated functionally as well. Further, the margin of possible cost saving by mass production of buildings will never be large because of the high proportion of final cost already represented by materials and components. A hand-made automobile engine costs 100 or more times that of a mass-produced one, while buildings at present seldom have more than a 60% on-site labour cost.

The development of mass production of other manufactured goods has rarely proceeded on an open system basis. The initial stages have always been on a closed system basis which exhibits reproducibility of the products made by the one manufacturer but no standardisation in the sense of interchangeability of parts as between manufacturers. Standardisation has developed slowly, beginning with the smallest or most elemental components such as screws and bolts which are both physically and functionally simple and can be put to diverse uses in large numbers. The larger and more complex sub-assemblies become standardised at a much later stage, if at all, beginning first with physical or dimensional and later with functional standardisation.

It is difficult to find justification for the assumption that industrialised building will be developed effectively by concentration on the development of open systems. The more natural and logical sequence would appear to be first to anticipate the development of closed systems for specific types of buildings similar in size and function. These buildings may be identical but not necessarily standardised in the sense that components are interchangeable with those of other manufacturers. Standardisation of the smaller, more repetitive units, which has already begun, can be extended to include larger components such as doors and windows. Standardisation can be extended logically and naturally, up to the stage of complete open systems, as and when the net advantage of such extension becomes clearly established.

Standardisation and coordination of dimensions

Several significant points arise from the previous discussion. Standardisation is not essential in the first instance for mass production. Correspondingly, closed building systems need not be standardised. There need only be a requirement for a sufficient number of identical units so that an economically satisfactory production can be established. Standardisation may, however, contribute to the success of closed systems in several ways. Closed system components and sub-assemblies may themselves be made in part from standard units or sub-components which are less costly than non-standard parts. Also, it may be desirable to offer some freedom of choice of finish materials such as floor and ceiling tiles and panelling obtained from other sources and offered in standard sizes. This may impose a measure of standard dimensioning upon the assemblies. Further, it may be possible to extend the use of selected components of closed systems in other applications if they are standardised, and thus reduce their cost through increased production.

The gradual evolution of standardised parts and of closed systems has been proposed in this paper as a natural and logical approach to the development of open systems. It may be noted that closed systems need not be standardised even though they employ standardised parts. They have the virtue of assuring that all the components necessary for the construction of a building are provided and that they will fit and work together. They accomplish this with a minimum of the overdesign which is required when components have to be adaptable to a wide range of uses in various kinds of buildings. It may be more economical at times to design on a non-standard basis. Nevertheless, taking a long view, the greatest facility will be provided in overall development toward industrialisation if as much coordinated standardisation as is economically justifiable can be introduced at all levels.

Fully developed open systems require that all the components required for a complete building be available preferably from various sources, and that they be standardised so that they will fit and work together. The degree of standardisation must go far beyond that of dimension alone, as already pointed out. This poses the very great problem of functional as well as dimensional integration of all the components selected. In addition, it will probably be necessary to limit the sizes of components to a much smaller range of choice than is offered by steps of one module.

The integration of standard units or components becomes progressively difficult as the components are increased in size and complexity. The functional complexity will in general increase in proportion, and the jointing or connecting of components, which is always a major problem, becomes progressively more difficult, since the joint must provide for functional as well as dimensional integration. The progress of development of modular coordination and of industrialisation can only progress as quickly as adequate solutions are found to the various jointing problems which are created. It seems fitting, therefore, to conclude this paper with a discussion of this topic.

Joints and standardisation

Modular coordination arose from the logic of arranging the larger dimensions of buildings so that repetitive units, notably bricks, could be used to form these dimensions without cutting. The methods of joining bricks, by the use of mortars, had already been well established. This was fortunate for it made the application of modular coordination possible. Such application does not create any particular problem with joints, on the other hand it can contribute nothing to the solution of any joint problem. The point being made is elementary but it is well worth emphasizing since an enthusiasm for modular coordination in particular and standardisation of components in general may make one forget the importance of joints.

It may be noted in the case of brick masonry that the mortar joint accommodates the functional as well as the dimensional requirements. Both types of requirements are likely to exist for any joint. The extent to which they can be met, rather than the properties of the components being joined will often be the limiting factor in the final performance of the combination.

The kinds of solutions to the joint problems which are commonly used in current on-site construction will not be adequate for industrialised building. New techniques and designs will have to be devised which are appropriate to the particular situations created.

The joint problems posed by open systems of standardised building will be more difficult than for closed systems. More versatile types of joints will be required since they will be called upon to serve for a range of selected component combinations as well as for a wider range in functional capability. It is certainly not beyond the capacity of human ingenuity to devise such solutions but whether they will be accomplished at a sufficiently low cost to make a marked advance in industrialised building possible remains to be seen.

R. Leoz de la Fuente

Division and organisation of architectonic space

By R. Leoz de la Fuente (Spain)

Man is the only created, terrestrial being gifted with the ability to conceive artificial masterpieces; that is to say, works which do not yet exist in nature as we know it on our planet.

The imitation of nature ought, therefore, to be only a means of improving the efficiency of our techniques and never an end in itself. This should be clearly understood.

The great works of art and genius will always be products of the human brain, because God so willed it. In saying this, we do not mean that we despise instinct and intuition, for these, in the intelligent man, are the two best allies of the brain in its creative work.

Thus, architecture which seeks to imitate nature is, in reality, retrograde compared with other earlier stages, and in the end purely cerebral creations of sovereign man will always appear again, as happened in the past with the Pyramids in Egypt, the Parthenon in Athens, the truly miraculous Gothic cathedrals and the remarkable creations of a Le Corbusier or a Mies Van der Rohe.

If we consider that man is not made like a swallow, a spider, or a beaver—to name only three of nature's great engineers—it is easy to see that the conditions in which these creatures thrive will not be the most suitable for man to live in, even when allowance is made for an appropriate change in scale. As long as man has his being in the earth's gravitational field, the basic elements of human architecture, which he will have to handle as a function of existence in that field, will be the resistant horizontal plane and the vertical elements, also resistant.

All other systems, of the kind put forward by great architects such as Torroja, Nervi, Candela, Fuller, etc., for all the talent and genius displayed in them, are no more than magnificent forms of covering; therefore, to regard them as fundamental or essential to contemporary architecture is, in my opinion at least, equivalent to beginning our houses by the roof. These solutions are amazingly ingenious, but they only serve for the rare cases when we need single story buildings.

Mathematics and especially the part of them constituted by geometry—both pure and genial creations of the human brain—are vital elements in the training of a good architect.

Le Corbusier, perhaps the greatest architect of our time, has called pure mathematics the language of God.

Together with mathematics, the other three sides of the architectural pyramid are the Fine Arts, Technique and the complex of the political, economic and social sciences.

The architect can never be a great specialist; if he were, he would no longer be an architect. Fortunately, his profession leaves him no time to become one. However, the architect needs to have studied and learnt many things in the course of his early training, if only to forget them apart from the deposit each of them has left within him; this has to be enough to give him very clear ideas about planning and full knowledge of the material possibilities and resources available to him and afforded by his medium.

While it is true that an idea that is architectonically good can be spoilt by professional incompetence in its execution, it is far more true that a bad architectonic idea can never be saved by anything or anyone. In architecture, general ideas are of prime importance and above all common sense when it comes to dealing with professional problems; furthermore, as in all human activities, without honesty and sincerity, nothing worthwhile can be achieved.

The world has come to a singular and remarkable pass. World trends are rapidly changing and the most powerful influences of our time are economic and social and, therefore, technical.

If the architect forgets this, architecture will be lost forever and its utilitarian functions will be taken over by other techniques which ignore art, among other things, because they have no training in it. However, it is not true that architecture today is backward compared with other contemporary techniques. The fact of the matter is that architecture came into being many centuries and millenia before all the other techniques in current use and its brilliant progress dates from very many years back, so let's be fair: a mature man cannot be expected to develop as fast as a newborn child.

Once again man will have to use his intellect to get out of what seems to be the present rut in architecture; he will not do this by imitating anything already in existence, but by original creation, in the same way that he succeeded in producing masterly creations at other crucial moments in human history.

The most important step the architect will have to take now, or in the very near future, will be to learn how to turn to account the new materials man himself has invented, always bearing in mind the limitations of those materials and the conditions imposed by their use, for he can be sure that if he overlooks these he will be bound to fail.

Architecture hitherto, even during its most resplendent periods, has always been carried out with the aid of craftsmen. From now on, it will have to be the task of industry; the order of our time makes this imperative. Mass production and standardisation of the elements that will be assembled by builders and architects in the architectonic structural units of the future is already inevitable. This will come about whether we like it or not, and it will come about very soon.

There is a real danger that architecture will cease to exist as a Fine Art if we solve our practical problems—especially those connected with housing—considering only the technical and economic factors involved, for such a course must fatally lead to dreadful and overwhelming monotony.

A possible way of avoiding this outcome, afforded us by geometry, will be put before you as clearly as possible, with the help of slides, in my work: Division and organization of architectonic space.

The proposed solution, properly speaking, can only be adequately explained by means of a very full verbal exposition accompanied by some three hundred colour slides.

After having seen the wealth of different results in widely varied fields, some of exceeding beauty, obtained with the system, we are reluctant to believe that these are only a matter of more or less skilful combinations of polyhedra and triangles: three different triangles joined in accordance with a given spatial rhythm which never changes.

The simplicity of it may seem astonishing; yet it should not surprise us when we recall that the entire world of created matter is the product of more or less complex combinations of about a hundred primary and distinct chemical elements.

Reflecting a little more deeply on what we are going to see, we think that the three triangles, or the four polyhedra, can be regarded as representing in the solution of our problem the role of severity, geometry and order, and the single spatial rhythm in which we combine them, that of art, rhythm and harmony: in short, the contribution of the human spirit.

The fact that the product of uniting order and art is always good gives us great faith in the solution we propose.

From the utilitarian point of view this for the first time permits architectonic prefabrication on an industrial scale free of the danger of monotony. The elements that have to be manufactured are very few but they can be combined to produce an infinite number of final harmonious results. That alone is a great advance.

The technical skill that will find the right answer to the practical problems of this prefabrication already exists in the world and will certainly help us to give effect to valuable ideas convincingly presented, because, I repeat: ideas are what is important; technique is no more than a means and never an end. At the same time we must not make the mistake of forgetting that nowadays brilliant results are only obtained by the collaboration between sound ideas and the right technique.

In Spain, we are already carrying out research with this in view.

With regard to collaboration between engineers and architects, Le Corbusier in "The Builders' Dialogue" writes:

"Since his training should never be that of a specialist and technique is indispensable for the attainment of his aims, the architect must learn the art of collaborating with technicians, each in his own sphere with his rights and responsibilities, but in architectural works the authority of the architect has to be the strongest".

In this work, Le Corbusier explains clearly what are the characteristics that should define the architect and distinguish him from the engineer.

Characteristics of the Architect: Understanding of man, creative imagination, freedom of decision, a keen sense of beauty and of order.

In short: Spiritual Man.

Characteristics of the Engineer: Respect for physical laws, resistance of materials, calculation and security.

In short: Economic Man

For the existence of fertile collaboration between the architect and the engineer – indispensable today – the personality of the architect should contain a reflection of that of the engineer: knowledge of physical laws, and the personality of the engineer should contain a reflection of that of the architect: knowledge of human problems.

Naturally, Le Corbusier is not referring to the anachronistic classifications expressed by academic titles, but to the persons who have the stuff of architects in them and those who have the making of engineers, regardless of their official qualifications.

Formalism and the desire of some contemporary architects to be original at all costs represent a serious menace to presentday architecture.

The system we may discuss with the help of slides is the antithesis of formalism; rather, it is a rigorous, structural theory which has been used many times in the past, though perhaps in an unconscious and intuitive form, by highly talented architects. It follows a law that is common and very general, but the results it obtains are infinitely varied. In reality, it is a question of a general change of attitude, which explains many things *a posteriori*; a question, we repeat, of a radical change in the standpoint from which the architectural phenomenon is contemplated of the kind that is taking place at the present time in many other fields, and above all, a question of the difference between seeing things in the round and not short-sightedly.

It is surprising to think that on one and the same basis, purely mathematical development can give solutions of great beauty applicable to all branches of architecture: as useful for town-planning as for paving, or for stained glass, etc.

In short, our method has been to tackle the essence of our problem in its most general form in order to elaborate thereafter an immense variety of particular industrial applications, all of them, however, comprised in the same theory of a Division and Organization of Architectonic Space.

The modular building system; a prerequisite to industrialisation of building

By R. Paulick (East Germany)

Transition to industrialised methods of building in the German Democratic Republic started in housing in 1955 and has been continued systematically ever since. Due to precast methods the cost per flat was eventually reduced by some 30% and the productivity per worker raised by 160%. A similar process took place in agricultural building where productivity was raised by 150% in the period from 1955 to 1960. Taking the experience into account that has been gained in the meantime, measures were taken in December 1961 to introduce a system of standardisation which was to form the basis for the subsequent comprehensive industrialisation of all spheres of building. Standardisation in building does not differ essentially from standardisation in other industries and is chiefly concerned with the typification and modular coordination of structural units, structural subassemblies, completed sections, and whole buildings as well as unifying the materials consumption and the construction methods.

Standardisation in building primarily serves the series and large-volume production of structural components and is prerequisite to mechanisation and automation. Standardisation is based on the analysis of the most advanced solutions on an international scale from the scientific and technical point of view and aims at achieving optimum technical and economical solutions.

During the past few years GDR standards related to building, building materials, and design have been adapted to those of the USSR. Furthermore, preparations have been made for directly assuming standards for buildings and equipment, particularly for industrial and agricultural buildings. This promotes the possibility of using Soviet precasting and building machinery and facilitates direct coordination of research and development work among the socialist countries.

The Modular Building System

The most effective means for introducing and implementing standardisation in building is the Modular Building System. Its chief merit is the fact that the range of structural and finishing units has been reduced considerably and that the grade of flexibility has been increased. The Modular Building System comprises the entirety of coordinating principles for designing versatile and interchangeable structural units to be assembled into structural groups, subassemblies, structural section and complete buildings for various functions and uses. The System therefore concerns all types of buildings.

In devising the Modular Building System in the GDR unification work previously carried out in the Soviet Union proved to be of great help.

The starting points for developing the Modular Building System in the GDR were the following basic principles:

Modular Coordination

Based on the module of M = 100 mm, modular coordination sets up a system of standard dimensions as well as the rules for coordinating these dimensions. It determines the dimensional interrelations, the preferred sizes, and the location for the dimensional end lines of units and structures.

Uniform system of tolerances and fits

A clearly defined system for tolerance groups and fits is indispensable to precast construction with units that can be mutually interchanged and combined.

Uniform system of catalogues

Application of the Modular Building System implies the transition from designs tailored to specific orders to a range of products that are offered for sale. The products offered by the building industry are listed in catalogues for

Groups of buildings,
Individual buildings,
Parts of buildings (i.e. sub-assemblies and sections),
Building components and
Building materials

Special attention is being paid to the development of efficient multi-purpose sub-assemblies and sections, as they form the link between the individual structural unit and the finished building. In many cases the functional and architectural requirements can be much better met with at the same cost combinations of standard sections than with complete typified buildings. The application of multi-use sections for all types of buildings and for certain types of civil engineering structures on this scale has been attempted in the GDR only, up till now. In some other countries separate unification systems have been devised for the chief types of buildings, e.g. for residential buildings, industrial buildings, public buildings, farm buildings, civil engineering structures, etc.

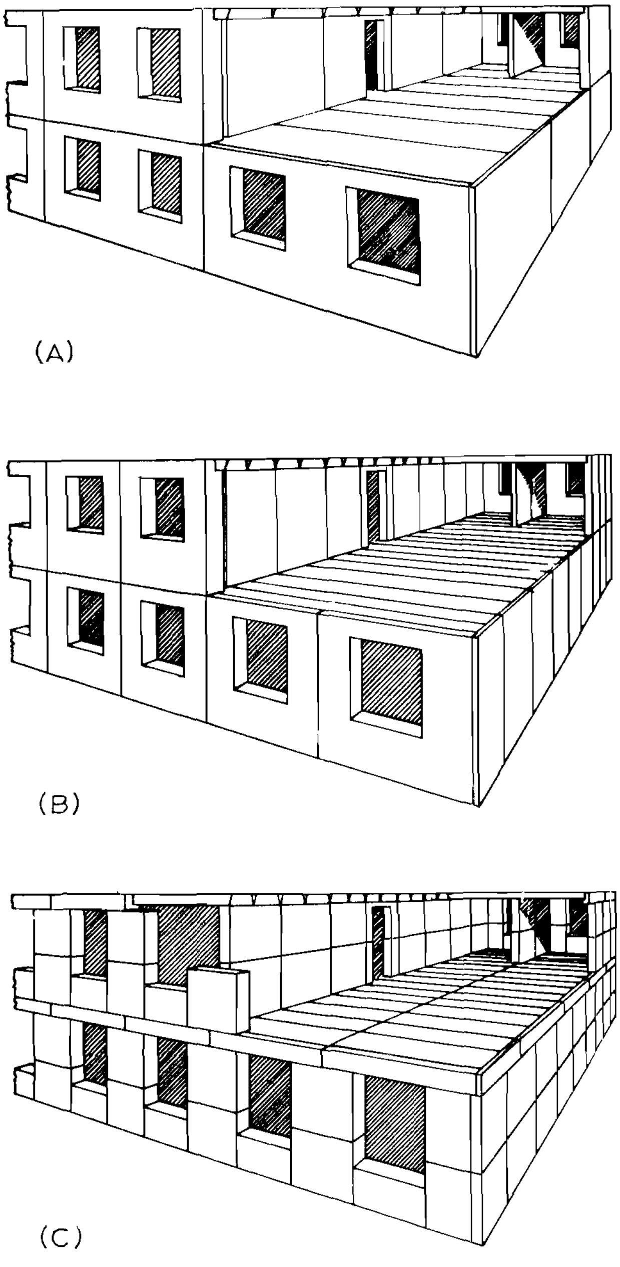

Fig. 1. Structural wall systems for precast concrete units in the German Democratic Republic
(A) Large panel system for 5 ton units
(B) Panel strip system for 2 ton units
(C) Large block system for 0.8 ton units

Structural Coordination

Apart from modular coordination, structural coordination is another important factor in achieving multi-use units and thus creating a large demand for a restricted number of units that can then be factory-produced cheaply in large series. In the *structural wall system* all vertical and horizontal loads are transmitted to the foundations through precast load-bearing wall units. The system is mainly employed in housing and in certain types of public buildings, farm buildings and factory buildings. Depending on the type of handling equipment available this structural system has been detailed for three weight groups, i.e.

(A) Large panel system for 5 ton units (Fig. 1A),
(B) Panel strip system for 2 ton units (Fig. 1B)
(C) Large block system for 0.8 ton units (Fig. 1C).

In the *precast skeleton system* the loads are taken by framing members of small cross section thus allowing the floor space to be used more elaborately. Depending on functional requirements two variants of the skeleton system have been detailed, i.e.

A) Multi-storey skeleton system (Fig. 2).

This system is chiefly used for multi-storey industrial and public buildings;

B) Single-storey skeleton system (Fig. 3).

Sections in this system are the most frequently employed and most versatile units for industrial buildings of nearly all types.

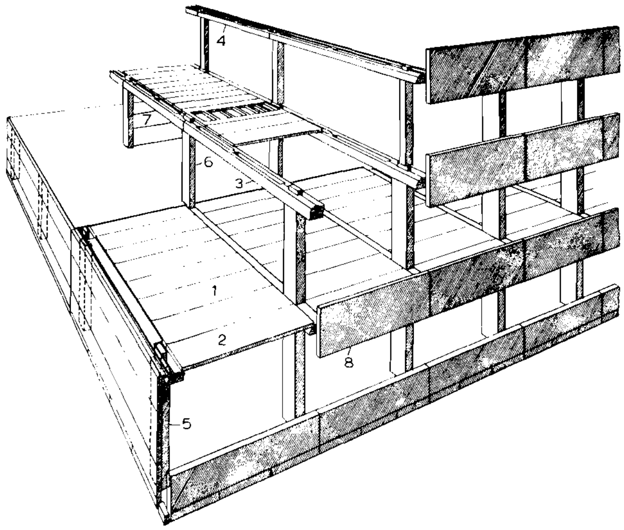

Fig. 2. Multi-storey precast skeleton system showing structural grid and framing members

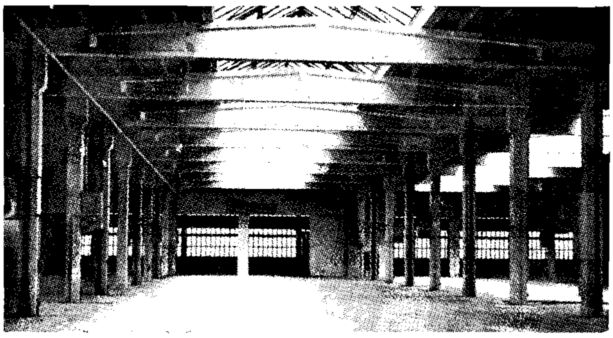

Fig. 3. Interior view of a single-storey factory hall showing the precast framing

Finishing units

Fundamental research work for unifying the chief finishing units such as partitions, storage walls, intermediate floors, and floor covering units was carried out in 1963. In detailing these units the corresponding structural systems had to be taken into consideration. The most expedient modular grid arrived at was one based on increments of 3M (i.e. 300 mm).

Technology

The Modular Building System is the precondition for optimum production and erection of prefabricated components, in particular of precast concrete units. A survey of the principal methods adopted in the GDR in precasting concrete units for housing construction is given elsewhere (1).

As standardisation necessitates improved standards in design, all design work was directed towards adopting the Modular Building System. Employment of the standard units and sections is compulsory in order to ensure their mass production. The compilation of the respective Modular Catalogues will eventually help to speed up and improve design work considerably. In the GDR the first catalogue for standard structural units was published in 1964. Apart from that, fundamentals for the Modular Building System in respect of function, structural theory, technology and economy are being investigated.

The results arrived at so far are by no means final results; they require further detailing in order to fully meet practical requirements. The ultimate aim is to devise comparatively small assortments of modular units that allow for large-volume prefabrication and that meet all architectural requirements.

An example for such a unit is the standard series of GDR floor slabs that can be employed in factory buildings, agricultural buildings, in housing, in public buildings and even in some civil engineering structures. A number of roof girders is also being employed in various types of buildings, e.g. in industrial buildings, in agricultural buildings, and in public buildings. The structural details and the principal parameters for external wall panels have also been detailed so as to adopt one range of walling units for all types of buildings, no matter whether for light-weight, medium, or heavy external walls. Of course, there will also be a number of units the interchangeability of which is small or which can only be employed in limited cases.

Conclusion. The chief demand to be met is to erect buildings and groups of buildings that most expediently meet the material and intellectual requirements of society. That also applies to the Modular Building System and its underlying principles. In this respect all work connected with the System is basically an architectural concern. Just as every other type of construction, industrialised precast construction has its own aesthetic laws. Reinforced concrete – the material – as well as dry construction – the method calling for specific structural systems – gives each building a definite character. Further aesthetic features are introduced by the new light-weight materials such as plastics, foamed materials, aluminium, and traditional materials such as steel and glass. All these component qualities, when used wisely, will produce a new beauty. A precondition is, of course, that the architect meets the demands made on him in coordinating all respective factors, concerning function, technology, and economy.

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2 "Baukastensystem, Grundlagen für Gebaude", Mitteilungen des *VEB Typenprojektierung bei der Deutschen Bauakademie*, Nr. 7/1964, Berlin

Modular coordination, repetition and architecture

By H. Schmidt (East Germany)

By modular coordination we mean a geometrical system which makes possible the construction, with prefabricated elements, of the most varied buildings. Economic efficiency of industry demands mass-production which will be achieved insofar as the number of various element-types are reduced to a minimum and that the elements be usable and interchangeable as much as possible. It makes standardisation on the basis of a single modular coordination necessary.

It is evident that such a step will have considerable influence on architecture. It is enough to remember that architecture throughout its history has used different mathematic and geometric regulating systems (the modular system of Vitruvius, the triangulation of the Middle Ages, the plaited mat units of the Japanese house). As these systems had, although only partially, a practical purpose in the construction of the building, they no doubt are an important aesthetic element with regard to unity, harmony and proportional relations between the parts and the whole of a building.

From a more recent period we can quote the Dutch architect Berlage who wrote in 1908:

"What prevents us from accepting, at the present time, that an architectural composition can hope to have this quality only insofar as it is based, down to the minutest detail, on a single geometrical system".

The construction of the Crystal Palace in London in 1850 by Paxton represents a remarkable advance in the direction of present-day modular coordination. The building is entirely made up of prefabricated cast-iron pieces. The size of the pieces are based on a basic module of 8 feet (about 240 cm) which correspond to a unit of the diagonal struts of the truss. Three types of truss of 24, 48 and 72 feet determine the distance between supports. The following range of length (in cm) results; 3 × 240 = 720, 6 × 240 = 1,440, 9 × 240 = 2,160.

On the basis of industrially produced elements assembled on the construction site, Paxton thus came out with a three dimensional modular system. In principle that is the road followed by present-day modular coordination.

The starting point is determining the basic module. The International Standards Organisation set the module at 10 cm which, later, was adopted by a great majority of the countries of Europe, both East and West. The Anglo-Saxon countries adopted the module of 4 inches. But simply adopting a basic module does not anyway give you an adequate system of modular coordination. Such a system, according to the convention of the building commission of the Council for Mutual Economic Aid of the socialist countries, consists of:

a) The modular system made up of the basic module and a series of preferential dimensions on the basis of the basic module;

b) the three dimensional frame which determines the junction lines and surfaces of the elements;

c) The system of tolerance which determines the relation between the gross and net dimensions of the element.

The most important standards are those concerning the modular system and the three dimensional frame.

To make mass production easier, the number of type elements must be kept to the lowest minimum possible. For this purpose it was necessary to choose between an *n* quantity of dimensions, based on the basic module and a series of preferential dimensions which form a single system. Guided by the constructions of the large industries the module standard of 600 cm, set by the U.S.S.R. was first adopted. The result is a series of 600, 1200, 1800, 2400, 3000 and 3600 cm which makes possible the standardisation of markets, farms, facing and roofing units. Architects working in the field of housing, etc. mostly ask for modules of 120 cm, that is a series of 60, 120, 240, 360, 480, 600, 720 cm. This series, which corresponds to that of Paxton, has proven itself valuable over some ten years. On the other hand, the large scale construction architects specify a 150 cm module, therefore a series of 150, 300, 450, 600 and so on. Up to now no agreement has been possible.

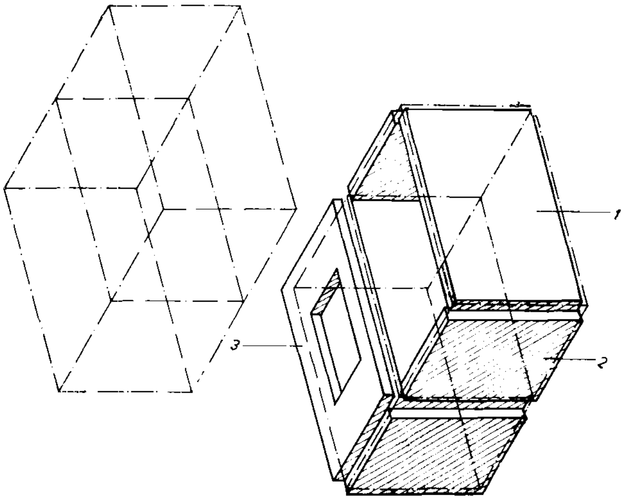

Fig. 1. Three-dimensional frame, schema and example of erection.
1 – Floor element
2 – Supporting wall element
3 – Facing element

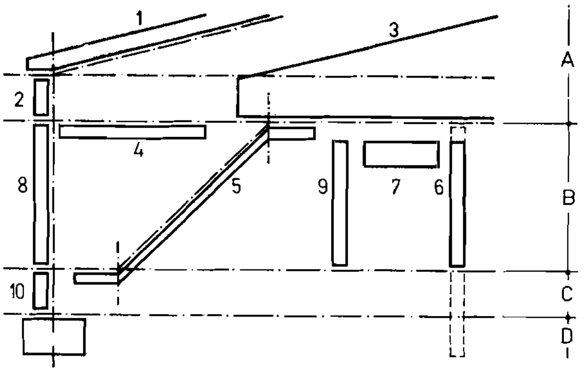

Fig. 2. Assortment of prefabricated construction elements

A – Roof
B – Storey
C – Base
D – Foundation

1 – roof-slabs
2 – outside surface of roof
3 – trusses
4 – floors
5 – stairs
6 – columns
7 – beams
8 – facing walls
9 – inner walls
10 – base walls

The second criterion of modular coordination is the three dimensional frame (fig. 1 and 2).

It is composed of a three dimensional grill, the lines of which determine the gross dimensions of the elements and the placement of joints between elements. Important points are the floor level above ground, the axis of the load bearing elements, the level of supports of the trusses, the inner surface of the facing which should be carried by a supporting structure of some sort. The grill also determines the height between floors, for which a series of 270, 300, 360, 420, 480, 600 cm is adopted. It goes without saying that the distances between the lines of the grill correspond to the standard dimensions of the modular system. In this way the frame of the grill permits the construction of the most varied buildings from an assortment of standardised elements.

It is evident that such a broad modular coordination cannot be introduced all at once. It will only be effective beginning with the moment the building industry places at the disposal of the architects a sufficiently complete assortment of standardised elements.

Let us now deal with the problems that such a system of modular coordination presents to the architect. It is a question of

- realising, through this system, useful surfaces demanded by the function of various buildings,
- of maintaining technical development,
- of the freedom of architectural expression.

In these three fields architects fear unacceptable restrictions to the flexibility of plans.

The first objection, one of the most important in fact, concerns the real possibility of standardising the dimensions of the various parts of buildings to the extent foreseen by modular coordination. The experiences attained in the G.D.R. with the construction of buildings planned on the basis of modular coordination have shown that there are a minimum number of complications in the field of industrial buildings. Here the large dimensions of the enclosed space permit a certain flexibility. In addition, we note the general tendency to build, instead of a "made to measure" building for a specific manufacturing process, buildings for multiple uses. In the construction of living quarters the 6 m and 12 m module was adopted quite early together providing a basic module of 60 and 120 cm. Research has shown that the same module can be used for other buildings of civil construction. The unity of dimensions is in this case also favoured by the introduction of free planning, the flexible living unit, the large undivided office, etc.

We can therefore state that the apparent contradiction between the multiplicity of functional needs and the rigidity of modular coordination does not present an insoluble problem.

The second objection to modular coordination concerns the so-called limited freedom of technical evolution. It is true that the geometric system, the basic module and the series of standard dimensions cannot be changed at the whim of everyone. On the other hand, the choice of elements, "the catalogue", can be freely changed according to technical evolution—material, construction, weight—always providing modular coordination is respected.

The principle of interchangeability of elements always allows the adaption of certain groups of elements to needs of technical progress without affecting the system as a whole. Even new constructions such as mushroom-shaped floors and thin shells can be coordinated (fig. 3 and 4). This is very interesting in cases where construction is industrialised, that is prefabricated or mounted. Modular coordination can also include the traditional monolithic construction. This permits the use in a traditionally constructed building, of certain "catalogue" elements, such as floors, roofs, curtain walls, etc.

Let us now deal with the last objection which fears the imposition of a limit on the creative freedom of the architect. The following points arise:

- Is the use of a geometrical system in contradiction to the development of architecture?
- How important is mass fabrication to architecture?

The Berlage formula demands the geometrical system as a basis for an architectural composition. At first the assumption of Berlage was not in contradiction with the evolution of architecture for some twenty years. Since then a conception termed "organic architecture" has gained ground and challenges the validity of geometry. An "informal" architecture, an "architecture of chance", is spoken of. It is evident that such a conception of architecture is incompatible with a unified geometric system and mass production in building. There are architects and theorists of architecture who draw the conclusion that mass production, "catalogue" architecture, would mean the end of architecture. If we stick to the classical conception which defines architecture as the sum total of function, construction, economy and beauty, it would be absurd to see in changes in the economic and technical parts of that sum-total, the end of architecture. We must stress the economic and social aspects of mass production. We must think of the immense number of houses, schools, hospitals, etc., required by the ever growing world population and add to that the no less large number of superannuated housing which must be replaced by new construction.

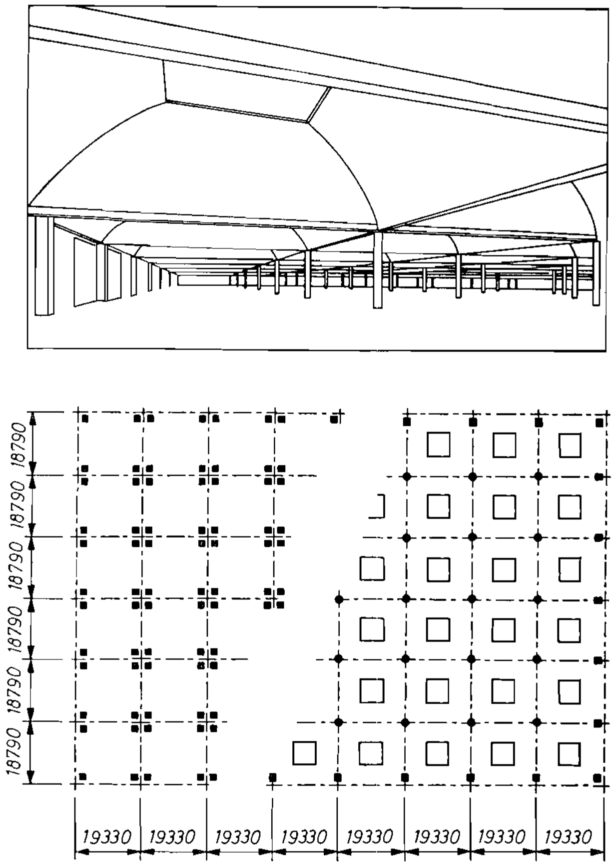

Fig. 3. Warehouse in Le Havre. The left side indicates the theoretical location of the modular pattern.

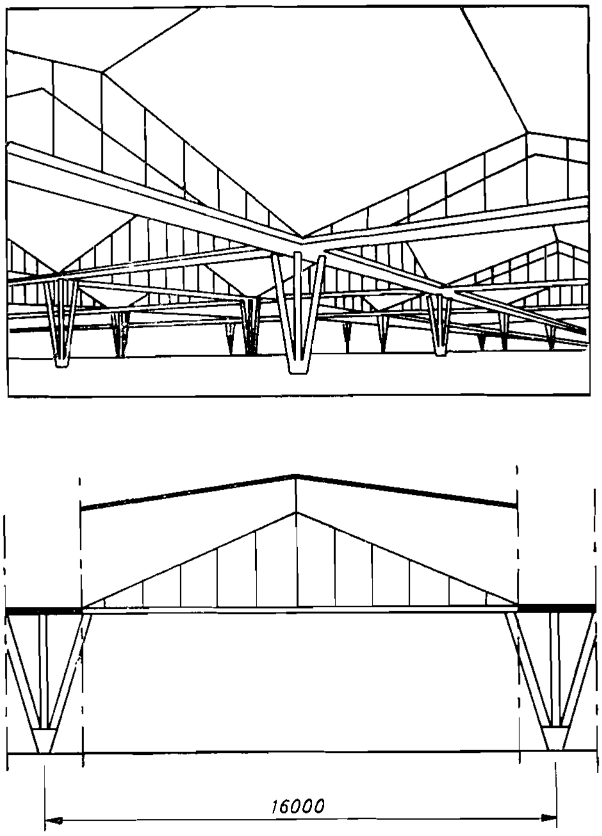

Fig. 4. F. Candela, factory in Mexico. The position of lines in case a modular system is used.

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According to the opponents of "catalogue" architecture, an architecture ruled in this way by technical, economic and social necessities would lose its character as a work of art. Yet the past shows us, in ancient towns and cities, a mass production of architecture born of harsh necessity and realised with very limited means. Today we not only admire the beauty of the Gothic cathedrals and the Renaissance palaces, but just as much the beauty of this anonymous mass production of architecture. Also, we are in possession of the experience of an almost hundred year old evolution in an architecture that had forgotten that necessity is the master of art ("artis sola domina necessitas"). The fatal results of an architecture of the superfluous, of the exceptional and of individualistic freedom are known.

The aesthetic problem discussed above in relation to mass production in building is uniformity and monotony.

Every standardised mass production has a certain uniformity of product as a result. But it is not the fault of modular coordination which as a geometric system produces a certain architectural regularity in the rhythms, proportions, etc., but which should not necessarily give the effect of monotony. Monotony and uniformity result from the repetition of equal-sized elements that make up the assortment, the catalogue of standardised elements. Nevertheless, as we have seen, from the technical point of view, the varying and enlarging of the assortment from the aesthetic point of view, is always possible. But there is one indispensable condition. Architects must have a sufficiently strong influence on the mass production of elements also from the aesthetic side. They must become active collaborators of the "catalogue". Otherwise architecture runs the risk of becoming a bazaar.

We can speak of monotony not only with regard to the uniform architecture of buildings but especially in the field of town-planning.

As a cure of monotony of whole cities generally, the greatest diversity in architecture, master-plan and the location of buildings is utilised. There results, in many cases, residential districts which lack a specific city character and which run the risk by their diversity, of producing a new kind of monotony, disorder and anarchy.

At bottom, monotony is not a purely aesthetic, but a social problem. The most famous cities of the past show how uniformity, being a social fact, is transformed into an aesthetic phenomenon. The Rue de Rivoli in Paris, Bedford Square in London, the façades of St. Mark's Square in Venice were all built according to a strictly uniform architecture. Why in those cases do we not speak of monotony? The buildings, the streets, the squares, the contrast between the residential districts and the public buildings, make up the social whole of the city. The uniformity which otherwise would cause monotony, has a well defined artistic sense. If we have understood the art of building cities in a social sense, the industrialisation of construction will support the city-planner effectively in his job as an artist.

Conclusions: Modular coordination sets up a system of geometrical order which will permit the unified mass production of standard construction elements that will be usable and interchangeable to a greater extent.

Modular coordination finds its true use when fitted to a unified building industry. Through this its usefulness and extended utility can only be judged from the point of view of the national economy of each country.

Modular coordination, in relation to the construction industry and mass production demands from architects and town-planners new conceptions and methods, not only in technique and economy, but also from the aesthetic point of view.

Practical methods for controlling dimensions of prefabricated concrete elements

By H. Senstad and B. Slettebø (Norway)

The Norwegian Building Research Institute has on several occasions been engaged to control the dimensions of prefabricated concrete elements for outer walls. This paper will give a brief survey of the methods used in the control work and the problems encountered.

The written specifications of the elements and the demanded tolerances are discussed with a view to the practical methods used in the control work. It is quite easy to write out theoretical specifications describing the geometry of the elements. The interpretation of these specifications and the working out of practical control methods which can be economically carried out is not at all easy. In most cases only a part of the elements is controlled. No statistical methods are used in picking out elements for control. If concrete or steel moulds are used, the control of the initial production is most important, the results being used to correct the moulds. If wooden moulds are used, it is important to follow up continually since these moulds become more inaccurate with time and use.

Though the control of the elements is a product control, much care is taken to discuss the results with the producer of the elements in order to correct the moulds and the methods of work.

Contracts, specifications and tolerances

Architectural considerations and durability are the most important factors in deciding the type of outer wall for office and commercial buildings. Costs, of course, are also important but not at all dominating the choice. It is the architect and the consulting engineer who design and write out specifications for the elements. The architect decides shape and surface treatment and the consulting engineer makes the necessary structural calculations and designs the attachment of the elements to the construction.

In a special chapter of the specifications, dimensions and tolerances for the elements are described. These descriptions, together with drawings of the elements, are the tender documents. Element factories are invited to submit tenders for production and delivery of elements to the site. The factory which gets the contract is then a sub-contractor controlled by the builder (investor) or his agent, in most cases the architect.

The main contractor has to accept any element lying within the described tolerances and mount it on the building. To make this possible the contractor has to rely upon the control of the produced elements at the factory. The aim of the control is to ensure that the elements delivered to the site have the dimensions and tolerances agreed upon in the contract between the investor and the factory, so that the main contractor can do the mounting of the elements. In theory, the main contractor is not obliged to mount an element lying outside the described tolerances.

To perform the control work it has been necessary to work out a document describing the control methods, instruments and what measures should be taken. This document is based upon the specifications and tolerances worked out by the architect and consulting engineer. It may be called an interpretation of the specifications and this is always discussed with architect, consulting engineer, element factory and main contractor.

Control methods, specifications and costs

The measuring devices and the way they are used are important. The NBRI had no experience in deciding what instruments to use. The first thing to do was, therefore, to construct devices for measuring, e.g. length. We decided to use lineals and sliding gauges of steel with rectangular section (5 × 40) mm and with scale in mm.

Fig. I shows an example of the use of a sliding gauge in controlling the widths of an element. In this case, two magnetic pieces were used as bearings for the sliding gauge. Evidently, the contact area between the magnetic pieces and the element has an influence on the measure. It has a marked influence if the surface is rough as in the case of an exposed surface. It is necessary, therefore, to describe the size of the contact area between the measuring device or bearings and the element.

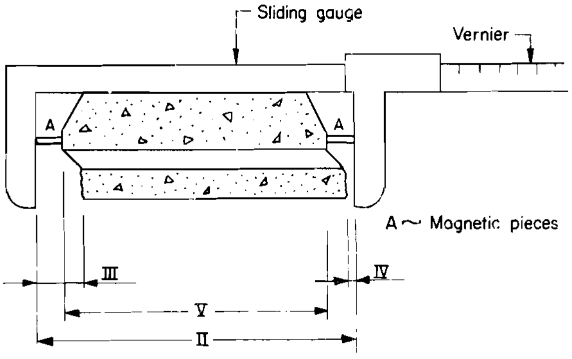

Fig. 1. Measurement of width of concrete element with sliding gauge. A – are magnetic pieces used as bearings for the gauge. The contact area between the pieces and the concrete influences the result of the measurements. A fixed area should be described when deciding the methods of control. A special wedge-shaped gauge – Fig. 3 – may be used when measuring distances III and IV.

It may also be necessary to describe where a certain measure should be taken and in some cases how many measures should be taken. For instance, a specification may request one side of an element to differ no more than 5 mm from a plane – horizontal or vertical. This is controlled by means of a stiff straight-edge supported on the plane. The position of the straight-edge is considered as the basis for measurement. Both the supporting of the straight-edge and its position on the element must be specified to control this. These definitions and interpretations are prerequisites to perform the control work and to limit it in time and costs.

It is not necessary to control every element, nor is it practical because of the costs. The optimalization of the total costs in production, control and mounting of prefabricated elements is very difficult. The producer has a feeling that small tolerances mean higher costs in production. It will also mean higher costs for control but smaller costs for jointing. So far, we know little about this. We have a feeling that the control costs should be

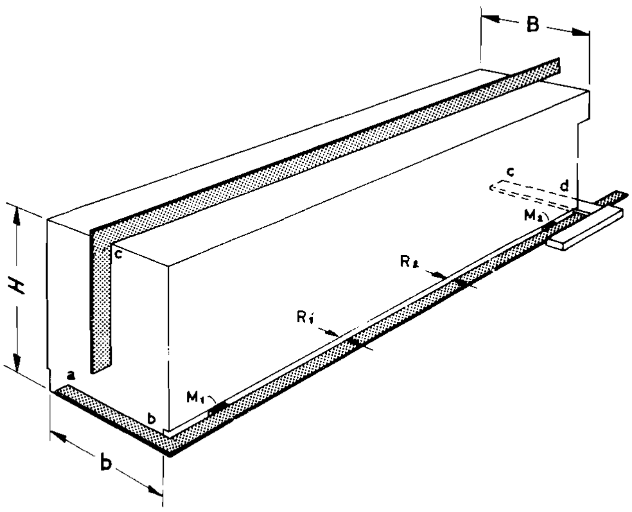

Fig. 2. Use of straight-edges with fixed square at one end for measuring lengths. A loose square is used at the other end. The straight-edge may be supported in different ways. Thus, the straight-edge along the lower side of the element is supported on magnetic pieces, enabling the distances between the straight-edge and the concrete surface to be measured with the wedge-shaped gauge – Fig. 3. This is a straightness control. The squares also make it possible to control angles at top and bottom.

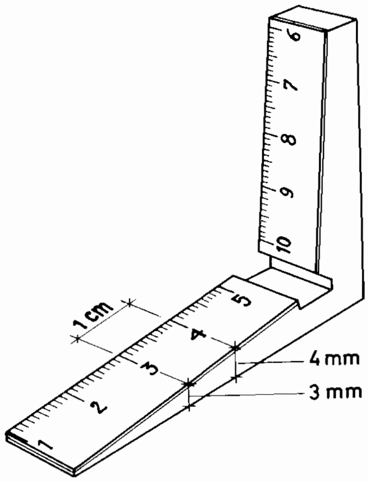

Fig. 3. Wedge-shaped gauge used to measure distance between concrete and measuring device such as straight-edge or stretched wire.

limited to may be some 2–5% of the total value of the delivery. in practice, a cost target for the control work is agreed upon and If necessary discussed when experience has been gained on the job.

Length, width and thickness control. Length, width and thickness are measured with stiff straight-edges and sliding gauges. The straight-edge may have one square fastened permanently on one end. A loose square which is moved alongside the straight-edge is used at the other end.

The straight-edge or the gauge may be supported on magnetic pieces or used directly on the concrete surfaces. An example of the use of straight-edges is shown on Fig. 2. If the measuring device is supported on magnetic pieces, it may be necessary to measure the distance between the straight-edge and the concrete surface. This is done with a wedge-shaped gauge, shown in Fig. 3.

Straightness control. Generally, the design specifications state that one side of an element should not differ more than a certain number of mm from a plane. The straightness variations are a matter of definition and ought to be based on the control method. The NBRI uses the straight-edge (Fig. 2) supported on magnetic pieces and measures the distances between the straight-edge and the concrete. The positions of the supports may be decided in each case. When the straight-edge is in position the distance is measured with the wedge-shaped gauge along the straight-edge, e.g. at points R_1 and R_2.

The readings may be interpreted differently. Should the maximum difference or the difference from the average be understood as the amount of variation in straightness? If the element is very long—more than 300 cm—a stretched steel wire is used as basis for the measurement. The wire is stretched so much that its deflections are negligible. The distance between the wire and the surface is measured with the gauge shown in Fig. 3. In order to observe when the gauge touches the wire, flash light bulb and battery were attached to the wire and the gauge, Fig. 4. The bulb will light up when there is connection between wire and gauge, thus giving notice of measurement. Often the straightness is controlled only near notches, but when there is a specification demanding an area such as one side of an element to be controlled, the straightness must be measured along several lines of control. This must be agreed upon in the control specifications. The straightness control as such, is only a way to control the deviations from a straight line.

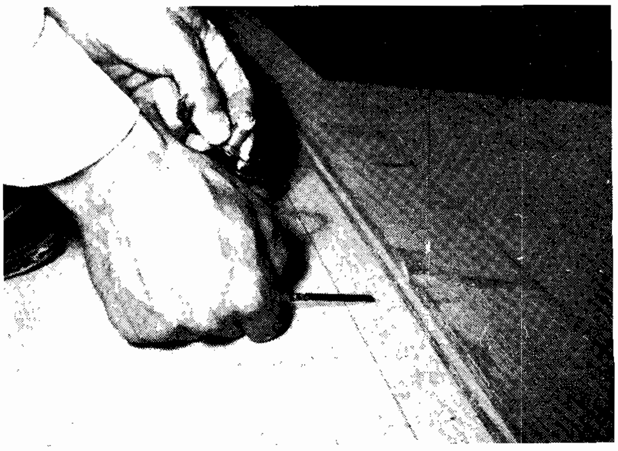

Fig. 4. A wire is stretched out supported on magnetic pieces. The wedge-shaped gauge is used to measure the distance between wire and concrete. Note flash light bulb.

Angle control. For large elements small variations in angles will have great influence on the width of joints. Squared and rectangular elements may be controlled by using the diagonal check. This is often difficult and the accuracy of the measurement is rather limited. It is difficult to establish the points (corners) between which the measures should be taken.

Large squares may be used in the way shown in Fig. 5. Here it is vital to eliminate friction against support, so a rolling steel cylinder may be used supporting one of the legs. For readings the wedge-shaped gauge—Fig. 3—is used in the same way as in straightness control. If there are great deviations in angles, it is difficult to point out which side deviates, so a diagonal check must be made, too. These controls are very elaborate.

Skewness control. The variations in a plane of a surface are also a matter of definition, similar to straightness. It is urgent also here that the means of control should decide what definitions to use. Further, the way the element is supported when performing the control must be taken into consideration.

In practice, four corners of an element may be selected as control points. The distance between one of the corners from the plane defined by the three other corners may be used as a definition of skewness. The measurement is performed with the help of steel wires stretched between the corners and the use of the wedge-shaped gauge and lightbulbs mentioned earlier. The principle is shown in Fig. 6.

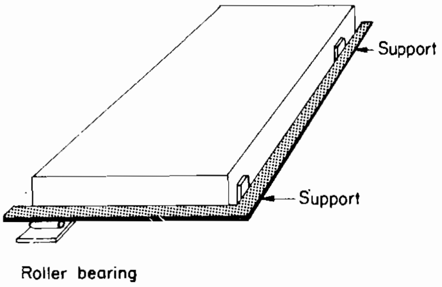

Fig. 5. A large square used for angle control. To eliminate friction one of the legs is supported on a roller bearing.

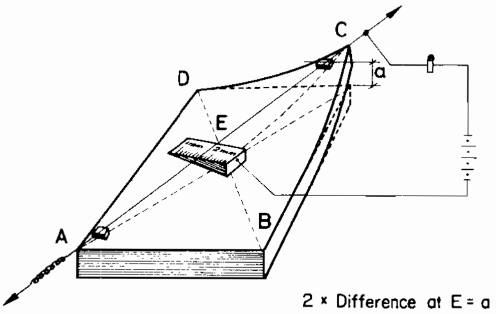

Fig. 6. Control of skewness or straightness of a surface is made with stretched wires. The wire is first stretched diagonally supported on steel pieces between two of the corners and the distance between the wire and the concrete is measured at the intersection of diagonals. The procedure is repeated along the other diagonal. The differences of the readings between the wire and the concrete are a measure of the skewness of the surface.

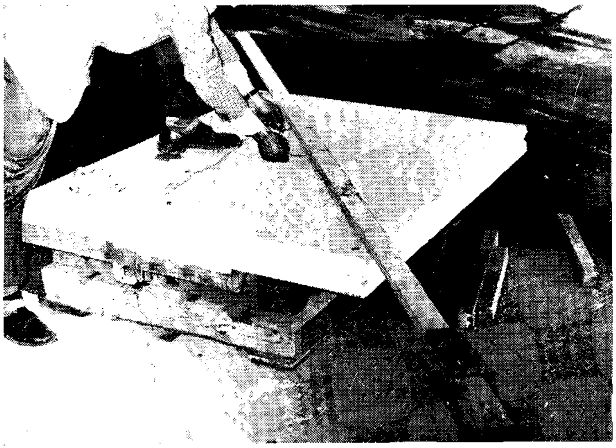

Fig. 7. Wire stretched diagonally to measure the distance between wire and concrete at the intersection of diagonals.

First, the wire is stretched out between two corners supported on pieces of steel and the distance between the concrete and wire is measured at the diagonal crossing point. Then this is done on the other diagonal. Twice the difference between the two readings is considered as the variation in planeness. An example is shown in Fig. 7.

Rectangular control. This control combines the angle, straightness and length control. The whole set of measurements may be treated so as to establish coordinates for the sides of the element and comparisons with the circumscribed and inscribed rectangles may be made. This is very time-consuming but actually what should be done if the specifications used by the designers are to be followed up.

Conclusion. Designers writing out specifications for dimensions and tolerances for prefabricated concrete elements must take into consideration how the necessary control work should be performed. If small tolerances are desired, the production and control of the elements will involve higher costs than if tolerances can be fixed more widely.

Obtaining smaller maximum deviations than ± 3 mm is very difficult and will demand grinding techniques to be used in production. This is very expensive, but may be used for architectural reasons.

The joints between prefabricated concrete elements are designed with widths about 12–15 mm. In one case where, theoretically, the width between the joints should lie between 11.5–18.5 mm, measurements on the building showed joints between 6 and 26 mm.

Clearly we do not know exactly how to determine the necessary tolerances for elements and their placing and come out with resulting widths of joints lying between fixed boundaries. Theoretical considerations are helpful but they must be backed with knowledge about techniques and accuracy of measurements and costs.

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L. Silvennoinen

Dependence of prefabricated unit construction and repetition upon modular co-ordination and typification

By L. Silvennoinen (Finland)

Planning in mechanizing building activity

The planning of mechanizing building activity follows the universal direction of development, consisting of continually enlarging units, areas, volumes. The acquisition of areas, the loan plans, the dwelling-saving principle etc., require the *planning of products to a certain stage many years prior to the realization phase*. Nevertheless, the projects have to be relatively elastic in order that alterations required by the time point can be considered. This calls for a planning chain.

The general character of mechanization

Mechanizing building requires the establishment of long-run production chains: the developing sub-supply activity brings along an expanding group of producers whose cooperation extends over a period of several years. This cooperation reaches its climax in the realization phase of the buildings, the most important link in the chain of activities. The aim is the eliminating of unessential work phases, i.e. construction according to a predetermined system. This is the form most clearly perceptible in an industrialized building activity.

The special character of system construction

There is a large group of forms of system construction, depending on the aims, materials etc. Each system differs in essential application from that of the others. Also, its "ideal product", the solution that suits it best, is different from the others. Thus, there exists no general solution, a general type that would be equally ideal to all systems.

The "own type" of system building

The standardisation of a solution, the typification, pays off if it causes a decrease of the price of production factors, i.e. the price of the product. In the price formation of system construction, which factors are essential, which are inessential?

If two, or more solutions demand the same material, there is no price difference among them as regards the system. If two or more solutions have the same transportation possibilities, the same installation possibilities, the same transfer possibilities, the same maintenance etc., they do not have a value-order with regard to the system. The suitability to the production system of the result of the project can thus be viewed more in detail, and its significance in price formation be examined. We arrive at the concept of profitableness tolerance of typification. Example: The standardization institute of SAFA (Finnish Building Standardization Body) carried out together with the wood working industry of Finland research on the effect of the size of series on the production price of a wooden standard window. The result of research: an increase of the size of series at first occasioned a steep decrease of the price, but as soon as a hundred units were reached the growth had only an inconsequential effect in lowering the price. Results of the same range can be obtained in certain factory products of the concrete industry. It is obvious that the significance of typification in price formation has been considerably over-estimated; the acquiring of a truthful picture requires additional research.

The basic and observable form of a type

In traditional construction there is much manual work, and learning means much in realizing the whole. Industrialised building needs clear assembly schemes which are very easily readable. The variation of assembly—the appearance of different types—does not have a mentionable decelerating effect; four or five elements in an hour are anyway moved to their places (Skarne's heavy system) into whatever kind of an order if their *quality of assembly is equal*. The difference of the components is only in the observable form, but their basic form and their quality of assembly gives similarity in regard to the system. For this very reason, for example, Ford's are able to produce varying units at the same time and automobiles of completely different observable forms. Sub-contractors are geared to producing components fitting the 'philosophy' of the main contractor: they are dimensioned to fit the crane grip of the mainband, their weight fits their capacity of transfer, they have a size that does not exceed a certain volume maximum, and, above all, their quality of assembly is such that it can be easily accomplished in the factory. There are millions of parts that fulfil these requirements—they are independent of the absolute quality of dimensions, but absolutely dependent on certain dimension zones. To understand system construction is to understand the basic form and the observable form of the solution.

The component and system construction

The development of well acting sub-systems is essential to the activity of the main system. It is the part of these sub-suppliers (in one or more production establishments) to deliver an odd number of part solutions that require generally some kind of mould technique, or mouthpiece technique in the future. What is the dimension limit of the moment? Let us take an example from the factory moulds of Skarne's heavy system: the maximum dimension will be 6 meters, dimensions that remain under this are managed by simple limiters, dimensions exceeding this by using two parts. The second dimension of the walls, the thickness, can be freely chosen so that the production of loadbearing and light units as well as the ventilation shaft units can be effected in the same system. The installer, moving between the moulds, may place the electric installations according to a free-selected installation plan. The vertical pipe channels in walls are made with the aid of removable bars; door and window frames are placed in the moulds—the location can be selected freely without modular restrictions. The main trait of the system is its flexibility—an absolute requirement in the development of industrialised building. In industrialised building, the question is more the development of the system itself than the standardisation of the product. After the system has reached some kind of a maturity stage, it detaches itself from the type requirement and becomes applicable in an ever enlarging sector.

System construction and modular co-ordination

In accordance with the aforegoing it is important to industrialised building that production in series is bound to time. Thus "series are made big" and satisfying the requirements of each time period. For the planners this means the developing of some continually improving planning units—concerning town planning, assembly-techniques and equipment etc. These planning units—be they kitchen combinations, bathrooms, standard and additional equipment of dwellings or something else, give the suppliers an opportunity to follow the direction of development. Accordingly they can improve the production system connected with their own sub-supply in such a way that it fits in practice with the main assembly methods. This refinement process may lead to the formation of certain "preferred zones" in dimensioning principles, and from this basis is laid out the possible basis for dimensional coordination. Its necessity in the light of the flexibility of production that already prevails seems, however, questionable. Storage production for example has in practice most probably been proved uneconomical, not to mention that *system construction favors the transfer of components directly from the manufacturing plant to the building site*. The development of machine industry, module-free in its main part, supports a module-free building industry, the activity field of which is uncalculably rich in application for an urbanized community.

Flexibility belongs to the basic nature of system construction, which it tries to improve continually by refining the friction points. The result is a method, the economy of which is almost completely free from the question of type, dimensional coordination and size of series.

Industrialisation of building through standardisation

By H. C. Visvesvaraya (India)

In any developing country housing is needed in practically every field of development—in city improvement, in industrial projects, in river-valley projects, in community development and so on. Specially in a fast developing country like India housing is required in a large scale and at a fast rate and the demands become exacting. The housing needed covers the variety of construction starting from simple houses for the labour and low income groups to large public buildings such as schools, hospitals, and offices. In fulfilling this vast and rather difficult programme, conventional methods are often found inadequate, slow and uneconomical and these methods have therefore to be necessarily supplemented by more advanced methods covering objective overall planning of targets and costs, application of mass production techniques, adoption of new building materials and construction methods and proper organization and management of construction works at site. This at once points to the need for adopting an industrialised approach in building construction which leads to organized production, increased availability of building materials and components, simplified and streamlined construction operations, and the development of the necessary technical skill and construction equipment for speedy and successful execution.

This paper attempts to examine some of the problems of industrialisation in building construction in a developing country like India with special reference to how standardisation activities at the national level can help in assisting and promoting such industrialisation.

Materials of construction

For the success of any programme of construction the basic requirement is the availability of building materials of the right type at the proper time. A developing country faces two serious problems in this regard—on the one hand the large scale constructions and the industrial approach to achieve the targets in as short a time as possible bring with them very heavy demands on materials of construction and on the other the building materials industry itself is developing and so is not capable of meeting the demands satisfactorily. This at once leads to rational utilization of available building materials, exploration and development of new building materials and some times even compromises in relation to proved practices in order to ensure wider absorption of natural resources and maintenance of high momentum in the building construction programme. In all these standardisation has a very important role to play. Given adequate thought and attention these standards could not only ensure wide absorption of natural resources but also provide guidance to the developing industries in achieving a high quality combined with high productivity.

As in many other countries, in India also materials such as timber, steel, concrete, stone and clay products especially bricks have formed the basic materials of construction in addition to the ordinary soil in its various forms.

In the field of timber, the most important aspect to be considered is the rational utilisation of timber resources. To assist in this rational utilisation, Indian standards giving characteristics, properties and availability of 90 species of Indian timbers have been published and attempts are being made to promote by every possible way the use of such species of timber which serve a given purpose and the use of which, at the same time, would reduce the pressure of demand on certain more well known species.

The steel economy programme which was launched over a decade ago and the simultaneous expansion of steel production in the country have gone a long way in helping the building activity in the country. To help in this important programme, a number of standards on materials, design and construction methods and best procedures have been laid down by ISI. The Indian Standard Steel sections—which aim at giving maximum performance characteristics with minimum material content in them—have received international recognition and many countries are exploring the possibility of changing over from the age of old steel sections to these Indian Standard sections as these result in a direct economy of about 15 percent apart from many other indirect economies due to their light weight.

Recommendations specifying strength grading of concrete mixes, rationalized acceptance criteria and modern methods of design have been incorporated in Indian Standards in the field of concrete and these have enabled considerable savings and quick progress. Availability of suitable aggregates in large quantities is often a problem. Since aggregates have to be procured from several sources in this country and methods of quarrying are yet to be developed on a modern basis, the quality and grading of aggregates have to be assessed frequently for proper use. To facilitate this, suitable methods of test have now been standardised. Moreover, in addition to natural aggregates, manufactured aggregates such as blast-furnace slag, sintered fly-ash, burnt-clay aggregates which are being fast developed will also provide additional resources.

For any industrialisation in building construction use of light weight materials and components is essential and fast developments in the production of different types of light weight concretes are taking place and special emphasis on this development is necessary for success in industrialised building construction.

In the use of stones, clay products and soil in various forms considerable technical progress is taking place on both the producers side and the users side.

Besides these conventional building materials, in any industrially progressed or progressing country, the utilisation of industrial waste product requires careful examination. With the large scale industrialisation the amount of industrial waste produced is colossal and a careful examination of its utilisation is called for not only in view of shortage of conventional building materials but also because of the difficult problems presented in its proper disposal. Blast-furnace slag from steel industry, fly ash from thermal power stations, cinder from railway yards and wood waste materials like wood wool, wood particles, etc., from the timber industry are perhaps the most important industrial wastes in this country from the point of view of the building industry. In the development of Indian Standards Specifications for various building materials, the utilisation of these industrial wastes has been given prominent consideration and this has led to formulation of specifications for portland blast furnace slag cement, fly ash for use as pozzolana, lime cinder concrete block, light weight aggregates from blast furnace slag, wood wool slabs and particle boards and a number of other related standards are under preparation with a view to assisting in the optimum utilisation of industrial wastes as building materials.

Dimensional coordination

Any approach towards industrialisation of building construction at once calls for a detailed examination of all aspects connected with building construction; planning studies with special reference to space distribution, construction operations with special reference to productivity at site and rationalised production and use of building materials are a few aspects which become important. But, these have their own limitations since there are certain other aspects which have an important bearing in achieving the desired economy, efficiency and speed in building construction and thus enable the industrialised approach to be successful. One such aspect is rationalisation of dimensions of building materials, components, units and in fact of the finished structures.

Rationalisation is a term which is very difficult to define but in so far as the present discussion is concerned, it is intended to mean application of a principle of simple dimensional relationship by means of a basic unit called "a module" and thus the dimensional co-ordination based on this module being popularly known as modular co-ordination. Ever since Albert Farwell Bemis brought out this important aspect as far back as 1936, considerable attention has been given to modular co-ordination by various countries and in fact this subject was taken up for study by the International Organization for Standardisation as far back as 1949. A Modular Society was set up in 1953 and Project No. 174 of the European Productivity Agency was started in 1954, the first comprehensive report of which came out in 1956 and the second one in 1961. It has now been agreed at the International level that the basic module would be 10 cm in the metric countries and 4 in. in non-metric countries. In India, the basic module of 10 cm was adopted in 1952 and the standardisation movement in the field of building industry is proceeding on the basis of this basic module of 10 cm.

In the practical application of this principle of modular co-ordination one comes across a number of problems but it is not intended to discuss these here for the sake of brevity and specially since details are available in the EPA reports mentioned above. A dimensional co-ordination on the basis of a well thought out and accepted module, such as the one already chosen, would lead to many advantages amongst which mention may be made of the saving in construction time, reduction in wastage of materials, saving in labour involved specially in cutting and fitting of building materials, simplification of quantity surveying, assistance in shop preparation and mass production, reduced risk of damage and consequent loss since many components including doors and windows could be fitted even at a later stage without calling for long storage at the construction site, easier setting out and supervision, greater impetus to pre-fabrication and mechanisation and so on.

Application of the principle of modular coordination by itself may not, however, result in the full economy and efficiency desired. In order to achieve these fully, consideration has to be given to the question of reduction in variety even of those components and units made to modular sizes. This at once leads to the question of selection of preferred dimensions of building components and units and work in this field is at the moment progressing in many countries including India. Many theories for the selection of preferred sizes have been put forward but it will be appreciated that a set of preferred sizes chosen in any form of standardisation would have necessarily to be a result of compromise taking into full account the functional requirements of the unit or the component, statistical or empirical studies of the most frequently used sizes and systematic mathematical series which would enable the largest choice with minimum variety. The following standards have so far been published in this field in India and a number of other related subjects are under our active consideration: 1) IS: 1233–1958 Recommendation for Modular Co-ordination of Dimensions in the Building Industry. 2) IS: 2375–1963 Recommendation for Modular Co-ordination Applied to Reinforced Cement Concrete Frame Structures. 3) IS: 2718–1964 Recommendations for Preferred Dimensions for Storey Heights.

Among the various building materials and components, perhaps the most essential building unit that needs attention for dimensional standardisation at the beginning is the common building brick. The choice of suitable modular sizes for brick has to be examined in relation to existing sizes so that the switch-over does not have undue difficulties in the manufacture and do not lead to extra cost in construction, in the matter of consumption of mortar, quantity of bricks or labour necessary for masonry. After examining all these problems, two standard sizes were specified for common bricks in India, the nominal sizes being 20 × 10 × 10 cm and 20 × 10 × 5 cm* (See Chart 1). Compared to more than 80 sizes which have been prevalent in various parts, if the production potential is concentrated on these two sizes, the facility for production and supply in large quantities should be self-evident. Moreover, in the present practice many of the building dimensions and component sizes are based on the size of brick as module, and introduction of the basic module of 10 cm in brick dimension is an essential step in achieving overall dimensional co-ordination.

Starting with the building brick, modular sizes have now been specified in Indian Standards for several other masonry materials like stone blocks, hollow concrete blocks, perforated bricks, soil-cement blocks etc. It will be of interest to note that except for stone blocks there are in all only 8 standard sizes to which the masonry units have to be manufactured. Dimensional standardisation based on modular sizes has also similarly been extended to flooring tiles, building boards and flexible coverings for flooring and waterproofing. In the case of building boards the sizes are in multiples of 30 cm.

CHART I. Comparison Between Modular Size and Existing Size Bricks.

Characteristics	Modular Size	Existing Size*
Nominal Size	20 × 10 × 10 cm	9 × $4\frac{1}{2}$ × 3 in.
Actual Size	19 × 9 × 9 cm	$8\frac{7}{8}$ × $4\frac{3}{8}$ × $2\frac{3}{4}$ in.
Net Volume	1 500 cc	1 750 cc
Number of Bricks per sq. m of wall, 1-brick thick	100	114
Mortar Consumption		
per sq. m of wall, 1 -brick thick	36 dm^3	45 dm^3
per sq. m of wall, $1\frac{1}{2}$-brick thick	59 dm^3	75 dm^3

* Only one of the predominantly used sizes is considered. Another size 10″ × 5″ × 3″ is also used over a large part of Eastern India.
dm — decimetre.

Another important field where dimensional standardisation has to be applied relates to door and window sizes. The sizes for various types of doors manufactured in this country range between 60 to 110 cm in width and 190 to 230 cm in height; for windows between 50 to 220 cm in width and 60 to 220 cm in height; and for ventilators between 50 to 110 cm in width and 50 to 70 cm in height.

Doors and windows form an important group of assembled components and, if produced in mass scale and supplied for ready erection at site, would save considerable time and labour in building operations. Also a variety of materials like timber, precast concrete, steel, aluminium etc., have to be depended upon for manufacture of these components and production to as many common sizes as possible and to limited variety of sizes would improve their supply for large scale house construction.

Streamlining operations

For streamlining construction operations and also to lay down systematic approach to time scheduling, it is essential to develop basic norms regarding productivity of various construction items in the building industry. These norms not only cover field operations but may be extended even to design and drawing practices. Such norms are already developed and adopted by various construction agencies in this country, but not in as scientific a form as experts in work-study would consider it should be. Moreover, it is often found that even in the same locality the norms for output differ with different construction agencies and there is need for unification. For a scientific study of the outputs for various trades through work-study techniques the essential operations in each item of work have to be followed clearly and standard Codes of practices provide assistance in this respect as they cover all the essential operations. Once the output standards are established, the times for each building operation could be predicted and various operations fitted in the time schedule so that the whole process of building construction progresses smoothly without interruption between different trades.

Use of mechanised equipment. Industrialisation requires introduction of mechanised equipment in building operations for speedy execution. However, the types of machinery that have to be developed and supplied would depend upon the types of jobs and sizes of material to be handled and also the technical skill available to handle the equipment. The types of machinery available should also allow for flexibility for choice. For instance, in the construction of a large number of single storeyed houses, the equipment more suited for handling these materials would be lift trucks or mobile cranes whereas in the construction of multi-

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* The actual sizes will be 19 × 9 × 9 and 19 × 9 × 4 cm respectively and the nominal size allows for a mortar joint thickness of 1 cm.

storeyed buildings in a compact lay-out, use of a tower crane would be more suitable. The machinery have to be simultaneously developed with the building materials and components and considerable judgement would be necessary to develop the proper type of equipment in the initial stages, these are most suited for the types of materials to be handled and situations of use.

Prefabrication. In some countries, prefabrication using building components of large sizes has found a certain measure of success and finds extensive application in industrialised building construction. However, the adoption of prefabrication in a similar way in developing countries like India may not have the same degree of success due to non-availability of handling and erection equipment, inadequate transport facilities, dispersed demand as against the desirable concentrated demand, and the relatively easier availability of human labour. However, as a gradual step, the improvement of the manual methods of construction with introduction of simple construction equipment would largely improve efficiency and productivity and as industrialisation gets greater hold into the set up, equipment for handling large prefabricated components would be automatically introduced. The components to be handled could be smaller in the initial stages as experience of concrete component manufacturers in this country has shown and partial prefabrication perhaps finds the best answer to meet the situation. As against complete prefabrication, partial pre-fabrication presents a number of advantages in a country like India in its present state of development. Partial pre-fabrication paves the way for subsequent full pre-fabrication when the situation becomes conducive to this. Partial pre-fabrication enables optimum utilisation of human skill along with mechanised methods. In the weather conditions met with in this country, where the characteristics of the external walls become important, the use of building materials such as clay bricks, which have stood the test of time could continue until such time as alternative types of wall panels and cellular concrete in between are proved to provide the desired performance characteristics. Moreover, it is now fairly well established that in a large number of situations composite constructions such as those adopting precast concrete in combination with cast-in-situ concrete and other types of composite constructions such as steel and concrete, concrete and timber, concrete and structural clay units and so on have a definite advantage over the conventional methods of construction and partial pre-fabrication has the advantage that it allows these techniques to be fully adopted without difficulty.

Functions of the building

Since industrialisation would generally be applied to situations where building has to be constructed in a very large scale and also in a continuous process, it will be appreciated that changes in design cannot be as frequent as in the case of individual construction and also they should be in line with the scheme of replacement and maintenance of such buildings which is generally possible for adoption. Therefore, a closer appreciation of the functions of building in relation to several aspects such as stability, expected life, waterproofing, insulation, ventilation, fire protection etc., are very important for the proper design of an 'industrialised building'. Standards dealing with such functional requirements also give a large amount of guidance with regard to the needs for various local conditions and contribute to the success of industrialised techniques.

Conclusion. For conditions in a developing country like India, the steps for industrialisation in building construction will be the following:

- availability of materials should be improved and standard specifications for building materials at the national level should pay attention to the utilisation of a wider field of resources including industrial wastes;
- recommendations in the form of standard guides on dimensional coordination on the basis of a module should well precede any intensive industrialisation of building construction. In the formulation of a specification for any building material, component or unit the question of dimensional co-ordination requires special attention; dimensional standardisation at once leads to a careful study of the tolerances on dimension which in turn leads to a detailed examination of the manufacturing and construction practices. Preferred sizes, with a view to increasing productivity by reducing variety should also be arrived at if the industrial approach in building construction has to meet the full degree of success;
- codes for various items of work need speedy formulation to facilitate organizing the building trades. This will also help in establishing proper norms for output on a unified and widely acceptable basis;
- for situations where industrialisation is needed, but advanced prefabrication techniques would not be possible, introduction of prefabrication in gradual steps in partial combination with traditional materials and components, and also introduction of composite construction techniques would be necessary.

Acknowledgement

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Development of the UNICOM method of house construction

By J. I. Zerbe (U.S.A.)

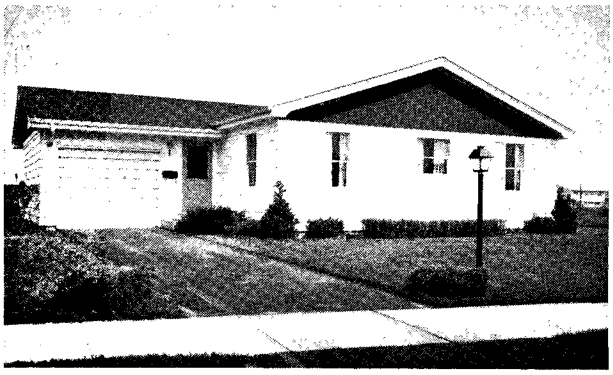

Fig. 1. One-story UNICOM house constructed in Wheeling, Illinois (USA).

Modular coordination of frame house construction, as practiced in the United States of America and which is becoming increasingly popular in many other countries, is made easier with an engineered modular building standard which has been available to the building industry since 1962. The method of construction is termed, "UNICOM", to indicate that it provides a uniform basis for the manufacture of components. It is proposed as a standard for manufacturing factory-built as well as on-site assembled homes.

UNICOM design standards are treated in a 124-page manual of design principles, 16,000 copies of which have been distributed throughout the world. This book shows how timber in sizes readily available from American sawmills can be used with minimum waste in the construction of houses of the popular types, which include 1-story (Figure 1), 2-story (Figure 2), 1½-story, bi-level and split-level types. Types of plans with combinations of rectangular shapes, such as L plans, T plans and H plans, are readily accommodated. Roofs are generally standard gables with or without hips, but they may be shed, flat or butterfly, and standard designs for dormers in the roofs of 1½-story houses are provided.

A second manual on UNICOM has been published recently and 5,000 copies have been distributed. It contains 248 pages of fabrication information with detailed descriptions of parts used in the manufacture of standard floor, wall, partition, stair and roof components.

For purposes of detailing framing member spacing intervals and the location of window and door openings in basic house plans, the 4-inch (10 cm) module unit is expanded to 16-inch (40.6 cm), 24-inch (61.0 cm) and 48-inch (122 cm) planning units. The modular exterior overall planning dimensions are held to multiples of either 24 inches (two feet) or, preferably, 48 inches (four feet). These dimensions are based on "out to out" measurements, i.e., the overall measurements are taken from the outside limit of one side-wall or end-wall foundation to the outside limit of the corresponding opposite side-wall or end-wall foundation.

Fig. 2. Two-story UNICOM house constructed in Des Plaines, Illinois (USA).

The UNICOM planning module is simplified with the use of a standard printed grid paper (Figure 3). All exterior elements are made to conform quickly and easily to standard horizontal dimensions and locations through adherence to the guide lines by the draftsman. Coordination of framing members in accordance with modular framing members results in the cleanlooking regular sequence of wall studs shown in Figure 4.

Vertical elements are also standardized insofar as possible. Thus, wall heights from rough floor to rough ceiling are set at 8′ 1½″ (2.48 m) for first floors and either 8′ 1½″ or 7′ 7½″ (2.32m) for second floors. These rough dimensions result in even floor-to-ceiling heights of 8 feet (2.44 m) or 7½ feet (2.28 m) when a ¾-inch (1.90 cm) thick finish floor and a ¾-inch thick finish ceiling are used.

Height to top of trim above windows and doors measured from the top of the rough floor surface is held to an even 7 feet (2.13 m).

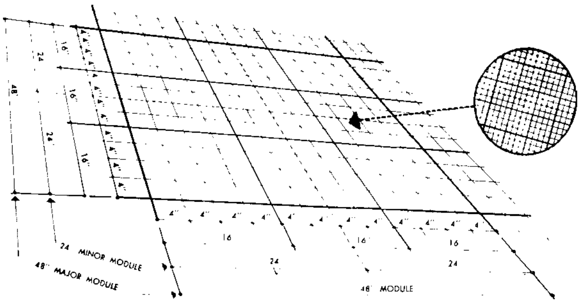

Fig. 3. Standard UNICOM grid.

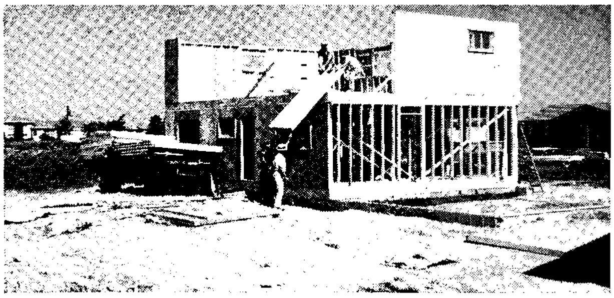

Fig. 4. Regular modular sequence of wall studs in a UNICOM house.

Slopes of gable-type roofs vary from pitches having a rise of two inches in a 12-inch run to a rise of 12 inches in a 12-inch run, but there are no fractional runs such as 2½ inches or 3½ inches. Roof framing members are often trusses as in Figure 5 but they may be the conventional joist and rafter type.

Floor framing for UNICOM houses is characterized by in-line placement of load bearing members shown in Figure 6 as opposed to the more common overlapping of joist ends where they bear on a girder at the center of a house.

Stair treads and risers are standardized according to floor-to-floor heights and depths of the structural portions of the floor.

Interior position framing is standardized to specified heights, but partition lengths may vary in 1/16″ increments. It was necessary to permit these non-modular lengths in the design scheme because wall thicknesses are non-modular when common types of finish materials are used on wood studs. Complete coordination of interior partitions may be accomplished by using a system of modular units plus filler units. Fillers are necessary for 30 or more partition intersections that involve thickness and assembly tolerances in the average small house.

Opportunities for further unification in house design exist in other interior components, which include storage units, kitchen cabinets, bathrooms and fireplaces.

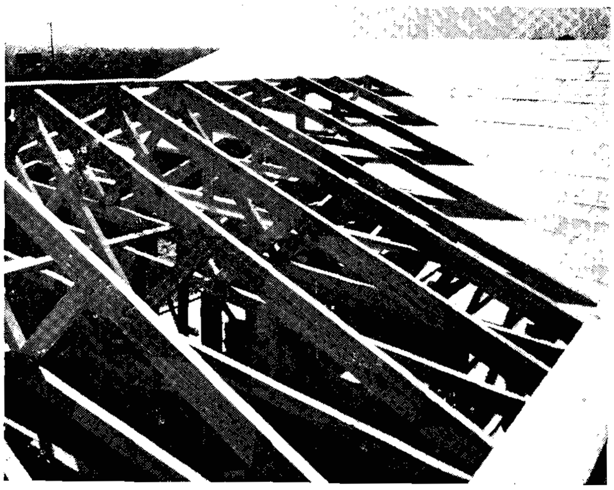

Fig. 5. UNICOM roof framing showing standard full span trusses meeting standard valley trusses in an L-shaped house.

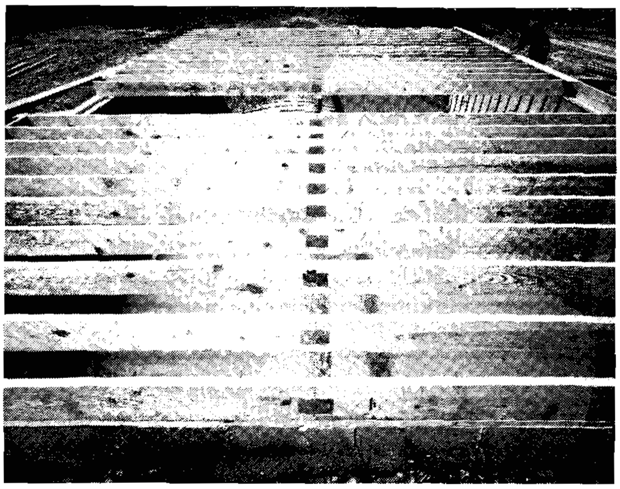

Fig. 6. In-line floor joists spliced over a central beam in a UNICOM house.

Since its inception, UNICOM has been adopted in its entirety or to a large degree by about 150 homebuilders in the United States. Use of standardized modular components has resulted in savings in homebuilding through reduced inventories, more efficient utilization of labor and elimination of material wastage. However, the greatest savings are still to come with a wide-scale adoption of the system and more general availability of windows and doors which are factory-fabricated to the UNICOM module. Another future refinement may be the programming of all standard components for computer use in quickly providing cost information for construction of houses which have been designed according to the UNICOM module.

Group F
Production Methods

Final report from the group rapporteur G. Blachère, Director of the "Centre Scientifique et Technique du Bâtiment", France.

In group F, Production Methods, the greatest number of papers was presented. Accepting also that more than 10 reports presented in other groups referred entirely, or in part, to Production Methods, a total of some 50 papers touched on this subject.

I am pleased that the rules referring to maximum length of papers were imposed. In this way it was easy enough to read such a large number of documents, and it is certainly possible to say in two pages whatever one has to say. Nonetheless it should be realized that even 50 papers are insufficient to encompass the whole of a subject such as Production Methods in Building, even when considered only under the aspect of industrialisation. Perhaps we missed having a sufficient number of reports of a widely based view, which would have provided foundations for the different parts of the subject. This might be considered as a lesson for any second application of the very valuable system of having numerous short reports.

If the title of this group was Production Methods, it is evidently necessary to take that title in the light of the general title of the Congress "Towards Industrialised Building". This title itself will be illuminated if one remembers that initially it was to be "Towards More Industrialisation". What we should wish the subject of the Congress to be is not the actual situation to-day, but the trend, the flow, and at the same time the trend from that flow, the acceleration of the transformation of building into an industry.

This vision was not always kept in view in the writing of the papers and the indication of trends did not often appear except in the concluding paragraphs of the reports. The discussion, particularly on the future of open and closed systems, was more devoted to considerations for the future.

The number of papers dealing purely with factual description of a production method already in use was high. However, although such descriptions are numerous, they are still insufficient to give a complete documentation on all methods, even on all types of methods. In the discussion these were rightly neglected, because this Congress did not have the aim of providing a platform for description of methods since such descriptions must always have a slight flavour of commercialism.

Mechanisation, a main trend

If one considers, as I maintain, that industrialisation of building is made up of the rationalisation of everything which makes up a construction, as well as the mechanisation of the realization (pending mechanisation of planning), it is clear, and reading the reports confirms this, that Production Methods intervene in industrialisation particularly on the mechanisation side: the replacing of manual labour, whether specialised or not, by machines, whether they are transporting machines or erecting machines, whether they are large size forms in factory, or large size forms on the site, or whether they are other kinds of machines for light weight materials.

At the root of our work an established fact was evident; the triumph of mechanisation.

If 6 years ago in Rotterdam numerous opinions put in doubt the efficacy of mechanisation and proposed to limit industrialisation only to rationalisation, in Cambridge the defenders of nonmechanisation were less numerous. However, to-day mechanisation is an established fact in all industrial countries. We saw Mr. P. Misch (F.22) (West-Germany) make some excuse for having to treat the evolution of traditional methods.

This situation is cause for satisfaction for those who have been for more than 10 years the champions of mechanisation under its different forms.

The clear cut grouping of West Germany and the United Kingdom, coming now to join France, the Scandinavian countries and Eastern-Europe, is due in each particular case to the increasing scarcity of qualified manual labour in building, and/or to its increasing cost.

During this Congress we again heard doubts expressed on the use of mechanisation when it is applied in construction in developing countries. I feel that these doubts will be swept away in turn as soon as construction in these countries is truly adapted to the rhythm which is necessary. We have won our bet in the industrial countries and we hope to win our bet also in the developing countries.

Mechanised systems of construction are used not only for the building of individual or collective housing but also, and for a long time, for industrial buildings or public buildings (papers by Mr. Gluckovski, F.10, Mr. Gorbuschin, Lazarewich, Skorov F.11, Von Halasz F.13, Kartashov F.19); for school building mentioned here by the reports of Mr. Grosgurin (F.12) and Mr. Ward (F.34), as well as for agricultural building. It is very interesting to notice in the report of Mr. Heckl (F.14) the following statement "Prefabrication is indispensable in agricultural building; how can it be done profitably despite the wide dispersion?"

System building has an interest also for services. We have an example here in the paper by Mr. Gabrielsson (C.6).

But circumstances do not always allow, at least at present, for complete mechanisation; many authors recommend therefore partial prefabrication. This can be done on site and brought into craft processes: paper by Peer (F.26) or on otherwise mechanised processes; paper by Mr. Canqueteau (F.4).

If is felt today that there is no longer any doubt that more industrialisation is synonymous with more mechanisation it may be asked what is the best setting for giving more mechanisation?

Open or closed system production

Up to the present, systems of construction applying the most elaborate mechanisation, and practically the only ones also where prefabrication provides finished elements which need only to be brought together for simple assembly, are those systems where elements are fabricated for use by a known builder; the elements are fabricated with a view to their use in a known operation; this is what is known in France as the *closed system.* In the West one can say that it is mechanisation by the builder.

However, prefabricated elements can be elements in large series, heavy or light, made in the factory and sold by catalogue; this is the *open system* of prefabrication, where the product may either suffice to be used in all types of building, or associated with traditional methods or associated with system building (in general giving the main parts of the building).

I have given (F.3) some thoughts on the consequences of the open system on design and integration. At the invitation of the President of this group, Prof. Mazure, the discussion in our group was devoted to the following point:

"Should one take it that open prefabrication for the catalogue and closed systems oppose or that they complement one another". The subject had already been touched upon in numerous contributions.

Triebel (F.33) studied the field of application of 4 methods of prefabrication which he distinguished, Barets (F.1) presented an original combination of open and closed, Von Halasz (F.13) distinguished the tendency to pass from individual production of prefabricated elements to the production of element types, Holbeck (F.16) drew attention to the existence of two types of production, Kartashov (F.19) proposed typification of parts of building rather than of elements, particularly in industrial buildings, Parkanyi (F.25) noted the contradictions which were apparent in the evolution of closed systems and held out for a "Meccano" system, Rachenov and Miss Tanova (F.27) drew attention also to the limitations of large panel systems and sought a solution in another system.

Plessein and Rozanov (F.28) in their very comprehensive paper on the actual situation of the large panel industry in Europe mentioned the problem particularly noticeable in Europe at the present time where the greater part of element manufacturers are also the assembling building enterprises, but also the other formula exists and in all cases element manufacturers use components in large series which they have bought from industry. Susnikov (F.30) implicitly pronounces in favour of the open system. Burgess (E.3) reports a study on the use of listed elements. Hutcheon and Kent (E.4) note that up to the present they particularly notice closed systems and are not very clear how the open system can come into existence. Finally Charrière (G.2), talking about the use of prefabricated elements based on the use of clay blocks, notices that in the future the open system will particularly gain ground, its development being easier in directed economies.

The discussion brought out again the necessity for a good definition of the words open and closed, terms to which it appears one can give a different connotation in English and French. When we come to put it exactly the distinction is:

Prefabrication of elements by order for a project already planned, and a client already known, who is usually himself the manufacturer: a closed system.

Elements produced without knowing who will use them and without knowing in what project they will be employed, offered in the market through catalogue: an open system.

There can be an endless number of closed systems. They are relatively easy to set going since the person who makes them is the person who will use them and there is no quality problem for the sold product. Intended for a known project they are made to required dimensions, which can be several. But the element production in series offered through these processes is small.

On the other hand in a national or multi-national determined market there can only be a limited number of open systems and it is ultimately preferable that there should be only one. The open system is made up through grouping together industrial producers, project planners and commercial users, all accepting common regulations which define quality (i.e. the "agrément") and dimensions (i.e. dimensional coordination).

Many speakers adopted contradictory points of view on the advantages of one or another system, with regard to freedom of expression. It seems true to say that in the closed system freedom of expression is on a different level depending on whether the control of the system rests with the architect or with entrepreneur. French architects expect more freedom of expression in the open system than in closed systems.

The future makes promise of the coexistence between closed systems and the open system, the latter offering possibilities of production in larger series, but unable to assert itself unless there exists a technology of production capable of taking advantage of these longer series. The manner in which the evolution will take place has not been determined in a clear way: the question whether there will be a deliberate effort to create the open system, or whether this will result from development of the closed system, was answered differently. Very clear thoughts were expressed by Von Halasz (F.13) who stated that one moves from specific production to type production (as also from satisfying separately the functions towards integration.)

Industrial production and flexibility

Another problem has been dealt with in numerous reports and became the object of considerable discussion; this was the problem of freedom of expression and adaptation offered by various mechanised systems, or the problem of flexibility.

Some compared the solution given by skeleton framework (i.e. load bearing framework), with that provided by load bearing walls. Gerholm (F.9) in order to satisfy the need for adaptability in the characteristics of buildings, excluded the less durable system of construction and chose the adaptability which he proposed to realize by structural framework.

Wadowski (G.17) adopted the same philosophy under the name of partly durable construction. It should be noted that Von Halasz (F.13) in examining the economic aspect of the problem decided to replace skeleton construction (framework and beams) by slabs and shells. Walley (B.20) sub-dividing the main structure with a view to prefabrication adopted the skeleton framework. This was also the solution chosen by Rachenov and Tanova (F.27) with a particular system of poststressed floors and columns.

Adaptability is sought also in augmenting span dimensions whatever their role in the construction. The same authors (F.27) envisaged spans of 720 cm for dwellings (longitudinally). Flexibility in industrial building is also sought through the use of spans of large dimension (Gluckovski F.10, Von Halasz F.13, Huygue F.18).

This search for flexibility and adaptability leads on the one hand towards the use of large spans and consequently substantial structural parts and on the other hand to prefer to the use of load bearing walls, the use of skeleton framework which itself does not appear to be economically competitive.

In the discussion we heard some optimistic bell ringing: there is no contradiction between flexibility and economy, Lupan told us, because in the long run flexibility provides economy. On the same topic Roc thought that flexibility and economy should be obtained together.

Examples were given of preconceived ideas with regard to flexibility in Belgium e.g. where public buildings are designed on the basis of planning supporting elements, spaced out, and incorporated in the elevation or in the central core.

Listening to so many people advocating the necessity of flexibility, Bergvall asked whether such rigid solutions which to-day make up industrialisation are erroneous.

In effect the debate was not so conclusive as it should have been; the matter was only touched upon. Nothing was sufficiently well delineated, neither the increased cost of obtaining flexibility nor the economies obtained from flexibility. The very need of flexibility is still somewhat theoretic since there are few examples of recent buildings which have been converted to other uses. It would appear that it is necessary to be prudent for the moment and make this problem the subject of study.

Technical evolution

A third theme obviously needed consideration by a group dealing with Production Methods and this is, in precise terms, the technical trends and the evolution of methods. Reading the reports one conclusion became evident; if one sees methods of mechanised construction gaining weight in production they are essentially the same over the last 10 years: large moulded elements, in place, on the site, have been made in the factory for 10 years. Timber prefabrication is even more early, and Production Methods are not so much different in detail. We may cite here several wellknown processes which were reported: Barets (F.1), Bergvall and Dahlberg (F.2), Canqueteau (F.4), Choulev and Kovandjiev (F.6), Gluckovski (F.10), Tchrosgurin (F.12), Huyghe (F.18), Orr (F.24), Susnikov (F.30), Zerbe (E.11). Bergvall and Dahlberg (F.2) showed a system based on the use of cellular concrete panels with modular dimensions, Fisac (F.7) showed a small closed hollow element; Parkanyi (F.25) proposed the use of standardised lost casing in gypsum. Siestrunck (F.29) suggested that manufacturers of ceramic materials should take an interest in using their products in increasing overall productivity. Ladijensky and Ward presented during the session systems which are new or little known in Europe.

A co-ordinated view of large panel technique was given in the report by Plessein and Rozanov (F.28) which described the tendencies of the evolution of the technique, notably: the increase in panel size to dimensions of 2 or 3 rooms, an experimental study on 3 dimensional prefabricated elements and complete mechanical finishing of elements. In the same sense, Herholdt (F.15) mentioned gliding shuttering. Plessein and Rozanov (F.28) insisted on vertical casting "en cassette" which Choulev and Kovandjiev (F.6) described in detail. Gliding shuttering and "cassette" techniques are used to solve a problem which can become very important, the finishing of the two panel faces without the necessity of having a skilled worker smoothing them. Gorbuschin, Lazarewich and Skorov mentioned the introduction of fabricating large panels (see also Plessein and Rozanov) in vibro rolling on the one hand or movable forms on the other hand. This method was also described by Howell (F.17), and the aim pursued is a saving in manpower.

The problem of making perfectly finished concrete elements without the necessity of using qualified labour is a very important problem for the future of large concrete elements: if it is not resolved, the constant increase in cost of labour will render large panel systems less and less competitive. It will be no surprise that this very technical problem was not discussed to any great extent within the scope of this Congress, but it is a question to be dealt with within the group which deals with large concrete elements, CIB Commission W19, as is the case with the examination of the trends noted by Plessein and Rozanov, and others equally mentioned, such as the concentration of production units, the unification of techniques of production of different kinds of elements or the production of elements to serve different functions.

Technology of production for the open system formed the subject of only a few reports: besides wooden elements which were dealt with in various reports, it is necessary to mention the production of partitions e.g. prefabricated brick partitions (Charrière G.2) and the study of Burgess (E.3).

We should note well that with the open system it is all parts of industry which can provide elements for the building and that all the technologies which allow the production of elements of large dimension can make a contribution: injection, casting, extrusion, pressing etc. This will be most advantageous for building but the technicians developing these methods of production are not "people in building" but specialists in their own discipline.

Other aspects of industrialised production

The group considered the question of the choice of cranes and the organization of assembly through two complementary contributions from Gavev (F.8) and Obretenov (F.23). These two contributions were concerned with obtaining the optimal utilisation of machines. It is a point of view. On the other hand one could take the opposite point of view; optimal utilisation of labour. The correct view without doubt is the optimal utilisation both of machinery and labour, a solution which depends on the cost and the relative scarcity of one or the other.

The establishment of factories for the prefabrication of elements forms the object of two reports, from Komoli (F.20) on the determination of the area to be served by a factory, and by Szukszta (F.31) applying linear programming to the choice for the location of a factory as a function of the location of construction projects, of natural resources and of facilities for transport. Barets (F.1) described the use of transport by cable to an assembly site.

Numerous reports alluded to the problem of tolerances. But this problem had more relevance to the competence of other groups than this one.

Calculation of industrialised constructions formed the subject of two reports, one from Kositsyn (D.4) showing the principals of calculation for newly developed structures and giving as an example large panels, the other from Lewicki (F.21) on the calculation of large panel constructions. The calculation of this type of construction has made considerable progress in recent years and is studied by various international bodies, in particular CIB Commission W23 and the U.E.A. tc.

These last subjects are in fact considered in working groups rather than in a Congress.

Economic problems were considered in numerous papers. One knows how difficult it is to make comparable economic analysis. It is all the same curious to note that if the papers give figures they do so without saying precisely to what particular dwelling the figures apply. Evidently the documents which we have here are not those which will give a solution to the problem of comparisons.

Among the figures given however one should note:

The figures of Barets (F.1) on the proportion of sitework, in relation to factory work in prefabrication in the factory: floors 0.20: facades 0.59: load-bearing walls 0.73.

Gorbuschin, Lazarewich and Skorov (F.11) on the proportion of sitework in relation to factory work, overall: 1.51 which is much different to the preceding figures. The same authors give 3.90 h/m^2 for construction by large panels against 6.50 h/m^2 for brick construction (for the bearing-structure probably).

Herholdt (F.15) gives 755 h per dwelling in large panels against 1800 in traditional construction.

Meanwhile Triebel (F.32) gives the following figures:
on site: preparation 1.8 to 2.5
assembly 1.5 to 2.0
finishing 4.7 to 5.5
total 8 to 10 h:
In the factory: 5 to 8 h. which makes a total of 15 to 16 h. against 20 h. to 22 h. in traditional construction.

We should note, moreover, the figures on prefabrication of elements on the site given in the paper by Peer (F.26) where he deals with the comparison of different systems of casting large panels, which shows the advantage of the "cassette" or the immovable horizontal mould over the movable mould for facade and wall panels, and the figures of Collardet (F.5) on different wooden elements and prefabricated individual houses.

But all this is not as convincing as it would have been if one had always taken care to indicate precisely the nature of the work or of the constructions to which these figures apply.

Towards rationally chosen quality and economy of production

In France we use an extremely simple method but apparently very effective for assessing the essential parts of buildings of equal composition, and to deduct also how large is the variety in prices and costs, this latter variety being due both to differences in the intrinsic costliness of the project as well as to the differences between conditions on site and in the firms. The conclusion to be drawn from the specification of these varieties is that one cannot draw any economic conclusion except on the basis of consideration of numerous operations.

The papers presented and the discussions did not permit a total coverage of the immense field contained within the title of the group Production Methods, but it did allow to reveal considerable unity of opinion between all participants whatever their profession. We have the impression of a growing collective conciousness in all those involved in building who are leaving empiricism and are moving towards a way of solution to the problem of building which is rationalised and industrialised, those people who together form "building, new style".

Only Hill (F.4) has reminded us that the progress in methods is based on research. This necessity of the knowledge of phenomena as support to the invention of new solutions is not yet perhaps very wide spread. Nonetheless we advocate it here as the idea which must in the near future impose itself on "building, new style".

An example of heavy prefabrication at high altitude

By J. Barets (France)

This is a report on construction of an entire ski resort at high altitude under very particular conditions and for which it was decided to use total prefabrication, by the Barets system. Aside from a description of the chief features of this operation, we shall attempt to demonstrate how prefabrication makes possible satisfactory fulfilment of particular requirements, due to the altitude as well as to the difficulty of approach of the work site, the severe climatic conditions, the time limit, and the operational conditions of the ski resort.

This work, whose realisation will require several years, was begun under the direction of the Société d'Etudes de Participation et de Développement (SEPAD), which had engaged the following technicians:

Bureau d'Etudes et de Réalisations Urbaines (B.E.R.U.)
Messrs. Marcel Breuer and Robert Gatje – New-York – architects
The Atelier d'Architecture at Courchevel
Mr. Laurent Chappis – architect at Chambery
Messrs. Gérard Chervaz and André Gaillard – Geneva – architects and La Compagnie Française d'Engineering Barets – Consulting Engineers.
The first contract unit was turned over to Entreprises Boussiron.

Construction Program

The utilisation plan for the mountain area between Arve and Giffre is based on an installation capacity of about 10,000 beds. The Flaine resort constitutes one unit of this plan, about 5,000 beds. The resort itself may be subdivided into units of differentiated level and purpose, including various categories of hotels, flat buildings, commercial and service installations, administration and housing units, station for the mechanical skilifts and, finally, a collective boiler unit.

Site and access

The site chosen is in the French Alps at 1,600 meters altitude. Road access from the valley to the ski resort involves these difficulties:

- a pass at 1,900 meters altitude, thus bringing the total difference in level to be crossed to: (1,900 – 500) + (1,900 – 1,600) = 1,700 meters,
- negotiating slopes of 8%,
- width limited to 5 meters on some old stretches,
- height of overall dimensions limited to 4.30 meters because of passage beneath a rocky overhang,
- road conditions ruling out intense traffic of heavy vehicles.

These conditions made it necessary to:

- reduce the tonnage to be carried,
- find another complementary means of transportation.

Climate

No need to point out the climatic features peculiar to high altitude: low temperatures and, especially, sizeable snow fall. As a result, a calendar year includes scarcely six possible working months in the site, these comprising a "campaign". Even so, each "campaign" must necessarily begin with a "priming" phase snow clearance and the reassembling of equipment, and end with a "withdrawal" phase prior to hibernation, shoring up certain parts of the construction exposed to excess weight of snow, and disassembling and removing part of the equipment. It was essential then to achieve the highest possible rate of construction on the site.

Effects on labour

In addition to the cold and to the snow, which make any outdoor work practically impossible for six months of the year, the altitude has physiological effects on the workers, whose output is less. Furthermore, the difficulty and duration of transport force all workers to lead a closed communal life which is undoubtedly more isolating than in the valley. Two reasons, therefore, for reducing the number of men working on the site as far as possible.

Operational conditions of the resort

The construction rate requested was 500 beds per year. Although "the snow market" is still relatively open, the competition among resorts led the client to open his resort, even in a partial state, at the earliest as soon as a first autonomous phase had been completed, and in so doing to lessen the intercalary interest on the sums invested.

Construction work had therefore to be carried on while the resort was in operation, yet with only minimal interference for the tourists. It was necessary for this reason to cut down site installations and workers housing, and to prevent transportation to and from the construction site from hindering tourist travel by road.

Choice of prefabrication

Within this framework of requirements and special factors, the conception of working conditions stems from the choice of the most complete prefabrication possible, starting from a factory set up in the valley and using cable transportation.

Transportation

This solution reduces transportation needs only to those materials effectively worked and avoids the transportation of timber shuttering and of most shoring and scaffolding equipment. We have calculated that each annual program corresponding to 500 beds represented roughly 22,500 m^2 of covered surface, in the following breakdown:

- 21,000 m^2 of flooring
- 9,000 m^2 of load bearings walls
- 7,000 m^2 of facade panels
- 6,000 m^3 of other panels, such as balconies, stairs, cornices, etc.
- 3,000 m^3 of concrete cast in situ
- 2,000 m^3 of masonry and materials all being prefabricated.

Rapidity of execution

At high altitude rapidity is most necessary for the assembling and joining of prefabricated panels, jobs which can be done only during the six months' annual "campaign", whereas the prefabrication of panels in the factory can, if necessary, be continued all year long, provided that sufficient stock area be available.

Labour

Prefabrication permits the reduction of labour needed on the site, insofar as superstructures are concerned, to the assembling teams only, as seen in the following table, which shows the ratio of man-hours needed for a given type of panel in the factory and on the site:

Man-hours ratio required

Elements	Factory	Site
Floors	1	0,20
Façades	1	0,59
Walls	1	0,73

It should be noted in addition that the total of manhours in the factory plus manhours on the site is far below the total required on a site with traditional construction methods. The result is therefore a sharp decrease in the labour employed on the site, with a resultant economic gain, since the labour in question is more costly and the output less good. Also, indirectly, the cut in labor determines the number of housing units, which constitute a hindrance to the operation of the resort, as well as the tonnage to be transported.

Conception of prefabrication

The decision to prefabricate influenced the conception of the buildings. On the one hand, as is well known, prefabrication in a factory, if it is to be reasonably profitable, requires the production of series of identical panels. On the other hand, in this particular

J. Barets

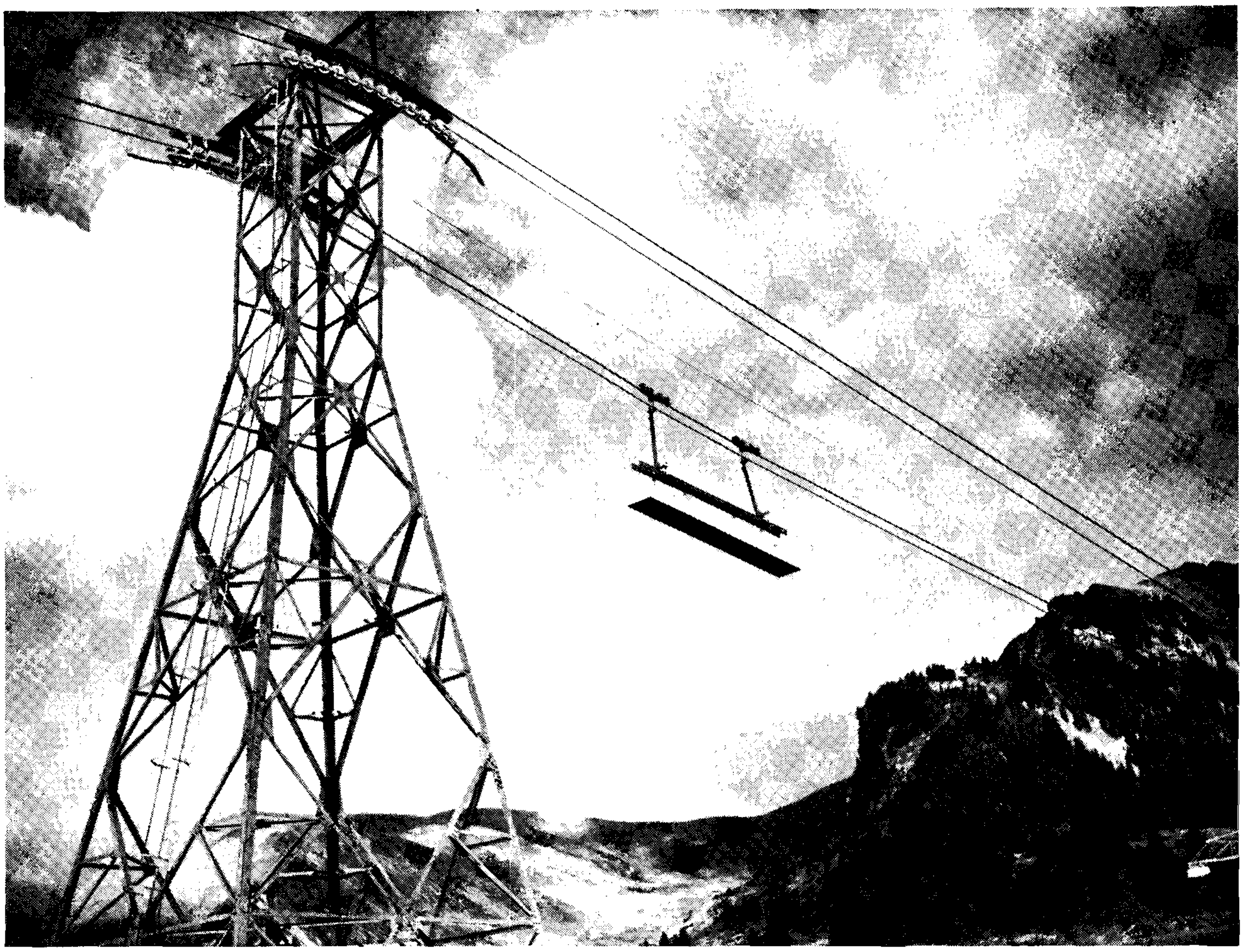

Fig. 1. Transportation of prefabricated element by means of cable.

case – the construction of a ski resort – there could be no question of settling for the debatable monotony seen in some instances of large building complexes.

The architect, working in liaison with the consulting engineers, was able to determine a certain number of normalized panels, capable of being rather freely interchanged, so as to construct different buildings with stylistic unity, based on standard panels. In practice, the prefabricated panels were determined on the basis of a few buildings making up roughly one tenth of the total, with the idea of systematically re-employing the same panels for the buildings to come. This was a gamble, but whose advantage is that it leaves the architect complete liberty of functional conception, all the while not exceeding the economic conditions of prefabrication. For instance: the complex forms of the façade bands were broken down into a small number of simple panels whose different possibilities of assemblage make for a considerable variety of forms.

The principle of prefabrication was extended to everything but the foundations. For the heavy beams and columns of visible structure, shells were prefabricated, in order to avoid shuttering on the site and to obtain the same appearance as the prefabricated panels. From the aesthetic viewpoint, factory prefabrication gives raw concrete panels a high degree of finishing and excellent regularity. The architect expressed this perfectly in his design by means of systematic use of raw concrete in even complex forms.

Organization of prefabrication

This is not the place to describe in detail the prefabrication installations, since they are in many ways quite classic. We should simply like to point out certain consequences of the conditions peculiar to this job and certain original solutions. Panels are prefabricated in a factory set up in the valley, stocked at the factory exit, carried to a point near the site by a cable, where they may be restocked, and finally assembled at their place in the construction.

The prefabrication factory

This factory in the valley is placed very near the road and the railroad, facilitating the use of these two means of transportation. It is also in proximity to the ballast-pit for the extraction of aggregates.

Its location in the valley also facilitates the recruitment and housing of labour. At an altitude of 500 meters, physiological working conditions are just about normal, and are made better by the conditions which obtain in a closed workshop and the relatively steady rhythm of production over 12 months of the year. The prefabrication moulds are metallic and the concrete is heated by the Joule effect by means of isolated electric resistances embedded in the mould and in the concrete. Outside of the "campaign" period, the factory produces solely for stock purposes, which called for a very sizeable stock area, placed between the factory and the lower starting point of the cable.

The result is two possible working cycles:

- an optimum cycle, continuous, feasible in the summer; panels are lifted directly to the site to be assembled without having to be stocked, which cuts handling to a minimum.
- an interrupted cycle, with stocking below the cable and if need be, a second stockpile at the upper end. A notable advantage of this second stockpile is that it completely frees the lower stockpile of already fabricated panels, making the lower stockpile ready to receive winter production. The upper stockpile also compensates beforehand for possible transportation difficulties.

The factory also includes workshops for the preparation and pre-assembling of the main elements of other trades of construction, always with the same aim of reducing work, labour and the installations needed above on the site.

The erecting site

The conception of the site itself was linked with the need to continue work after the resort had begun operating without bothering the tourists. Therefore, the installations which, as we have seen, were reduced to a minimum, were pushed outside the perimeter of the resort.

The volume-production concrete mixer is set up at the upper terminus of the cable; concrete for foundations and for those parts cast in situ are brought by mixer-trucks. No concreting station, no cause of noise and dust, is to be found near the resort.

Transportation

The problem of bringing materials up to the site was from the outset one of the difficult aspects of the job. The solution of transport by cable, a rather original idea, was suggested, the cable once construction was finished, could be turned over to tourist use. Our using the cable means that the road is freed for tourist convenience during the intermediary phase when partial operation of the resort has to be achieved simultaneously with construction. The cable in question is a bi-cable telecarrier with a 1,250 kilogram trolley and maximal yield of 30 tons per hour. The lower terminus is set up at the exit of the factory next to the stock area. Handling is done on a siding.

Bulk materials, such as cement and aggregates, are carried in containers of 1 cubic meter; their arrival and departure circuits are mechanized by belt or compressed air conveyors.

The transportation of prefabricated panels is done by two carrier trolleys coupled by a gauge or spacing bar for prismatic pieces—beams and floors, and by rigid compensator for slab facing and wall panels.

Hooking and unhooking operations are done by a hydraulic elevater trolley with mobile platform.

In conclusion: we believe that our experience as reported above illustrates the great capacity for adaption of prefabrication to very special requirements; we point out this capacity because it seems to us that it is as yet largely overlooked.

Further, this experience illustrates the advantages derived from prefabrication in this particular case, advantages which have little to do with the arguments usually put forth in favour of prefabrication in more classic cases. Finally, our experience shows the possibilities of expression belonging to prefabricated concrete and which it is possible to achieve if the choice of method is made early enough in relation to the conception of the construction.

Assembly building methods combining design flexibility and light weight

By L. Bergvall and E. Dahlberg (Sweden)

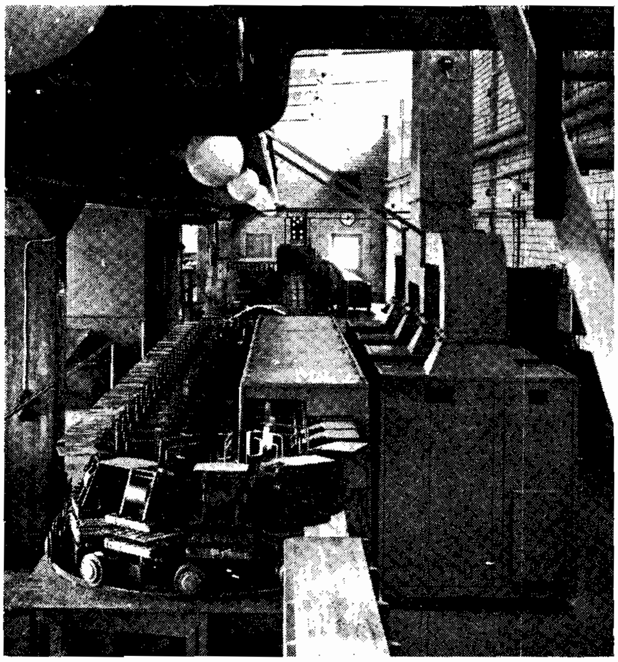

Fig. 1. Automatic production of lightweight units for prefab houses.

The most advanced, or rather the most well known systems of prefabrication are usually developed in densely populated areas around large metropols like Moscow, Paris etc., where the conditions for prefabrication are particularly favourable. A very substantial market can be reached within a limited freight distance. In such areas even prefab systems using very large, i.e. heavy elements may well be economcial.

In less densely populated areas, as for instance large parts of Sweden, a market large enough to form the basis of any advanced prefab industry can usually be found only by accepting fairly long freight distances, which exclude the use of the heaviest types of prefabrication. As pointed out in a recent report from the United Nations Economic Commission for Europe, ECE, the low per ton value of the building structure sets narrow limits for the economical transportation distance of its components.

Therefore, in countries where the population is not mainly found in metropolitan areas, prefab systems, using light or medium heavy components, represent an interesting alternative to the heavy systems. With such lighter systems the production of components can be centralized and thus highly mechanized, even in rather sparsely populated regions. In order to keep the component weight down, the component sizes in such systems must usually be fairly small or medium sized.

The wider the market area, however, the less rigidly can the house production be standardised, as soil conditions, topography, climate, dwelling habits etc. will vary much more over a large region than in narrow metropolitan areas. Thus the light weight prefab system with a spread out market must be constructed for a fairly high degree of flexibility in design, which again calls for small or medium sized components.

Below, two Swedish light weight prefab systems will be described, one for house production in operation for 10 years and one for production of apartment houses, so far only in pilot production.

Highly prefabricated house building system

This system, called the "Element House System", has the following characteristic features

a) the combination of an unusually high degree of mechanization in production with flexibility in design, achieved by the use of fairly small units;

b) the prefabrication comprises everything that goes into the house, not only the structure but also all plumbing and pipe installations, electric installations and other equipment. In order to provide for this, particular emphasis is laid on the dimensional accuracy of the elements as well as of the erected structure;

c) as a consequence of this high degree of prefabrication no technical skill is needed for the erection, not even of the service installations, so that a crew of four men from the factory erects everything, even service installations according to a special agreement with the labour unions;

d) as the erection normally takes only about 2 weeks from ready foundation to a ready-to-move-into house, it must be avoided that the erection crews are kept waiting for missing parts and therefore everything that goes into the house is shipped in containers directly from a central storage at the factory, regardless of where it might be produced;

e) in order to ensure that all these parts fit together on the building site the production is to 100% based on the now internationally established decimetric modular coordination system, without which a production like this one would simply not be possible.

The exterior wall units are 20 cm wide only in order to provide for flexibility in design with a height usually equal to the storey height, and 20 cm thick. Similarly the floor and ceiling units are 20 × 20 cm in cross section, produced to lengths, being multiples of 20 cm. Interior wall units are likewise 20 cm wide but only 10 cm thick. In order to secure a 10 cm rather than a 20 cm flexibility in planning, a few interior wall units 10 × 10 cm are produced as fitting pieces. All these structural units for exterior walls, floors and ceilings as well as interior walls are designed with the same principal cross section, which allows them to be manufactured on the same automatic, continuous production line. In principle, all these units are a kind of box beam construction, the flanges consisting of 2 × 20 cm panels of 3-ply cross laminated wood in order to ensure that the width of the units is under control, regardless of variations in moisture content. The webs in this box beam construction consist of 3.5 mm hardboard, which, in turn, keeps the thickness of the units under control. The interior of these box beam units is filled with an insulation of shavings, compressed in a special process in order to avoid shrinkage. By thus using the waste from the manufacturing of the wooden parts as insulation, the timber raw material is very thoroughly used. The exterior wall units are already covered in the factory on the outside with a layer of thin oven enamelled aluminium sheet in a number of standard colours.

Such an accurate, highly prefabricated structure is not compatible with the roughness of a brick chimney, the erection of which should also require special skilled craftsmen, and therefore a special type of prefab chimney is developed for this system, consisting of a cast iron core, insulated with a special high temperature resistant mineral wool.

The heating system consists, as usually in Sweden, of a hot water system, but in this case arranged as a 1-pipe, perimeter heating system, which provides for a very strict standardisation, as this allows the same pipe dimension to be used everywhere in the heating system and in all houses, big or small. All parts of the pipe installation come ready from the factory, in modular lengths and with the ends ready for connection (threaded or equipped with the predetermined connectors).

The electric installation in walls is installed already at the factory, complete with outlets and switches; in floor and ceiling premade installation units are installed during erection.

Windows come glazed, lacquered and with all hardware attached. In the same way doors and cupboards are also fully prefabricated, only that the cupboards, wardrobes etc. are delivered flat, being assembled on the site in order to save transportation volume.

At the factory, everything that is to go into the house is loaded in containers taking 4–5 tons. Four to five such containers are used for one delivery and special devices allow the easy transfer of these 5 ton "parcels" from railway cars to lorries and from lorries to the ground on the building site.

Light weight system with good sound insulation

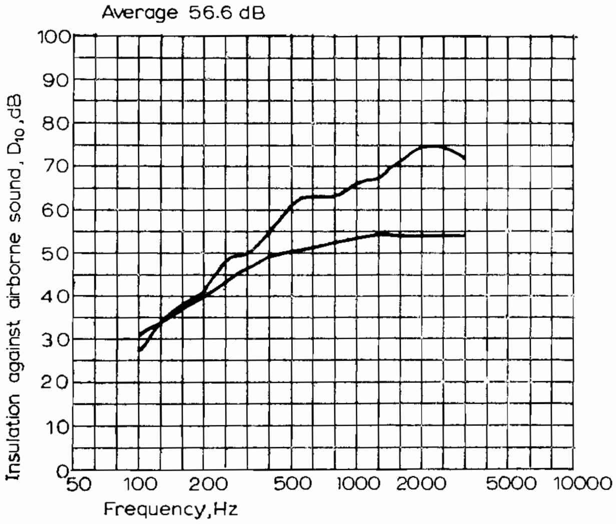

Fig. 2. Sound insulation diagram for lightweight concrete slabs in pilot apartment house.

This system was developed in order to provide a light weight system primarily for apartment houses as an alternative to the heavy concrete element systems. The structure, walls and floor construction consists of aerated concrete planks (Siporex) with a standard width of 5 m (50 cm), which at the time being was the standard size of such elements in Sweden. By cutting a few of these planks into 2 and 3 m units a set of sizes (5, 3 and 2 m) was achieved by which all modular dimensions could be reached. For the test house one unit in a large group of apartment houses was chosen and through this flexibility in design that unit could be built identically with the rest of them, being designed without any regard to the system. The town plan, according to soil conditions, called for only 2-storey buildings, which considerably reduced the cost of the experiment building, but still allowed all necessary studies to be made.

The use of aerated concrete ($\gamma = 0.5$ kg/cm^3) for both walls and floor construction reduced the total weight of the structure by about 60% as compared with normal "heavy systems". As this includes also the partitions between adjacent flats, as well as the floors between the storeys, sound insulation could not be secured through the usual method of keeping the weight high enough to secure sufficient sound insulation (400–500 kg/m^2). This problem was solved by making use of the new technique of preventing sound radiation by using sheets of controlled flexural rigidity as finishing, for which in this case gypsum board was chosen. Through a consequent application of this technique, covering all interior wall surfaces as well as ceilings with gypsum board, it was eventually possible to achieve with this light construction a sound insulation superior to the one usually found in buildings of the heavy type of construction. This was, however, achieved only after extensive testing of various alternative methods of application of these gypsum sheets. The tests clearly revealed that even rather minor changes in details might have a deciding influence on the resulting sound insulation. First a large number of constructions for walls and floors were tested separately and thereafter the most promising of these were tested in combinations in a small test house, designed particularly for the purpose. Although the test house was only 5 × 7.5 m in two storeys, it gave all the answers needed and later tests in the actual apartment house confirmed the findings made in this small test house, which was, of course, also used to test the proposed system and its details in respects other than sound insulation.

Sound insulation thus called for a larger multi construction, by which all the internal surfaces of the aerated concrete structure were covered by gypsum board, which was eventually found to offer great advantages also in respects other than sound insulation. Also on the exterior surface of the aerated concrete walls technical reasons called for an extra layer of sheeting to provide a "rain coat" for the house, in this case consisting of oven enamelled asbestos cement sheets. Thus the structure was in no way visible, which allowed a simple, fairly rough handling of these units during transportation and erection. With this system also an air space, about 25 mm, in thickness, was created between the structure and the gypsum board, an excellent space for pre assembled ducts for electricity, heating etc.

All windows arrived at the site glazed, lacquered and with all hardware attached, as also doors, cupboards etc. for which the standard units of the above mentioned "Element house system" were used. It might seem, as if this multi layer system would not be sufficiently "prefabricated". The experiences gathered, however, show that the important factor is not that all units are fully ready made, including finish, but that everything that is left to the building site is organized and dimensionally coordinated, with due account of tolerances, so that all parts to be assembled on the building site really fit together without adjustment.

As it proved to be very easy to drill holes in the aerated concrete, provided a tool is used designed for the purpose, no units had to be delivered with holes for pipes ducts etc., which permitted a very rigid standardization of the number of unit sizes.

The experiences from these two building system seem to demonstrate that there are realistic possibilities for combining industrial production with flexibility in design and low transportation weight for both houses and apartment buildings. The experiences also show the great advantages of a total prefabrication, which includes also all equipment and service installations, as mixture on the building site of erection of prefab units with ordinary crafts work must be avoided, in order to maintain the advantages of prefabrication. This also, and particularly the practical experiences from the "Element House System", indicates that the full benefits of prefabrication can be gathered only where it comprises the whole building operation, including foundation. Therefore, at present new experiments with a prefabricated basement and foundation are being carried out.

F 3

G. Blachère

The consequences of the open system on design and integration

By G. Blachère (France)

In France, "open system" or "open prefabrication" is defined as the construction method making use of large precast units listed in catalogues and bought from industrial manufacturers by contractors. Units must be understood as meaning finished units suitable to produce a complete structure by simply connecting them, once in place: wall units must produce a complete wall, meeting all quality prescriptions such as mechanical stability, thermal qualities, lighting, appearance, etc., i.e. the wall unit must include the inner face as well as the outer, and the load bearing parts as well as the windows. In the expression "large units", "large" should be understood to mean units with at least one dimension equal to that of a room.

Efforts presently made for developing "open prefabrication" are justified by the hope of creating a wide market for large prefab units, issuing in their mass production by highly mechanized and soon to be automated methods. These efforts are welcomed by our architects who are conscious of the necessity of industrialising the building industry, and who feel that the use of these large units does not protect their position in the construction team as much as values which justify their intervention in a project, such as adaptation to the geographic site, to the architectural style of the town, and to the personality of the client for whom the construction is being built.

After all, the large units in the open system are manufactured objects such as have always been used for building, except that they are larger and above all form in themselves, a functionally complete part of the building.

In order that the open system may be set up, a rule must be established which is accepted by manufacturers and users alike: the units produced by the manufacturers must be accepted in advance by the builders, i.e. the architects and the contractors. Conversely, the constructions envisaged by the architects must be possible from units listed in the manufacturers' catalogues. This rule has two aspects: one concerns quality, the other size.

Under the section dealing with the unit's quality neither party is free to choose the "rules": we well know that the building as a whole must satisfy the physiological, psychological, sociological and economic requirements of the user and that, in order to satisfy these requirements, the different parts of the building must present precise characteristics; in other words, they must, as we would put it, meet all quality stipulations.

The content of these rules depends on the general dispositions chosen for the building. For example, they will vary according as construction stability is ensured by the walls themselves or by an independent structure, or according as proper comfort in the warm season is ensured by the outer walls' qualities or by means of a mechanical system. These quality stipulations are expressed in physical terms, scientifically established, or in functional or "requirements" terms, reproducing the user's own requirement. They are enforced on the manufacturer and the builder. The only thing they still have to establish is how to check that these stipulations are fulfilled.

Some twenty years ago these rules only existed in their technological expression: the "rules of the art", often oral, sometimes written into standards and codes of practice. And every one made it his business to verify them personally. It is not the same today. On one hand, checking the rules themselves calls for numerous, costly and difficult tests and measurements; on the other hand, in many instances what is necessary is not checking the manufactured products but watching over production. Lastly, a very considerable proportion of large units manufactured for the open system are not traditional; in other words their quality stipulations are only incompletely established and an expert judgment must be sought as to their suitability for use.

All this shows the need for procedures which are no longer individual but cooperative; and since there is a need for information both from the manufacturers and builders, a parallel procedure. These will be procedures about conformity to standards, conformity to codes of practice, "agrément" of non-traditional materials, whether the procedures are applied to each individual manufactured item or to the type of production only.

In the matter of sizing the units, the rules can be chosen with greater freedom. It could be said that any convention for sizing is valid so long as it is respected. Actually there are necessary conditions which the size convention must meet, such as the additive rule for the selected dimensions. The lengthy work of the International Modular Group, CIB Working Commission W. 24 resulted in recommendations which coincide with the prescriptions of our standard NF P. 01. 101 that determines the possible sizes of the principal building elements. In this manner the rule for the manufacture and utilisation of large manufactured units under the open system is completely defined.

It is important to point out that this "rule" with its two sections (agreement on a procedure for recognition of suitability for use and agreement on a sizing convention), provides, in the open system, two of the bonds between the manufacturer of such units and builders, the third and last bond being the catalogue in which the manufacturer presents his range of products which may differ in details where the "rule" allows freedom.

By adopting the rule, the authors of the design lay down outright instructions somehow, for manufacturers and builders, whereas in traditional building procedures such instructions differ from one operation to another; for in traditional building only amorphous materials and sections are the subject of set specifications, i.e. the standards and codes of practice. This set of outright rules involves a voluntary restriction on design freedom. But all this has been said long ago, what some call freedom, others call license. In the present building condition such a set of rules is a reasonable, necessary and indeed profitable decision.

It should be fairly clear that the result of the adoption of the "rule of the game" by manufacturers and builders can in no way be interpreted as an integration of the manufacturer into the building operation. On the contrary, the manufacturer is external to the operation, though linked to the builders by the contract concluded through accepting the rule.

While integration is being preached on all sides, should we be alarmed because, in creating the open system, we are on the contrary advocating a distinction, if not an actual segregation?

We do not think so, for there is nothing to prove that complete integration of the various parties to a building project is invariably necessary or even profitable in all cases. On what, then, does this theory of the need for integration rest?

Essentially on an analogy with other industries: in the latter, it is said, the product is both designed and produced by the manufacturing industrialist alone. Therefore if we wish to industrialise building along these industries' lines, we must do the same thing: we must integrate the architect, the contractor, the manufacturer, and possibly also the client as well as the labour. But to quote an old French adage, "comparison is not reason". Besides, what does "integrate" mean? Simply that one of the participants will absorb the others: so will it be the architect, the contractor, or someone else? Does it mean that the building team will have to be closely knit together and, if so, along what lines? In reality "integration" is only one of these fashionable words sorely in need of being defined before being used.

Actually, we are also well aware today that industrialising is not striving to look like other industries without knowing what really makes those industries industrial. *Industrialising* is *rationalising* and *mechanising* and also automating since that is the term used to describe the mechanisation of intellectual processes. The equation: *Industrialisation = rationalisation + mechanisation + automation* is a fundamental one in all endeavors to improve the building industry. It is indeed in order to achieve a higher degree of mechanisation that we advocate the open system. Hence if a specific form of integration will permit greater rationalisation and mechanisation, then it is welcome. But if this is not so in regard to some other form of integration, then the latter may prove useless or detrimental. Let us therefore substitute lucid analysis for the magic spell of fashionable words: the craze over integration is a form of reaction against certain flaws in the adaptation of traditional building structures to new facts like the development of non-traditional methods, and also the need for rationalisation. Let us take a look at what is needed in order to build well, or rather in order to build better and cheaper: basically, the client for whom one is building must define what he wants to be built in a program in the words of which lies already the whole construction. The successful drafting of such a program depends upon collaboration between the architect and his client. Clearly, that cannot be called integration.

The next step is to translate this program into a design, and this design must define everything that is needed to implement it. It must therefore be complete, i.e. contain plans of the works together with a description of whatever cannot be read from the drawings, the execution plan down to its last details, including the site organization (in space), and the operational schedule (in time). This design must not only be complete but also the best possible one; in other words it must represent the best construction for the price for which the client has given consent.

Obviously, in preparing such a project, the participation of the man who will be responsible for its execution, namely the contractor, is imperative. To require that a form of collaboration should be established between the architect and the contractor that will result in a design having the qualities referred to is necessary and sufficient.

Although effective integration of the contractor with the architect or vice versa will establish such a collaboration, it is by no means essential. However, whether or not to integrate the manufacturer or merely have him cooperate in the design study is a decision that must be pondered: indeed, if it is hoped to get the manufacturer to supply units to order based on a pattern exclusive to the particular design, then it is indispensable that he cooperates in preparing the design. But then surely, such units made to order on an exclusive pattern will be "haute couture", a form of luxury, which is exactly the opposite of industrialisation.

If, on the contrary, one is looking for greater rationalisation and mechanisation in the production of building units, then catalogue units must be used, with perhaps a request to the manufacturer for information on certain features of his product. And that would certainly not be integration. It can easily be seen in studying the design execution phase, where the contractor's position is predominant, that even this phase does not really call for integration. In order to build well, to industrialize, it as necessary, not to "integrate" the various participants in the building project, but merely to ensure that the required bonds are set up between the program, the design and the execution, so that they have the wanted qualities.

Where the open system is concerned, these necessary relationships are established between the manufacturer and the other participants by the "rule of the game" i.e. by the procedures for determining suitability for use and by the size convention, as well as by the catalogue of the manufacturer's products.

Heavy and light prefabrication; advantages and drawbacks

Principles of choice

By A. Canqueteau (France)

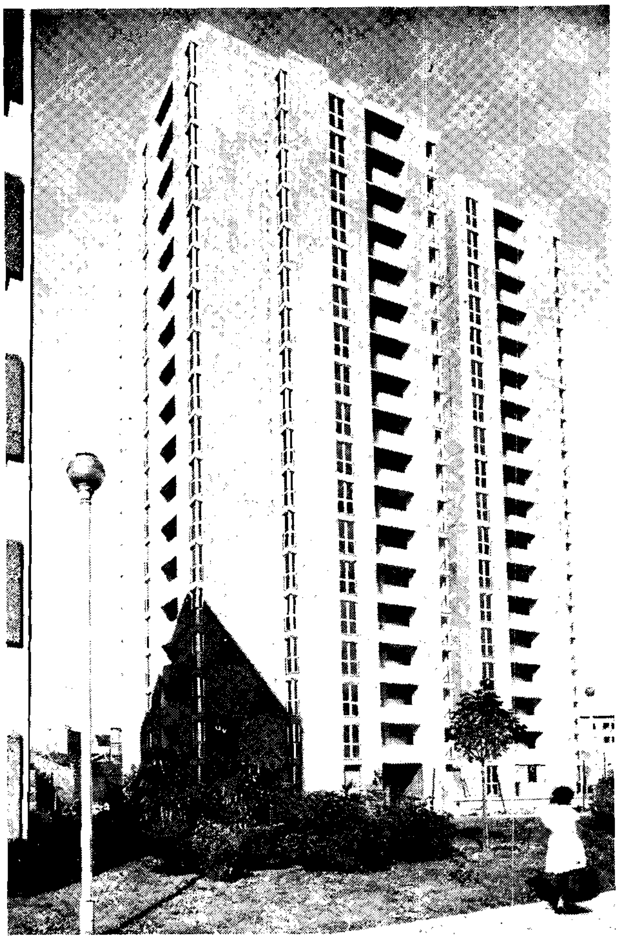

Fig. 1. 17 storey tower block for low-cost family housing.

Much hope was placed in total heavy prefabrication. Less dependence on the inclemency of the weather, stability, improved manufacturing plant were to greatly increase manpower output and building quality standards. In spite of the considerable support it was given, total heavy prefabrication does not appear to have gained a leading competitive position. What were the difficulties encountered?

First of all, *heavy prefabrication*, usually effected in factories, involves substantial investments, to the tune of NF. two to three million per dwelling/day produced, in the case of a plant working in two shifts. It requires the use of cumbersome lorries with attendant traffic difficulties in modern cities. A few years ago, such plants' operating radius was over 30 miles; now it is on a downward trend and hardly exceeds 15 miles in the Paris area.

It would be a relatively simple thing to run these factories if production were confined to building a limited number of carefully planned and repeatedly the same types of houses. Unfortunately, buildings in urban areas must keep to the pattern of a particular site and conform to town planning regulations. Such buildings were planned by different architects; they are hardly ever suitable for factory prefabrication without complicated adjustments resulting in an often considerable number of different components, with consequently high planning and development costs and extensive storing area.

The trend of techniques to incorporate most of the piping into the heavy structural work implies a more diverse and elaborate range of components. It also often raises very serious problems of connection in the course of assembly.

To secure an adequate turnover in their business area, factories are compelled to seek business with building sites of too modest a size or ill-adapted to their manufacturing techniques.

Site assembly has the spectacular advantage of speed. On the other hand, it requires considerable hoisting equipment. Building components are subjected to a certain amount of damage in the course of transport and handling with heavy hoists. This leads to the necessity of considerable finishing.

Light part prefabrication, much older than heavy prefabrication, has profited by all the recent improvements in site organisation; light column slewing cranes, concrete production points, distributing appliances, vibrators, percussion-rotation boring machines, resin mortar for facing and repairs, sand-papering machines, glues, etc.

Unlike heavy prefabrication, light prefabrication is not an automatic process. Deciding to prefabricate or not is related to cost price and to the economics, for each single building component, of purchasing a ready-made unit, or of prefabricating it in the shop, or of producing it locally using the ordinary process or by means of improved shuttering recoverable for repeated further use.

According to such techniques, the frame work and floors are generally cast on the site. As a matter of fact, the foundation can seldom be prefabricated; the vertical bearing components should, in discriminating construction work, be vertically continuous to ensure wind-bracing. Even the floors, acting as horizontal beams to convey wind-pressure against the vertical bracing, should also be continuous.

Finally, it is easy to incorporate piping into concrete when the frame is cast on the site, whereas this raises major locating and connectings problems in the case of total prefabrication.

Present requirements in the way of heavier structures to ensure improved sound insulation as well as a more steadying thermal factor have rendered more prominent the problem of transport and assembly of heavy prefabricated components. On the contrary, increasing by a few centimetres the thickness of horizontal and vertical slabs costs little in the event of site casting.

Satisfactory production at the plant of floors with sound insulation beneath the covering is a practical impossibility and, anyhow, fringe joints have to be made on the spot.

There is no room in this paper for a full survey of the development of light prefabrication since the second world war. Many trials were carried out, many failures were registered. We propose simply to bring out the salient features of things as they are now.

For light prefabrication use is made of hoists (slewing column cranes) with a capacity hardly ever in excess of 30 t/m, i.e. 1,500 kg up to 20 m, the reach usually required to serve all the parts of a building in the course of erection. It was consequently out of the question to hoist whole vertical slabs or floors. The division of vertical slabs and of floors into small units of not more than 1,500 kg was attempted. However, this technique implied quite a number of connection problems and is being discarded in favour of the use of site-cast vertical slabs and horizontal slabs, by means of prefabricated casting forms. The shuttering components weigh 40 to 50 kg/sq.m. Their maximum surface is therefore approximately 30 sq.m; this enables to cope with all current building problems.

The best floor shuttering is that used as a slide between two bearing partition slabs. This shuttering is occasionally a standing table. According to a patent system this table rests on adjustable brackets fixed to the bearing partition slabs. The cost price of skeleton structures built following these processes is not higher than that of factory prefabrication. Surface quality is about the same. The laying of all sunk piping is so much simpler. Joining horizontal and vertical slabs is also made easier.

Such shuttering is a working tool that is recoverable for repeated further use. It may be metallic or metal and plywood. Under French climatic conditions, mixed shuttering makes possible, after a period of 24 hours, the dismantling of vertical components.

The horizontal shuttering component parts, constantly used for the vertical part of the building, include, permanently, parapets for safety, edge shuttering and location of all special features such as: lift shafts, opening for tubing, etc.; hence a very substantial reduction in lay-out and less mistakes.

To the site-cast framework, carried out with prefabricated working shuttering, are added all the prefabricated components which it is possible to produce in a shop, located under the jib of the service cranes.

These are, in the main, façade walls divided into component units of less than 1,500 kg, smoke and ventilation ducts, in components one-storey high, staircases, stacks, sheaths and internal partitions also produced in one-storey high components made of plaster or concrete and assembled on the spot.

External facing of outer walls is cast either at the bottom of the form or on the top. The best results are obtained with casting at the bottom of the form. Facing may be of reconstructed stone or natural stone, tiling, surface enamelled glass, fine gravel or boulders, etc. The internal surface and insulation may be incorporated into the fabrication. The separate placing of individual lining and insulating components may be more expensive, but it gives better results. There are several jointing systems that afford perfect tightness.

The prefabrication equipment consists essentially of face-plates. This name applies to plates generally made of concrete and perfectly plane. These plates swivel around stands so as to be used horizontally and swing round to a vertical position when the components are taken up by the hoist. This process avoids having to put excessive concrete steel reinforcement which only bending stress on dismantling warranted.

The plates bear cheeks, generally metal-reinforced wood. Wooden cheeks, much lighter to manipulate, are preferable to metal cheeks. If properly handled they do not get out of shape; so it is possible to fabricate component units with a tolerance of less than ± 2 mm. As the plate is perfectly plane and squared to the exact size of the part to be cast, all the elements produced with the same casting-mould are strictly identical.

The prefabrication area is usually divided into three sections; a sliding cover provides shelter for the section in activity. Each section comprises the necessary casting moulds for a day's fabrication. A gang consisting of a pair of fellow-workmen and of two unskilled labourers will produce something like 40 sq.m façade a day, plus three or four multiple tubes and a flight of stairs.

Heat is usually not applied to accelerate hardening, components being hoisted the third day following casting. However, builders working under a severe climate have found it convenient to place a light polystyrene insulated cover over each casting-mould for the night following casting. Steam is introduced inside this bell-shaped cover so as to provide a moist temperature of some 35 to 40 °C over the casting mould.

Another system consists in sinking the coils inside the concrete plate and creating a flow of water, the top of the mould being also protected by a bell-shaped insulating cover.

Fabricated outer wall components weigh about 175 kg/sq.m. (with separate lining). The end component will therefore measure 8 sq.m. Prefabrication of lined components gives a weight of 250 kg/sq.m, the end component will thus measure 6 sq.m.

The cost of a casting mould is in the region of NF 2,000 for a 6 sq.m component.

The concrete plate can be used an almost indefinite number of times. The wooden parts afford re-use from 100 to 200 times. Under such conditions the range of building components often required by architects is no major obstacle and light prefabrication is so much more flexible than heavy prefabrication.

Operating conditions at an open-air plant are not so different from those in a fixed factory engaged in heavy prefabrication. As a matter of fact, only assembling and dismantling forms take more time, because, whereas the plates have to remain under the component parts for three days, the cheeks are taken down the next day for use with other plates. That is the reason why it is of advantage that they should be light in weight. Very few shuttering components of over 25 kg are used. Concrete is supplied directly by the crane from the concrete production point. Pouring concrete, as is usually the case, even at the factory, is done by hand, especially around bare parts, in order to achieve a perfect surface.

On the whole, it is important that prefabrication should be conducted in relation to progress with the heavy structural work. A memorandum briefs the shop as to the parts to be produced day by day.

After a small stock has been built up to replace a part damaged by dismantling, it is advisable to transfer the components directly to their location in the building, as they come out of the casting mould. This procedure, together with the operation of a sensitive crane, i.e. allowing an almost millimetric lowering of loads, provides almost full elimination of damage by chipping to the prefabricated building component. In actual fact, less than 1 % of component parts set into place have suffered such damage.

The outer wall assembly method is simple; the workmen on this job are inside the building. No resurfacing is needed; no external scaffolding is used.

Concrete stairs are produced in a casting mould with which dismantling can be effected after a lapse of 16 hours. It is possible to install the staircase complete with banister, storey by storey as the heavy structural work proceeds. Consequently up and down traffic is easy and without danger.

Three recent findings make for considerably improved finishing of buildings, erected by the heavy or light prefabrication methods. First, resins added to the mortar and concrete provide a means of repairing component parts without splitting. Using the same resins it has been possible to develop thin polishing coats giving concrete a better finished surface than obtained with plaster coatings. Thanks to this finishing coat, a site-cast light prefabricated framework compares very favourably with the best heavy prefabrication achievements. Moreover, the gluing technique, increasingly applied to skirtings, partitions, brackets, wall lining, gable wall insulation, enables this work to be carried out properly and cheaply on the spot; such operations were formerly very expensive.

Lastly, the modern mason and technical building trades are equipped with drills with which holes as neat as in metal are bored rapidly, thus getting rid of all the whole drilling and sealing performed at a later stage, and of often disastrous joining.

In conclusion, it is claimed that light prefabrication always costs less than heavy prefabrication whenever the latter is not applied under favourable conditions, that is to say, to building designs to which it is specifically suited. Furthermore, light prefabrication presents the advantage of affording architects a much wider range of means of plastic expression. It is more flexible and requires a much lighter financial commitment on the part of contractors applying this technique. It is also less affected by unfavourable economic trends, whilst being in a position to cope rapidly with a great increase in demand. And finally, light prefabrication has enabled well organised medium-size contractors to continue to hold their own in the building business.

F 5

Centre Technique du Bois

The prefabrication of timber structures and the industrialisation of building

Paper prepared by the Centre Technique du Bois (France)

Raw materials often account for 60% of the cost price of ordinary wooden structures. In most cases, mass prefabrication does not at present allow of a substantial cut in cost price. Nevertheless, by means of techniques, not applicable to work on order or to site work (glued timber connections, lamellation, etc.), it should be possible to cut down substantially the quantity and cost of raw material in structures and buildings using wood and by-products. Anyhow, already now a noteworthy saving is being effected on building site labour by careful planning aiming at making use of structures with a higher degree of prefabrication and prefinishing (e.g. finishing and glazing windows at the factory).

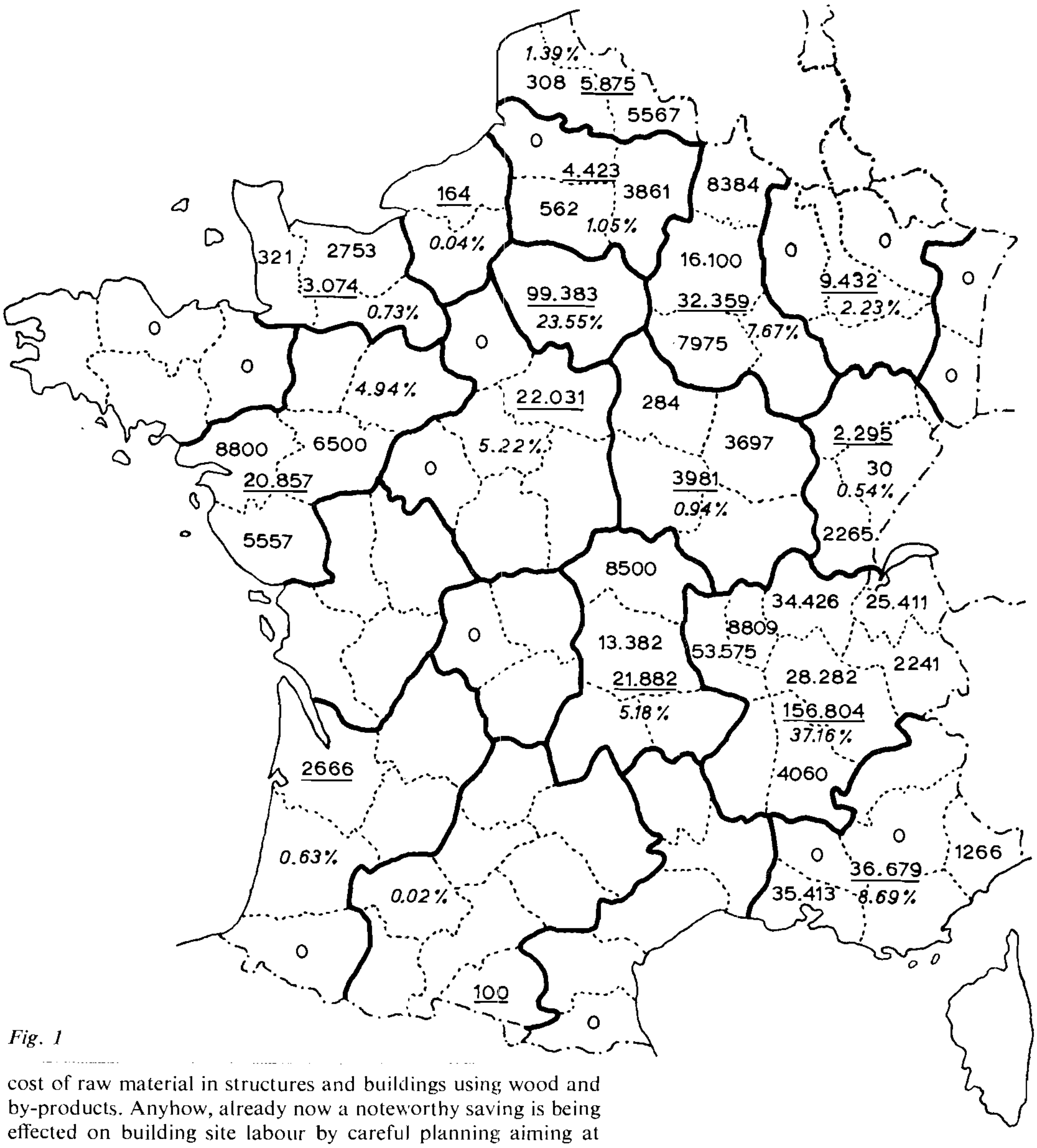

Fig. 1

Structures and building components of modern design often make it possible to effect a much more important saving on man working-hours required for fabrication and erection. By rational structural designing, particularly in the case of prefabricated houses, it is permissable to reduce the amount of materials (wood and by-products) which go into their construction. This is an economic advantage, not just the saving on raw materials, but also in respect of shaping, handling and transport (less weight).

A few examples will be given, illustrating such various features of the application of wood and by-products to building, and the economic benefit this may provide.

In some comparisons between new industrialised procedures and ordinary methods, e.g. separate houses and partitions, it should be kept in mind that structures do not always have comparable distinctive features, particularly where heat and sound insulation is concerned.

Windows. If there is no need to prove the economic benefit of window mass production, on the other hand the case must be proved for placing temporary window frames.

Appendix 1 indicates that, compared with usual placement practice, final cost is 25% up. The cost of fabrication, transport, placement and painting the temporary frame is but partly compensated by the saving on painting and glazing the casement window at the factory and on placing it. However, it should be remembered that windows placed in the ordinary way are usually rather badly damaged during site work. Furthermore, exposure to bad weather causes deformation and dimensional variations due to dampness setting in again, because more often than not they were treated only partly or received just a nominal protective coat. The financial effect of necessary repairs sometimes outweighs the difference in price between the two techniques. Often again ,when for instance the architect specifies some clearance if wood is much swollen during a damp spell, damage is permanent.

It is consequently true to say that the temporary window frame fixing procedure makes for better work quality, especially painting and glazing, and the effect on final building cost will hardly be greater than with the usual placing practice.

Facing panels and wood-framework curtain walls. A new prefabricating feature was introduced in recent years: facing panels and curtain walls making up in the form of an integrated element the façade closing wall and building joinery (windows, French windows and shuttering). This should produce substantial building time saving, or at any rate lower cost price. Their use, recently introduced in France, has registered rapid development (in 1962 the timber industry produced and carpenters placed 322,936 sq.m of fabricated panels). In 1963 some 40 firms produced over 422,000 sq.m.

The map (Fig. 1) shows the geographic distribution of building sites in 1963. The technique is most popular in the Rhône-Alps and in the Paris areas. It is in the same areas that most of the timber factories are located.

If building conditions remain favourable, it is reasonable to anticipate the production and placement, in coming years, of over 800,000 sq.m of facing panels and curtain walls per annum. This is quite likely when it is considered that, at the rate of 36.5 sq.m of panels per dwelling consisting of 3½ rooms, the 300,000 or so sq.m of fabricated and placed panels so far in residential buildings only, just account for, and no more, 8,200 dwellings per annum, viz. approximately 2.3% of built dwellings.

As a matter of fact, the distribution over different types of construction of facing panels and curtain walls, made and placed by the building timber trade in the course of the last two years, is given below:

	Facing panels	Curtain walls
Houses	89%	11%
School buildings	46%	54%
Office buildings	48%	52%
Industrial premises	57%	43%
Sundry constructions	53%	47%

The development of facing panels has, in fact, been at a much quicker pace than that of curtain walls. The former account at present for 81% of outside wood framework panels. They are in demand particularly for houses (nearly 90% of total fabricated facing panels) and in addition (9%) for school buildings.

On the other hand, houses and school buildings each account for 40–45% (in surface) of placed curtain walls. Then come office buildings and sundry structures (5% each). It is possible to-day to go into the advantages of these new techniques by taking as examples some large blocks of school buildings and of residential buildings.

Effect on building costs

As regards manufacture of and placing wood framework facing panels, the price bracket ranges for 1000 sq.m operations from Fr. 150 to 300 per sq.m (including tax), with glazing (October 1964).

For supplying and placing wood-component curtain walls, the price ranges (for 1500–2000 sq.m operations) from Fr. 250 to 500 per sq.m (including tax) with glazing.

Manufacturing time is generally taken to be:

- facing panels without temporary pre-framing 2 man/hrs. per sq.m
- curtain walls 3 man/hrs. per sq.m

Average placing time is 1.5 hr/sq.m for the former and 2 hrs/sq.m for the latter.

The cost of a facing panel compares with that of an ordinary façade. It comes in for 11–14% of total structural cost, and this remains within accepted standards for ordinary construction. Facing panels may therefore to-day be considered as competitive in relation to façades made of hard and stony materials. It may be that masonry is in some cases cheaper, but as a rule it does not provide the same heat insulation.

On the other hand curtain walls are usually a relatively more expensive proposition than the ordinary façade, but they offer other architectural possibilities.

There is another distinctive feature having a bearing, indirectly, on structural cost: the lighter weight of panel-made façades.

1 sq.m facing panel weighs approx. 25 kg
1 sq.m curtain walls weighs approx. 30 kg
i.e. roughly 6–8 times less than masonry.

According to a cursory enquiry it appears that, in the case of buildings of current height (up to 12 stories) on firm soil, the weight reduction provided by light façades is, as a rule, not reckoned with in designing bearing elements and floors. On the other hand, in the case of very high structures or of buildings of current height on loose ground (1.500 kg/sq.cm), it is estimated that a light façade results in a 10% reduction in load on foundations.

Building speed

The speed of erection of facing panels and curtain walls on the building site may be put to full advantage only if there has been suitable preparatory organisation work bringing together the architect, the foundation and main wall contractor and the carpenter, to make sure both that the mason keeps to the measurement figures and that the carpenter works to a strict building-site time schedule.

Two cases have been picked out to illustrate the speed of erection of facing panels and curtain walls; the working time schedules are appended.

1) Erection of 6180 sq.m light façades in a residential building. Placement is with pre-framing, in two stages:
a) adjustment and placement of pre-framing;
b) fitting up the facing panels on pre-framing.

There is a 3 to 6-week gap between the two stages. The panels, finally fitted up after completion of all the other building trade jobs, are delivered after prevarnishing at the factory.

2) School building with wood-component curtain walls. The working time schedule indicates that erection time for buildings A and B is very short (one month) as compared with work carried out by the other building trades and, moreover, that full erection is completed in one operation, whereas the other building trades often have to work in stages.

Partitions. A comparison of unit cost has been made, for a group of 50 dwellings, between ordinary cavity-brick partitions and "dry" extruded wood-particle panels.

Price sq.m Design ex(-tax)	Effect second structural work cost price	Effect time required for fitness for habitation and maintenance	Final cost per sq.m
Ordin. partitions 38.08	5.82	15.96	59.86
Panel partitions 42.00			42.00

It is obvious that the attractive economics of prefabricated partitions would show off better still if the matter were, to begin with, gone into in detail together with all subsidiary building trades (electrician, heating contractor, plumber, plasterer, etc.

Flat doors and door units. A comparative study (cf. Appendix 2) between three types of door cases shows that the price of a door case with pre-framing is 18% higher than that of a door case with an ordinary section, placed in the usual way, with door furniture fitted at the factory.

It should however be noted that, whereas temporary preframing must still be supplied in advance to the building site, before erecting the partitions, such is no longer the case with the door cases proper; these may be delivered at a very late stage in building work, i.e. just before painting. They, therefore, have much less to suffer, than in the ordinary practice, from damage caused by the other building trades or from deformation due to stocking and to erection under conditions of excessive dampness. In spite of these advantages, the technique consisting in placing door cases with temporary pre-framing is at present generally considered as too expensive. On the other hand, covering door cases are undoubtedly a good proposition.

Floor-boards. Much research work has been carried out in

France to turn out wood-floor covering board components, fully prefabricated at the factory, according to current practice abroad. The technical problems seem easy to solve; on the other hand, the application of such new types of floor-board has been somewhat held up by mere habit on the part of makers and by users' exactingness. At any rate it is certainly feasible to produce on an industrial scale prevarnished components with a sound-insulating sub-base and, possibly, protection against dampness, for placing loosely on a bearing floor or on a sand bed.

But it has been possible greatly to increase the extent of prefabrication by producing prefabricated floor panels complete with parquet flooring. This process, developed in France in 1956, has materialised into a certain amount of onsite building work. It is mostly in Britain that it has been applied on an industrial scale. The parquet floor components are made of 5 thin wood plates assembled by means of undulated metal joints driven half way through into the counterfacing. Moreover the plates are given a special impregnation treatment to reduce dimensional changes. The components are placed in position upside down, that is with the joints on the top, on the bottom of a mould (see Figure 2). The mould is then filled with concrete to make a prefabricated slab following the usual processes. Time for placing the parquet floor components is, to fill the mould, 3 minutes for a workman per sq.m. Such time does not include touching up, which is necessary when the slab is in position. As a comparison, it takes 10 minutes for a workman to glue 1 sq.m of inlaid mosaic flooring on the building site.

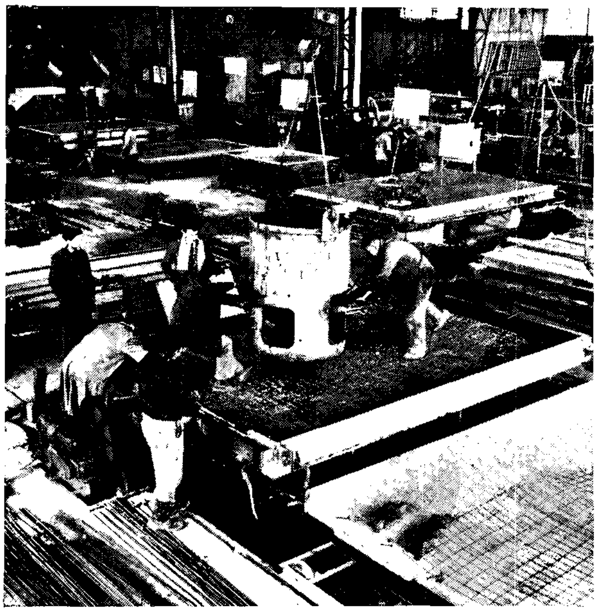

Fig 2.

An advantage of this process is that it cuts down time required before the building is fit for occupation, since once the slab is in position there remains only touching up and pumicing. On the other hand, much time is required for the heavy masonry structure to dry before placing the parquet floor into position on the site.

Prefabricated framework. It is possible to include roof trusses among the components provided for separate houses by producing braced framework trusses made of nailed planks, or also web beams or with gusset plates of nailed and glued plywood. This type of truss, which requires no special equipment to make, may be produced at the factory in the same way as the other building components. Such type of truss may be applied to all short-span structures, even built in small numbers.

On the other hand lamellated framework can only be manufactured by specialised factories in view of the equipment and material required. Its price, per worked sq.m, is much higher than that of the above types (from 30 to 60% at present), but it is generally possible to save on the amount of wood and to produce medium or long spans. It also provides a new solution which may compete with metal or concrete.

Prefabricated separate houses

Prefabricated separate houses are offered for immediate possession, time for completion being one month. A wood framework 100 sq.m house can be built (excluding foundations) and erected in 600 work hours, that is, half the time required for a corresponding French H.L.M. dwelling. The cost price of such houses is Fr. 500–600 per sq.m (excluding foundations).

Manufacturers think that it should be feasible to complete a house, ready for delivery, in a day's time, provided foundations and service connections are prepared in advance.

The following are the various stages in the building of a lodge with 4 main rooms (built area 68 sq.m) on a site already provided with sanitation. The structure of the "light"type is with wood frame-work. External lining consists of thin asbestos cement plates, interior lining is plasterboard and glasswool is used for insulation:

Foundations	130 hours
Fabrication	250 hours
Erection	150 hours
Sanitary installation	80 hours
Electricity	45 hours
Outside painting	50 hours
Inside painting	130 hours
	835 hours

Such type of house, labelled "prefabricated" is actually only very partly so. Wall, partition, floor and framework components are, together with joinery, the only ones that come from the manufacturer's shop and are assembled by him, plus roof covering material delivered directly to the building site. All the rest, various earthwork and foundation masonry, plumbing, sanitary equipment, kitchen equipment, special floors, electricity, painting, shelves and cupboards etc. are provided in the ordinary way by various suppliers or makers chosen according to the location of the building site.

There is no doubt that, in the lay-out of integrated housing estates and in applying new techniques, it should be possible also to prefabricate some of these items or to do some of the jobs in series.

There are already certain types of prefabricated separate houses in which the electric installation is housed in the building components at the time of factory prefabrication. A great part of painting could be done in the same way, or be cut out altogether by using certain types of lining materials, not to mention the possibility of prefabricating part of the foundations in the form of component units.

Appendix 1

1.	*Ordinary window*		Basic Price (ex-tax)
	2 casements 1.40 × 1.50 wall thickness		
a_1)	placing casement window on building site with tightening material		12.50
b_1)	placing glass pane on building site		8.00
c_1)	painting casement window on site		18.00
d_1)	fabricating casement ex-works – ex-tax		140.00
e_1)	transport ordinary casement window		3.00
			Fr. 181.50
2.	*Window with pre-framing*		
a_2)	placing casement window on pre-framing on site, with tightening material	$a_1 - 10\%$	11.25
a'_2)	placing pre-framing with tightening material (new item)	$a_1 - 10\%$	11.25
b_2	glazing casement window at factory	$b_1 - 4$–5%	7.60
c_2	painting casement window at factory	$c_1 - 6$–8%	16.56
c'_2)	painting pre-framing on site (new item)	$c_1 - 20$–25%	4.50
d_2)	fabricating casement window ex-works, ex-tax		140.00
d'_2)	fabricating pre-framing (new item)	$d_1 - 25\%$	36.00
e_2)	transport painted glazed casement window	$e_1 + 50\%$	4.50
e'_2)	transport pre-framing (new item)	$e_1 - 25\%$	2.25
			Fr. 233.91

Appendix 2

Comparison of cost of supply and placing 3 types of door cases:

a) Ordinary door case
b) Door case covering partition
c) Door case with temporary pre-framing + permanent framing.

The comparison refers to a 50 mm thick partition .Door 34 mm
Door fittings: door handle to be studded, with aluminium fitting.

	Supplies							Placing	total %
	Ord. Door case	Door case cov. partit.	Door case temp. prefr.	Perm. fram.	Door	Fitt.	Mould.		
Ord. door case	0.29				0.23	0.12	0.08	0.28	1.00
Door case covering partition		0.35			0.23	0.12		0.24	0.94
Door case with temp. preframing + permanent framing			0.18	0.22	0.23	0.12	0.10	0.33	1.18

F 6

B. Choulev and M. Kovandjiev

Large panel production in Bulgaria

Cassette production methods, conveyor technique, stand mould production

By B. Choulev and M. Kovandjiev (Bulgaria)

Technology used at the House-building Combined Works, No 1—Sofia

All production methods at our Works have been borrowed from abroad. For the production of face panels we use a reversible stand mould, German type, and conveyor equipment of a modified Czechoslovakian type. For the production of inner, carrying and floor panels we use cassettes, of a German type, conveyor equipment of a modified Czechoslovakian type, and package stand equipment, Bulgarian type. Staircase shoulder members, stair landings and other small elements are manufactured according to a production line aggregate technique and stand moulding technique.

The stand reversible forms for face panels are constructed with 20 cm thick steel concrete bottoms, having built-in steam ducts and steel sides that cannot be dismounted. These forms have three basic sizes: 3.30/2.75, 3.60/2.75, and 5.10/2.75, and are suitable for the manufacture of 9 member varieties after Nomenclature 3—61 of the Institute for Typified Designing and Industrialisation of Construction. All changes in the configuration of the elements are obtained by placing corresponding inserts adjacently onto their rigid sides. The upper surface of the steel concrete bottom is shaped by a 2 cm thick mosaic layer of basalt crushed stone.

The conveyor technique uses steel concrete mould trucks made of prestressed concrete, having dimensions of 3.60/5.10 meters. Members of different sizes and varieties can be cast by means of a side casing which lies freely onto the mould truck and made of U-shaped iron No. 20, 14 and 10 dependent on the required thickness of the member. The shape of the elements is achieved by means of steel inserts welded onto the sides. Thus, with one set of sides we can produce members only of the same dimensions and shape. The upper surface of this mould truck is shaped by means of a 2 cm layer of crushed basalt stone mosaic. These mould trucks pass through treatment stations and are steamed in tunnel steam chambers at a conventionally accepted quota of ± 0.0. The woodwork of the face elements is built into the panels with the casting of their concrete. Fourty-eight hours prior to pouring the concrete into the forms, all woodwork is ground and covered with a single coating of oil paint.

The German type cassettes applied in Bulgaria comprise a 10 cm thick steel concrete partition wall with built-in steam ducts. Both large surfaces of these partitions are finished in a 2 cm thick layer of basalt mosaic. The distance between the separate partitions, which is equal to the thickness of the produced panel (14 cm for inner-wall members, 10 cm for floor panels), is obtained by means of spacing U-profiles which also serve as side casing and bottom. The height of the cassette for inner elements is 2.78 m, and that of floor panels—3.60 meters. The packing of the cassette (its tightening) is effected by means of bolts at the upper end and by means of jacks at the lower end. The concreting of the cassette is carried out by means of a placing skip carried by a portal crane, which pours the concrete in batches. The concrete is then vibrated by means of a group of spear vibrators.

The Bulgarian type package stand equipment, which is applied at the House-building Combined Works No. 1—Sofia for the production of floor panels, makes use of steel concrete forms having a system of built-in steam ducts which contribute to the manufacture of lighter members of greater rigidity. The upper surface of the partition plates which serves as bottom of the form is finished in a 2 cm thick basalt mosaic. Each package consists of five such partitions positioned horizontally one after the other. Each partition plate serves as bottom of the element cast over it and as lid of the element cast under it. During the working process these partitions can be shifted cyclicly and successively between the different packages, the charging of each package being effected from the bottom upwards.

Technical appraisal of the different kinds of production methods applied

Our experience from the exploitation of the reversible stand forms has shown the following: all forms greater than 3.60 m in size have proved inappropriate for panel manufacture, owing to their considerable deformation during operation. The upper surface of the partition walls shows warping of the order of ± 20 mm, which may lead not only to a torsion of the panels but also to a deviation from their designed trajectory of movement during the removal of the panel from the form. Thus, the panels catch and chip off, particularly in the corners.

The use of forms greater than 3.60 m has shown that their basic disadvantage is the rather small rigidity of the inserts, which lie freely adjacent onto the sides and which get deformed during the removal of the casing, at a tolerance of ± 10 mm.

As to the use of the conveyor technique, our practice shows that in the first place the base plate of the mould truck running on its four wheels follows more or less the deformities of the rail track over which it runs, thus causing the transported member to crack. This happens most often in the mould truck type made of steel concrete without any prestress, where substantial diagonal cracks usually appear, whereas such cracks are found much less in those of prestressed steel concrete, calculated for the most unfavourable support conditions (when one of the four wheels is unsupported), without obtaining any stress strain in the partition plate. Our experience also shows that the upper mosaic layer gets damaged after a year's use when the elements are spear-vibrated, which in turn causes certain uneveness on the panels. The side casings freely lying onto the mould truck do not provide an accuracy to the members, corresponding to modern requirements in large panel production. In the Table below are given the deviations found in one part of the forms and finished panels measured:

Type of element	Number of measure-ments taken	Designed size	Average size in mm	Meansquare deviation in mm
Face members	14	3280	3286.8	4.53
	14	3280	3288.4	3.54
	14	3280	3284.9	2.25
	14	3290	2892.5	3.74
	14	3290	2894.8	3.43
	14	3290	2894.4	5.04
Inner panels	24	4650	4645.8	5.11
	24	4650	4652.2	6.38
	24	4650	4647.2	5.03
	24	2760	2761.2	5.29
	24	2760	2762.7	6.77
	24	2760	2758.8	4.34
Floor panels	10	4770	4770.2	5.84
	10	47770	4782.3	6.93
	10	4770	4768.7	4.85
	10	4770	3267.9	6.28
	10	4770	3265.4	38.54
	10	4770	3267.6	5.13

A typical phenomenon is warping in the middle of the moulds and the finished panels, and especially in the lower end, on account of insufficient rigidity of the U-profiles which get particularly distorted during their stripping. The use of clamps and telescopic screws, which shift the sides laterally, can limit this warping. Here we give, for comparison purposes only, the results of measurements made on inner panels longitudinally.

The deformation of the sides also affects the adhesion of the base plate onto the mould trucks. Some sides rise, which causes a thickening of the members and an overexpenditure of concrete. Our measurements show a mean arithmetic thickening of 4.3 mm

Number of measurements	Designed profile	Average size measured mm	Mean square deviation in mm
7	2760	2764.4	2.4
7	2760	2764.1	1.9
7	2760	2765.5	3.0

in 334 cases of floor panels and that their mean square deviation is 4.42 mm; a mean arithmetic deviation of 6.9 mm and a mean square deviation of 4.55 mm in 298 cases of inner members; and in the case of 3111 face members—a mean arithmetic deviation of 8.5 mm and a mean square deviation of 5.65 mm. The subjective appraisal of the tightening of the forms and the identity of their diagonals also contributes to a great degree to the deviations in the size of the members. A genuine solution of the construction of a mould truck, designed by the Construction Office of the House-building Combined Works No. 1—Sofia and executed by the Hristo Smyrnensky Works in Sofia, is a three-wheeled steel mould truck. Owing to one of the sides being always defined by three points arbitrarily situated in space and the three wheels of the mould truck following the unevenness of the rail track, no console stresses ever appear on the base plate itself. Thus a most efficient use of the materials is obtained, a minimum truck weight and a deformation below 2 mm. Since no other similar solution can be found in the available literature, we presume that it will be of interest to CIB, and its description is given below.

When using the cassette technique, the pouring of concrete by means of a placer does not provide a uniform filling of all cells of the cassette, which causes different types of warping of the partition walls in one or another direction. There are no distance limiters in the middle of the cassette to prevent any alteration in the interval between the partitions. The tolerance in the thickness of the element is ± 10 mm.

This question has yet not been solved. During the working process, cement grout accumulates on both large surfaces of the partitions, and mostly on their upper ends, over a 50 cm wide strip, which infringes upon the smoothness of the panels produced in them.

The weakest point of the cassette technique proposed by the German Democratic Republic is the mode of vibrating the concrete by means of spear vibrators. This insufficient thickening of the concrete is most strongly manifested in the production of elements thinner than 14 cm, and in members with a double reinforcement. The increase of the panel height over 3 meters also diminishes the quality of the panels produced. That is why these disadvantages of the cassette technique pose certain limitations regarding the dimensions, thickness and reinforcement of the panels which in some cases may lead to an uneconomic utilization of the section of the concrete, to an inadequate architectural solution of the inside layout of the house, and to an increase of the number of panels requiring heavier hoisting assembly mechanisms. Our efforts in designing nomenclatures for overcoming these limitations by producing members of increased dimensions, of lesser thickness and increased reinforcement, have proved to decrease the efficiency of applying this kind of technique and to render it both technically and economically inexpedient owing to the unpacked sections in the members and to the delay in the form filling process. The above disadvantages make it necessary to seek to use more plastic mixtures (slump after the cone of Abraham—14 to 15 mm); they require an increase in the cement content by 10 per cent and an increase of the duration of their steaming by 40 to 50 per cent, which decreases the efficient use of the capital investments. Owing to the fact that the partitions of the cassette actually do not cool below 50° during their reinforcing and concreting, where the concrete mix is immediately submitted to a thermal effect at normal cement setting rate of about 2 hours at 20 °C, the beginning of the setting of the concrete, under the temperature of the cassette, actually starts considerably earlier. The consequence of this firstly is a decrease of the strength of the concrete by 10 to 15 per cent, as compared to that of the steamed one, and secondly it causes, during the vibrating of the last concrete layers when the vibrators come into contact with the steel, the latter to start moving, which breaks its connection with the concrete of the lower layers that have already lost their plasticity.

Economic assessment of the production methods applied

Technologically, the time necessary for the production of 1 m^3 of panels of concrete under the different types of technique, as well as the production cost of 1 m^3 of concrete of different kinds of panels, are given in the Table below:

No.	Type of element	Type of technique applied	Necessary time man-hour/m^3 casting	Total	Production cost leva/m^3
1.	Face elements	Conveyor	8.13	12.38	77.46
		Stand form	8.52	12.13	80.25
2.	Inner panels	Conveyor	6.30	10.31	43.75
		Cassette	5.74	8.72	40.63
3.	Floor panels	Package stand	5.07	10.08	53.25
		Cassette	5.78	11.53	58.22

The data from the above Table confirm the basic economic inferences made from the exploitation of the different technological solutions at the House-building Combined Works No. 1—Sofia.

The time necessary for the production of 1 m^3 of face panels is almost the same both with the conveoer and the stand frame production techniques. This indicates that the consumption of labour in both these methods is identical. Capital investments under the stand form technique are higher, which leads to an increase in the cost of the panels by 4 per cent.

The production of inner panels by means of the cassette technique is more economical, from a labour consumption point of view, by 0.56 man-hour per 1 cubic meter of casting, and by 1.5 man-hour per cub. meter together with the reinforcement works. At a level of development of both techniques similar to that in Bulgaria, the application of the cassette technique is more expedient. This also affects the cost of the finished products. Keeping in mind the fact that the cassette technique gives, without any additional consumption of labour, two smooth panel walls, thus reducing the quantity of finishing works on them, this comes to reinforce the benefit of this method in the production of inner wall panels.

The application of the cassette technique for the production of floor panels in Bulgaria has greatly decreased its efficiency on account of the increase in the panel height, the decrease of its thickness and its double reinforcement, which render the vibration of the concrete much more difficult. These expenditures of labour are increased by 34 per cent, and the cost price is increased by 9 per cent. In planning solutions with axis longer than 3 meters, the use of the German type cassette proves technically and economically inefficient.

Most expedient techniques for the production of large panels

No determination can be made in general, of the most expedient technique to be applied in the production of each type of panels (face, inner and floor members).

Our experience in large panel production has shown that the concrete solution, the degree of development of the equipment, the capacity of the designed enterprise, and the constructional, reinforcement and planning solution of the panels are all of great importance for the technical and economic effect of the use of one or another technique. In any case, the best technique will remain that one which, with the least expenditure of labour, will give the most exact size members, because it is possible to reduce the finishing works of buildings and those at the large panel works only when the members are prefabricated with a precision of ± 2 mm.

Closed, hollowed forms used in precasting reinforced concrete light elements

By M. Fisac (Spain)

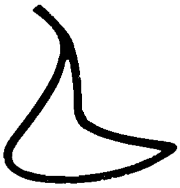

Fig. 1. Closed hollowed form.

Fig. 2. Example of the element as used for the entrance of the Centre d'Etudes Hidrographiques at Madrid.

Up to the present there is no natural or man made building material able to compete with reinforced concrete as regards resources and building possibilities, and even more, after discovering that its steel component can be given all the desired working tensions, before or after its manufacture, by prestressing or poststressing.

Recently there has been much research on this material. Nevertheless, it is evident that its possibilities have not been exhausted.

The theoretical suggestions and practical research I am presenting may be helpful for the use and development of reinforced concrete.

The shuttering problem

Concrete is a matrix which needs to be shuttered to aquire the solidity and resistance necessary to work by setting. The characteristics and material of the shutters, chosen for their building possibilities and cost price, determine forms and sections. For these reasons timber shutters are generally chosen and give rectangular forms and sections to the concrete and are the easiest way to obtain the calculation sections, although they do not necessarily give the best working section or the smallest material quantity. Neither do they give the lightest weight or an adequate aesthetic appearence.

It seems logical that research into a more adequate form for an element be realized in the opposite way to which it has been made so far, i.e. calculating first the sections which will best suit the stresses required from this element, keeping in mind the minimum recommended stock thickness, and last but not least, including an agreeable form with well equilibrated plastic stresses and beauty.

Once the best form has been obtained, we must look for the cheapest method to carry it out. It is quite clear that, should the form and shutters be complicated, the only way to make it economically possible is to use permanent shutters (usually steel shutters) which, despite of their high cost price, will be cheaper as they can be used indefinitely. This method requires precasted bits-and-tructions fitted by a simple poured-in-situ cement (or other bonding), touch welding or by poststressing the various elements between themselves.

Working sections

An element section has to be determined first by its function in the architectural design, as it would be better that this element meet with an architectural function (roof, floor, wall), instead of being only a support for them. On the other hand, the section is determined by the working characteristics, and must give the surface and outline measurements required by the different resisting modulus. The calculation necessities demand large sections but, should the precasted elements be thin, they would present a great fragility during the necessary transportation and fitting.

The solution I propose, to obtain light elements of high resisting modulus (following the instruction of nature in the bone structure of the vertebrates), is to build hollowed and closed forms.

Should these hollowed elements be prestressed it would be possible to reduce the thickness of the element walls to 15 mm; I obtained 20 m long elements with walls of this thickness, and concrete cylindrical test sample, after three days of setting, showed a compression coefficient of 400 kg/cm^2 while the steel tensile strength was of 16,000 kg/cm^2.

Weight and other characteristics of the elements

Should the element sections be carefully determined so that the working coefficients, in their various points, observed exactly the different resisting forces to which they will have to be submitted, in the case of hollow and closed elements—which is the proposed solution—we would obtain a great lightness by reduction of the concrete quantity since it is well known that, as regards concrete girders submitted to a pure bending, a great part of the section does not work and constitutes a dead weight for the structure.

For this reason also, apart from reducing weight, we get first a lower cost and a great rigidity during transportation and fitting, since these hollowed and closed solutions are undeformable, and also a good insulation from noise and heat, particularly since roofs and walls with air-chambers could be filled with glass or rock-wool, cork, etc.

Aesthetic appearances

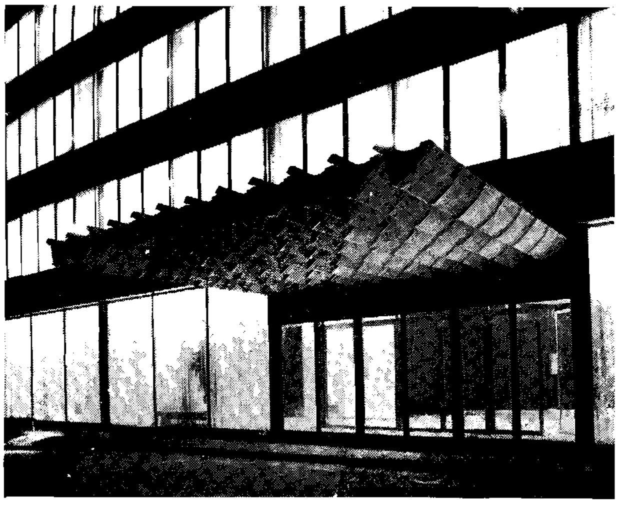

Fig. 3. Entrance canopy at the Centre d'Etudes Hydrographiques, Madrid.

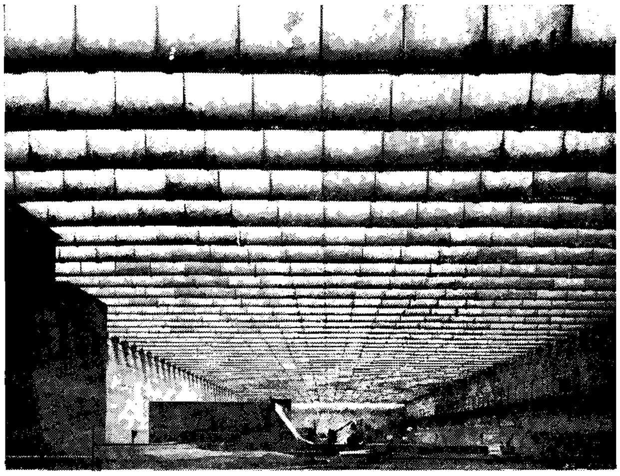

Fig. 4. Ceiling at the Centre d'Etudes Hydrograpihques, Madrid.

The materials and forms used, till now, to shutter reinforced concrete and the constant tendency, during all architectural history, to copy the forms used for already existing materials have the result that, with the exception of shells, reinforced concrete structures have always false appearances copying those of wood, laminated steel, etc. The use of the closed hollow form that I propose, avoids having to depend on an inflexible design in order to get a load-bearing structure, as is the case with laminated steel or wood, but rather gives the possibility of using an element itself to give load-bearing force, as well as a satisfactory architectural expression.

The liberty of formal possibilities in the elements' conception has given to them, and to the ensemble they form, such proper and essential characteristics which are at the origin of a new aesthetic, totally different from those obtained with other materials.

General conclusions on the system proposed

The proposed system is only economically recommendable in the case of precast bits- and -truction solutions, as the obtained elements are generally of difficult sections which require expensive shutters and a careful precasting. The essential ideal is the creation of forms corresponding to the very nature, characteristics and expressivity of reinforced concrete, both in its manufacture and in its working form.

The practical results which might be obtained are:

- light elements, the weight might be reduced by 70% comparatively with the normal one piece rectangular girders;
- material saving—about 75% on the same above mentioned normal solutions;
- lightness and undeformability during transportation;
- increase of noise and heat insulation in the floors, horizontal roofs and outside walls;
- a great building-architectonic synthesis, as the elements meet with their architectural function and at the same time are load-bearing-structures without the necessity of any other kind of structure;
- an aesthetic expressivity completely adapted to the material characteristics, entirely different from that of other materials such as wood, laminated steel, aluminium, etc...

Rational coefficients in the use of erecting mechanisms with respect to their hoisting capacity

By G. Ganev (Bulgaria)

The utilisation of erecting mechanisms according to their hoisting capacity depends chiefly on two factors:

- the system of construction chosen and the variety of the elements by weight;
- the erecting mechanism selected.

The value of the assembly works, and more particularly the expenditure on mechanisation, depends on the amount of machine time necessary and the coefficient of utilisation of the erecting mechanism with respect to its hoisting capacity. If during the designing and the organisation of its execution the above questions have not been correctly solved, the cost of prefabricated construction is raised. As an illustration I shall cite two characteristic examples from our practice.

Bolt factory—Plovdiv. As a rule, the general construction and organisation of the building site were well solved and executed. For the roofing construction, however, were envisaged small concrete columns of 0.08 m^3 volume each, or of 200 kg approximate weight. From the analysis carried out, it was found that one cubic meter of steel concrete in the form of a fully completed and mounted column costs 326 leva, of which 200 leva went for the assembly work. Of these 200 leva, a 100 leva (50 per cent) were spent on the erecting mechanism, which was capable of hoisting elements up to 10 tons in weight. In this case, the erecting mechanism was utilised 2 per cent with respect to its hoisting capacity, which is extremely unsatisfactory. We must note that by volume the columns under consideration constituted only 5 per cent of the volume of the whole roof, and in value 10 per cent. This is explained by the inadequate utilisation of the erecting mechanism with respect to its hoisting capacity, as a result of an irrational method of design and execution of the column assembly, involving much machine time, which is disproportionate to their insignificant weight.

State Industrial Enterprise "G. Dimitrov"—Sliven. This factory has a shed roof. The weight of its main beams is about 10 tons, and that of the roof plates—250 kg. In the case of this construction site, it is of great importance that the number of roof plates is large, and that not more than two such plates can be hoisted at a time. The utilisation of the erecting mechanism in this case will be 5 per cent for a large part of the elements. As a result of this, the construction cost will inevitably be raised, and its assembly time will be considerably extended.

The above and other similar examples show that the question of the influence of the utilisation coefficient of erecting mechanisms with respect to their hoisting capacity upon the cost of assembly works remains as yet unsolved. With our present investigations along this line, we have made it our aim to elucidate analytically this phenomenon, and, with this end in view, to specify the most rational limits within which this utilisation coefficient can vary, in order to reduce the costs on assembly works to a possible minimum. We assume the following basic magnitudes and their corresponding indications:

K_i – utilisation coefficient of the erecting mechanism with respect to its hoisting capacity;

T – Hoisting capacity of the erecting mechanism (for bridge cranes, excavators tower cranes, automatic cranes, etc. having a hoisting capacity that is independent of the working length of the jib) in tons;

T_i – weight of a given prefabricated element in tons;

$$K_i = \frac{T_i}{T} \qquad (1)$$

C – cost of machine shift for the selected erecting mechanism in leva per machine shift of 8 hours;

N_i – the necessary machine time to assemble the prefabricated element;

M_i – cost in leva for the erecting mechanism, necessary for the mounting of one element;

m_i – cost in leva for the erecting mechanism, necessary for the mounting of one ton of the given element

$$M_i = N_iC \qquad (2)$$

$$m_i = \frac{M_i}{T_i} \quad \text{or} \quad m_i = \frac{N_iC}{T_i} \qquad (3)$$

From formula (1) we obtain

$$T_i = K_iT$$

We substitute this result in formula (3):

$$m_i = \frac{N_iC}{K_iT} \qquad (4)$$

Since C and T are constant quantities for a given erecting mechanism, we can assume that:

$$\frac{C}{T} = A = \text{constant.} \qquad (5)$$

where A is in fact the cost of one machine shift as referred to one unit of hoisting capacity in leva per 1 ton.

From formulas (4) and (5) we shall obtain the following:

$$m_i = A\frac{N_i}{K_i} \qquad (6)$$

If we mount an element having such a weight that $K_i = 1$, i.e. $T_i = T$, and indicate its counterparts N_i by N_1, then formula (6) will assume the following appearance:

$$m_1 = A \cdot N_1 \qquad (7)$$

Index "1" indicates that we have a 100 per cent utilisation of the erecting mechanism with respect to its hoisting capacity, and we assume the value m_1 as a standard, a basic unit of comparison in our further investigations. When we divide equation (6) by equation (7) we obtain

$$\frac{m_i}{m_1} = \frac{A\frac{N_i}{K_i}}{A\,N_1} = \frac{N_i}{K_i\,N_1} \qquad \frac{(6)}{(7)}$$

$$\frac{m_i}{m_1} = \frac{1}{K_i} \cdot \frac{N_i}{N_1} \qquad (8)$$

When $m_i = m_1$ we shall have:

$$\frac{m_i}{m_1} = 1 = \frac{1}{K_i} \cdot \frac{N_i}{N_1} \quad \text{or} \quad \frac{N_i}{N_1} = K_i = \frac{T_i}{T}$$

Consequently:

$$m_i = m_1 \quad \text{when} \quad \frac{N_i}{N_1} = \frac{T_i}{T} = K_i \qquad (9)$$

By making analogical deliberations in the instances when:

$$\frac{m_i}{m_1} > 1 \quad \text{i.e.} \quad m_i > m_1$$

$$\frac{m_i}{m_1} < 1 \quad \text{i.e.} \quad m_i < m_1$$

we shall derive the following condition:

$$\text{If} \frac{N_i}{N_1} \gtreqless K_i, \quad \text{then} \quad m_i \gtreqless m_1 \qquad (10)$$

From the expressions (9) and (10), the following basic inference can be drawn: in order not to raise the assembly cost per ton of the element by the expenditure on the erecting mechanism, when the latter is not fully utilised with respect to its hoisting capacity ($K_i < 1$), it is necessary for the assembly work to be organised in such a way that $(N_i/N_1) < 1$, i.e. the relation between the standards of the machine shifts of any element and that, at which $K_i = 1$ ($T_i = T$), should be less than 1 and at most equal to $K_i = T_i/T$.

If we assume that: $N_i = A_i N_1$, formula (8) will assume the following appearance:

$$\frac{m_i}{m_1} = \frac{A_i}{K_i} \qquad (11)$$

$$m_i = \frac{A_i}{K_i} \cdot m_1 \qquad (12)$$

The situation is normal when $N_i/N_1 = A_i \leqq 1$, otherwise ($A_i > 1$) the organisation of the assembly work has some substantial and inadmissible faults.

The interdependence between m_i, m_1, A_i and K_i is shown graphically in Fig. 1.

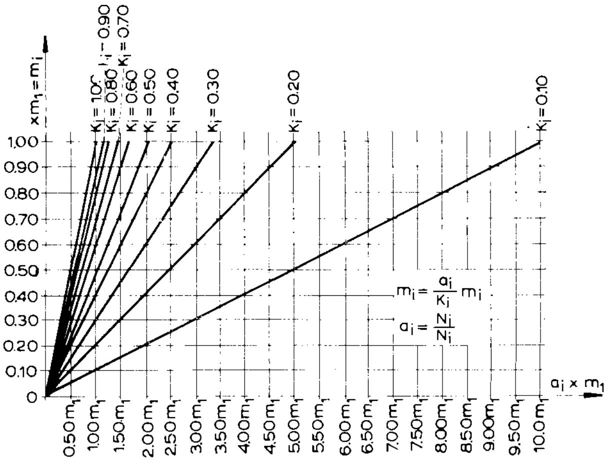

Fig. 1.

The determination of the loss of means, which is realised (or the increase in cost) for a building on account of not fully utilising the erecting mechanism with respect to its hoisting capacity, will be carried out by means of the following formula:

$$O = Q\,(m_{cp} - m_1) \qquad (13)$$

The basic magnitudes in Formula (13) are determined in the following way:

m_1 – preserves its former meaning according to formula (7) leva/ton;

Q – Total weight of elements in tons.

$$Q = n q_{cp} \qquad (14)$$

n – total number of elements;

q_{cp} – average weight of one element,

$$m_{cp} = A \cdot \frac{N_{cp}}{K_{cp}} \qquad (15)$$

A – preserves its former meaning according to formula (5);

K_{cp} – mean coefficient of utilisation of the erecting mechanism with respect to its hoisting capacity for the entire building,

$$N_{cp} = \frac{\sum\limits_{i=1}^{i=n} N_i}{n} \qquad (16)$$

$\sum\limits_{i=1}^{i=n} N_i$ – total machine time necessary for the mounting of all elements;

N_{cp} – average machine time necessary for the mounting of one element.

As a rule, $\sum\limits_{i=1}^{i=n} N_i < n \cdot N_1$, i.e. $N_{cp} < N_1$ as during the assembly of elements having a weight that is less than the hoisting capacity of the erecting mechanism fewer machine shifts are effected than during the assembly of elements of a weight greater than the hoisting capacity. Any contrary situation should be considered as a rare exception imposed by exclusive reasons. We must underline that this fact does not have any influence whatsoever on the basic formulae and conclusions, i.e. the latter are generally valid from this point of view.

Determination of the rational limits of K. Having as a basis the above analytical investigations, we can determine comparatively the most rational limits, within which K_i should vary, in order to reduce to a minimum the costs on the assembly of prefabricated constructions.

In order to derive the necessary expressions, which shall solve the above question, we shall make use of the independent effect of the basic factors A_i and K_i directly influencing m_i, which can be seen from the basic formula (12).

1. Influence of A_i

We assume that K_i = constant. Then m_i/K_i = const. = D.

$$m_i = D.A_i \qquad (17)$$

The linear functional dependence between m_i and A_i is evident; its graphic expression is given in Fig. 2.

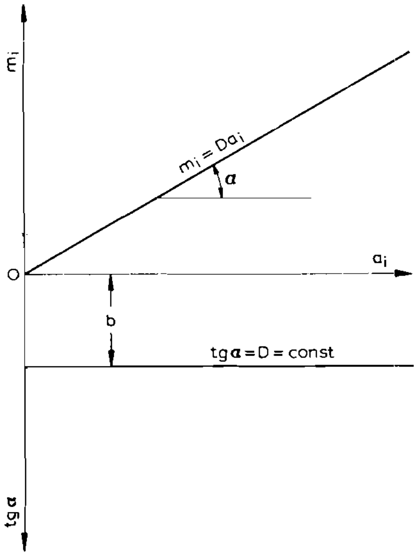

Fig. 2.

$$tg = \frac{dm_i}{dA_i} = D = \text{const.} \qquad (18)$$

The slope of the straight line represented by equation (17), which is expressed by $tg = dm_i/dA_i$, determines the tempo and the manner in which m_i grows with the increase of A_i. Since tg = const. (Fig. 2), the changes obtained in the m_i lines are uniform, identical in magnitude and sign, with corresponding changes of argument A_i.

2. Influence of K_i

We assume that: A_i = const. Then $m_i \cdot A_i$ = const. = B

$$m_i = \frac{B}{K_i} \qquad (19)$$

In this case the dependence between m_i and K_i is inversely proportional (hyperbolical), its graphical appearance is given in Fig. 3.

$$tg\beta = \frac{dm_i}{dK_i} = -\frac{B}{K_i^2} \qquad (20)$$

It can be seen from formula (20) that $tg\beta = dm_i/dK_i$, expressing the magnitude and the way in which m_i changes with composed changes in the argument K_i, is not a constant magnitude. It is in a function with K_i whose graphical appearance is shown in Fig. 3. Consequently, in this case (influence of K_1) there is no uniformity of the changes in size of m_i, which is also the vital difference from the first case (influence of A_i on m_i). This characteristic feature gives us ground to turn our attention to the second case.

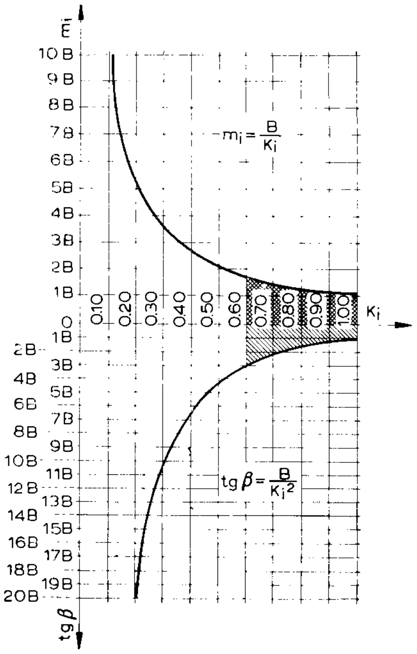

Fig. 3.

When examining the graphs in Fig. 3, the following situation inevitably suggests itself.

The changes in the lines of K_i are most appreciably reflected on the size of m_i when occurring in the interval from 0.10 to 0.60, i.e.

$$0.10 \leqq K_i \leqq 0.60 \tag{21}$$

And on the contrary, these changes render a lesser influence on m_i in the interval from 0.60 to 1.00, i.e.

$$0.60 \leqq K_i \leqq 1.0 \tag{22}$$

The intervals shown in the expressions for K_i in (21) and (22) determine in fact the irrational (0.10 to 0.60) and the most rational limits (0.60 to 1.00), within which the coefficient of utilisation can vary in the erecting mechanisms with respect to their hoisting capacity—K_i.

For the needs of practice it is necessary that the following rule should be accepted and observed:

In order to spend minimum means for the execution of the assembly work, the designing, construction and execution of the erection should be performed in such a way that the coefficient of utilisation of the erection mechanisms with respect to their hoisting capacity should be at least equal to 0.60.

In prefabricated construction there are substantial reserves for lowering its cost and cutting down the contruction terms. To discover and utilise most rationally these reserves is an important task, the solution of which will push still further ahead Bulgaria's construction. The determination of the optimal weight of the elements in prefabricated constructions, with a view to achieve a most rational coefficient in utilising the erection mechanisms with respect to their hoisting capacity, constitutes an exact elucidation of the reserves involved in this respect. We have determined the most rational limits for K_i, thus solving indirectly the question of the optimal weight of elements. It should not be assumed that it will be an absolute figure, generally valid for all cases, but should always be connected with the respective erection mechanisms. Consequently, the selection of the optimal weight of elements should be carried out in parallel, in compliance with the above conclusion.

Flexible design of concrete multi-storey buildings

By T. Gerholm (Sweden)

Buildings provide places where people live and work and therefore should be suitable to our way of life and needs. They are continuously transformed following changes in living habits, largely caused by the introduction of new machines and new housing equipment for lightening work and raising the standard of living. Before the rapid industrial development of the post-war period these changes were slow and habits of living more or less static. In addition, houses were so built that changes could be made relatively easily. They were serviceable for a long period, the only limit often being their technical length of life. Now changes are taking place more rapidly; the rebuilding and demolition of houses, even of good quality, is an every-day occurrence.

This development can be met in two ways. Houses can be made of such low quality that they are ready for demolition in a short time, or they can be made of high quality and flexible. The first case involves waste of labour and material that are so badly needed in a time of housing shortage. The second places great demands on perfection of form based on advance planning, and construction with exact building units by skilled workers. These requirements lead automatically to precast building elements and construction by mechanics; that is to say, from being mainly a handicraft, the work becomes purely industrial.

This contribution deals with a method for the erection of flexible concrete houses. The static part of the building has been tested on full scale models, in so far as it was already known.

Requirements

Rapid changes are taking place in the centres of cities, where dwellings have to make way for office buildings. This is usually done by demolishing dwelling-houses, even if they are still serviceable. If walls, wiring and pipes could be easily moved and new local connections such as doors and stairs could be made, most multistorey houses could be used as offices; thus less material and labour would be required for office building and the resources for the building of dwellings would be increased.

The following conditions are possible if:

1. The inside and outside walls are not load-bearing.
2. Walls and floors rest on a quickly erected skeleton structure without being firmly joined to it.
3. All pipes and wires are led up fixed vertical structures such as staircases and then, supported by the floors, are led to the various parts of the house where they are to be used.
4. Only the framework, the staircase and possibly some ducts for pipes and wires are rigid, but not firmly connected with the flexibly assembled members of the building. In this connection the skeleton of dwelling-houses must probably be over-dimensioned when the possibility exists of the building being changed into a block of offices or being rebuilt.
5. All these building elements are standardised with exact measurements and strength properties and with modules that make possible large variations in construction.
6. The pipe and wiring installations and other fixtures are also standardised and easy to assemble.
7. Everything is planned in advance and thus the work on the site can proceed smoothly.
8. We realise the need for variation because we are building for human beings with individual needs and not for robots.

The usual method of building dwellings with load-bearing party walls and fixed self-contained room units makes changes almost impossible for economic reasons—in any case in concrete houses. The static life of these houses is very long and they will have to be demolished long before they are worn out. There is a grave risk that we may build houses in the centres of cities that will turn into slums in a few decades, and these houses will be very difficult to pull down.

The method with floating walls and floors and sound traps on all water-pipes where they pass from the climbing shaft to the floor also gives better sound insulation.

Description of the load-bearing skeleton

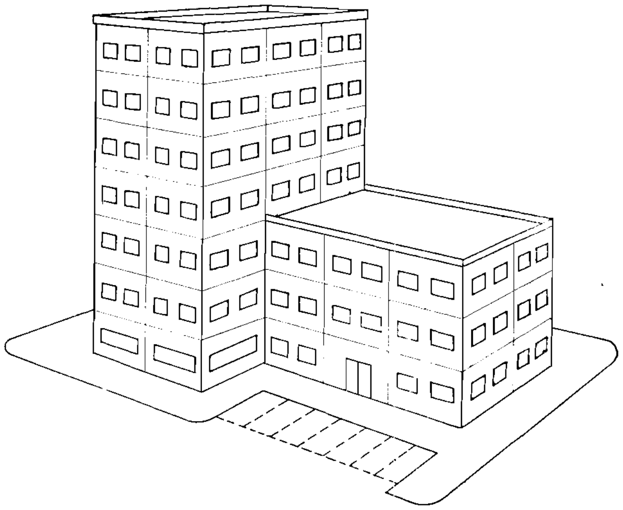

Fig. 1. Exterior of an apartment house or office building.

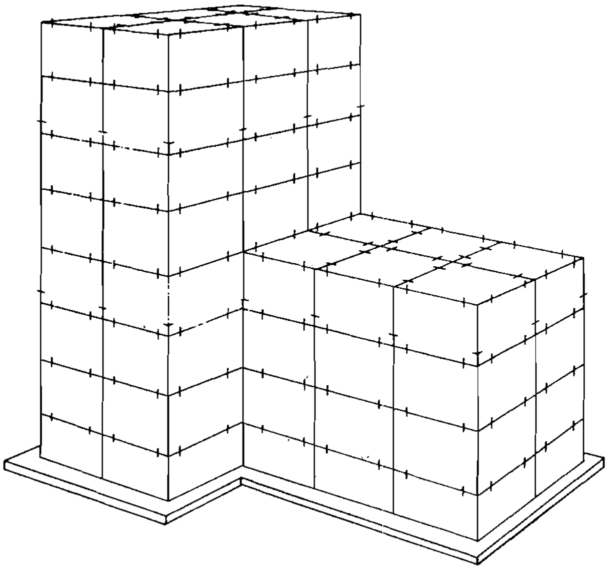

Fig. 2. Skeleton of the same building with marked joints beween column and beam elements.

Fig. 1 shows the outside of an office building or apartment house, and Fig. 2 the skeleton of the same building. The framework consists of columns made of concrete elements that can be two or three storeys high, and facing and centre beams and cross members serving as lateral force stiffeners attached to the columns. All these elements are made of reinforced concrete and

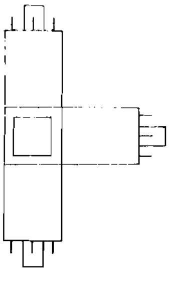

Fig. 3. Column element seen from above with protruding beam supports and groove for the column.

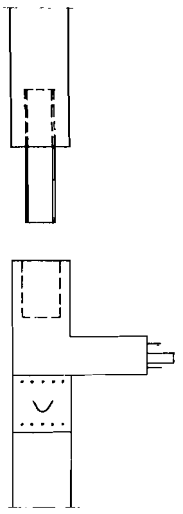

Fig. 4. The column to be jointed.

joined to the columns to form a solid bearing system. In the same way the column elements are fixed one on top of the other to the required height. The horizontal lines in Fig. 2 show the points where the jointing is done. Fig. 3 shows a column element from the side and seen from above. The columns have protruding beam ends for fixing in the members. Fig. 4 shows part of the jointing of two column elements. The lower element has a groove in the top into which a steel jointing member protruding from the element above can be fixed, so dimensioned that it can transfer stresses in the joints. Before the assembly of the element above, its height is adjusted with spacers in the groove. After assembly the element is fixed in position by the joint mould shown in Fig. 5.

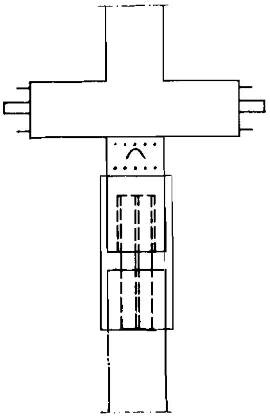

Fig. 5. Column being jointed. The mould also serves to hold the column parts in position during jointing.

The jointing between the columns and beams is shown in Fig. 6. The beams placed on pads automatically get the right position in height and laterally and do not need to be supported when the joints are cast. The work is described in the following.

The cross-beams are so designed that their lower side is on a level with the lower side of the floor forming a flat ceiling.

The members are jointed on or near zero point. The steel connecting bars are dimensioned to absorb shearing stresses that may occur in the joints. After the joints are welded, at least 50% of the calculated load is transferred to them and after being jointed together they function as if the construction were monolithic.

The building process

(a) The columns are placed and embedded in the grooves in the foundation or in the underlying column.

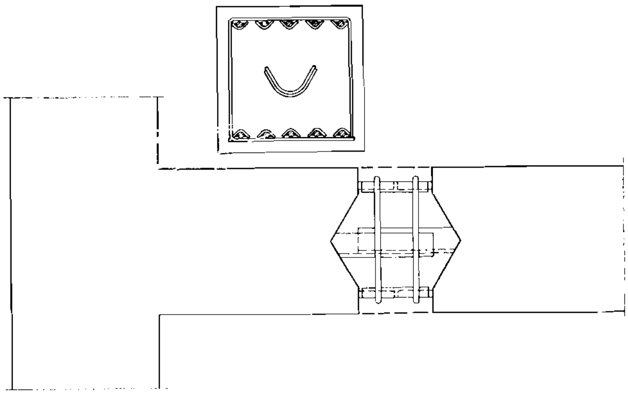

Fig. 6. Jointing between column and beam. The beam is mounted on the support protruding from the columns. The reinforcement is welded to the bent connecting plates. The joint can now take the building load. At a suitable time the joint is concreted.

(b) The load-bearing beams of the first storey are erected on the abutments of the columns and are welded. When all the beams are welded, the placing of the beams of the next storey can begin immediately at the same time as the beams of the first floor are jointed. Meanwhile the joints of this floor take all structural loads without being supported.

(c) When the top of the bottom columns is reached, new columns are jointed to them in the way described above. These joints also immediately take the loads that may occur.

(d) After jointing the load-bearing beams of the first floor, the floor elements resting on an elastic bed, e.g. rubber, are placed and jointed together.

(e) When the floor and ceiling of a storey have been erected, the walls are erected, the party walls being made of double concrete elements with an intermediate layer of air and walls between rooms in the flat of single elements. All the concrete elements are placed on elastic underlays, e.g. rubber, and are jointed by rubber concrete at the top to the floor above and to one-another in the same way (fig. 7).

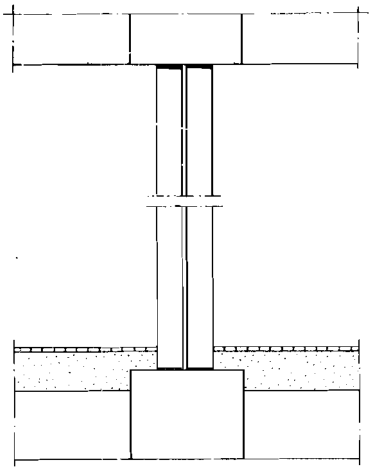

Fig. 7. Party wall formed of a double concrete element. It rests on rubber and can also stand on any part of the floor. The element is jointed with rubber concrete on the top and in between. The distance between the floor surface and the underfloor is sufficient to hold the pipes according to the text.
The wall between rooms is made of single elements.

(f) The outer walls should be filled in with light-weight transposable elements. Several systems of this type already exist.

(g) The pipes and wires are drawn up the staircases or up independent shafts which are jointed to floors and walls with rubber concrete. The distance between the surface of the finished floor and the top of the concrete elements forming the floor below is made large enough for the pipes to lie on the concrete floor under the finished floor and be led to wherever they are required in the flat.

What are the advantages of this system?

Strictly speaking, this method is an application to concrete houses of the methods used for building steel houses, combining the rapidity of erection in steel with the finished surfaces of concrete, its workability, its fire resistance and sound insulation properties. It has got flexibility without the sacrifice of technical quality. Owing to the fact that the floors and walls float on the skeleton and thus every part is elastically jointed to the next part, the sound insulation is good. Changes in the flats by removing walls and pipes and wires can be made without the rest of the building being affected.

If sufficiently small modules are chosen, e.g. 2 – 3 × 30 cm, the need for types of elements is reduced to a minimum in spite of the fact that the variation in the use of the elements is very considerable. The room heights and the widths of the houses are now also standardised to a few measurements, and thus the column elements and the load-bearing beams of the skeleton are also standard.

If can be gathered from the above that this type is suitable for mass production in factories and that the assembly must be done by mechanics. The houses should, if possible, be delivered with the skeleton assembled. In fact, it seems likely that, with the possible exception of the painting, everything is the work of experts. This is also the case with any changes that may be made later, which should be done by experts in the job.

As long as house-building is a handicraft or a combination of work on the site and prefabrication, it will be impossible to catch up with the housing shortage with the resources we have in labour and material. The only way to succeed is to industrialise completely the building of apartments or offices and build adaptable houses made entirely of standardised parts.

Design and erection of prefabricated shells

By K. A. Gluckovski (U.S.S.R.)

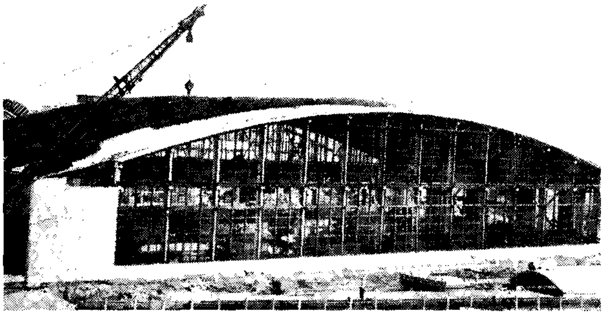

Fig. 1. 100 m span barrel vaults.

This report presents the Soviet experience on the design and construction of large-span buildings. The subject of the report is limited to consideration of spatial structures of the shell type, assembled of prefabricated reinforced concrete elements.

The monolithic reinforced concrete shells of former days were of unique construction and required bulky form-work and supporting scaffolding.

Fabrication of precast reinforced concrete shells was started in the USSR only in the previous decade. Primarily shells were made individually. In 1955 2 first positive double-curved shells (18 × 18 m) were fabricated in Leningrad. Among later erected structures the most prominent are: a shop of the Leningrad House-Building Plant with a 100 meter-span barrel roof, a bus garage with shells (dimensions 40 m × 40 m), the Sports Palace (the dome 76 m in diameter) in Tbilisi, and an exhibition pavilion with a shell (48 m × 48 m), etc. Up to the present moment, up to 1 million sq. m of different types of prefabricated reinforced concrete shell constructions have been made.

Cranes with a hoisting capacity of up to 5 tons may be suspended by precast shell constructions and lighting may be placed on them.

Survey of designing and scientific research

At present much progress has been made in designing spatial structures in the Soviet Union. Practical methods of calculation are being worked out and improved. In addition to elastic stage calculations Soviet researchers have developed methods of calculation, taking into account non-elastic deformations as well as methods of limited equilibrium calculation. Application of these methods will help to assess correctly the carrying capacity of shell-roofs. Models and natural-size samples of precast shell constructions are being experimentally studied. The present experience is summed up in the "Instructions for the Designing of Spatial Thin-walled Roofs and Floors".

Application of computers for shell calculations is being planned. Within the last 10 years several types of precast shell constructions have been developed in the USSR: cylindrical (short and long), Gauss double-curved type (positive and negative), barrel, channeled vault type, etc. Despite the great variety of the types, all were designed with a view to dismembering them into units satisfying the requirements of prefabrication and erection on the site.

Prefabricated shell elements are manufactured on highly-mechanised flow lines of modern ferro-concrete plants and are carried to construction sites to be erected there. After setting elements into the desired position, shell joints are made monolithic. Such structures are referred to as prefabricated. Cylindrical and positive double-curved shell constructions are finding the widest application. Depending on the technological requirements of production, hence on the desired network of columns, this or that type of shell construction is preferred (see Table).

Application of short cylindrical shells assembled of flat slabs (3 m × 12 m) saves up to 8 per cent more materials and labour as compared to the use of plane roof constructions, and meets the requirements of unification and installation of suspension transport facilities. Application of long cylindrical shells made of curvilinear elements saves more concrete and steel, as well as labour and erection time. These shells satisfy construction unification requirements, and permit to solve the problem of suspension transport facilities and suspension ceilings installation in buildings with a 12-m pitch of columns, on a rational basis. Application of precast sloping shell constructions of positive curvature, intended for roofs of buildings with a large network of columns (rectangular grand plan) is of particular interest. Up to 25 % of concrete and steel is saved.

In 1961 designs of precast sloping positive shell constructions for 10 similar sizes (18 m × 18 m to 26 m × 36 m) were developed for the first time. This construction is a sloping double-curved ribbed shell supported by stiff diaphragms along its contour. The shape of shells of the series is a polyhedron with rhombic faces inscribed into a translational surface.

The shell of the construction is assembled of 3 m × 3 m flat square slabs provided with stiffening ribs. Joints of slabs lend rhombic shape to a shell made of square slabs. Contour diaphragms are designed as braced, or braced latter, trusses. Slab-shells are joined together, and to contour trusses, by welding; reinforcement bar ends and joints are made monolithic. Dowelled joining of shell elements which does not require welding is being developed. With a view to making shell construction assembly easier and cheaper, the designers have developed multichannel shells (36 m × 36 m) made of slabs (3 m × 12 m). Plans of a series of shell constructions to be assembled of slabs (3 m × 6 m) are being worked out. Such shell constructions (12 m × 24 m to 18 m × 36 m) are assembled without scaffolds and with the aid of rigid traverses. The development of designs of a series of

Technical and economic performance of prefabricated shells.

Name of constructions	24 m span			36 m span		
	Concrete consumption cm/m^2	Steel consumption kg/m^2	Labour-consumption hours/m^2	Concrete consumption cm/m^2	Steel consumption kg/m^2	Labour consumption hours/m^2
1. Barrel shells	7.80	10.1	1.91	8.60	12.70	2.43
(column pitch 12 m)	73 %	76 %	91 %	75 %	81 %	96 %
2. Double curved shells	7.40	9.0	1.81	8.1	9.7	2.09
	68 %	68 %	86 %	70 %	60 %	82.5 %
3. Standard plane slab	10.70	13.20	2.10	10.50	16.0	2.53
constructions	100 %	100 %	100 %	100 %	100 %	100 %
(column pitch 12 m)						

Note: Standard plane slabs are reinforced with prestressed bars.

multi-channel shells (12 m × 24 m to 36 m × 36 m) assembled of large-size slabs (3 m × 6 m and 3 m × 12 m) is nearing its end.

Prefabrication of reinforced concrete shells

The powerful precast reinforced concrete production industry organised in the Soviet Union within the last 10 years has created facilities for mechanised prefabrication of ferro-concrete shell elements. In its turn, prefabrication called for maximum unification of elements as well as development of construction which would be made of the minimum quantity of finished articles of similar sizes.

At present, a number of technological lines operate in the Soviet Union. For instance, the Leningrad Ferro-Concrete Plant has a special shop fabricating elements of reinforced concrete double-curved shells. The shop produces flat ribbed slabs (nominal dimensions 3 m × 3 m) and contour diaphragms which are assembled into shell constructions (18 m × 18 m to 36 m × 36 m). Elements are fabricated on the mechanised conveyor production line. Panels are moulded by the jarring machine which is a self-propelled gantry concrete placer provided with a vibrating cap which rests on the edges of the mould during operation.

The annual rated capacity of the shop is 265,000 sq. m. of roofing. Contour constructions in the form of prestressed trusses are fabricated by the stand method. They are produced on the frame type stands which operate as steam-curing chambers at the same time. Metal moulds are used in fabricating shell slabs and truss diaphragms.

In Pskov, curvilinear elements of cylindrical shells (3 m × 12 m) are fabricated on the mechanized production line with the capacity of 40,000 sq. m. of roofing per year.

This installation turns out panels by the stand method in metallic moulds with steam jackets. As the surface of panels (3 m × 12 m) is cylindrical and its generatrix is a straight line, moulding can be also effected by means of a machine with a vibrating cap, which travels along the curvilinear ways of the mould.

A similar production line equipped with 12 steel moulds (the annual capacity – 130,000 sq.m.) operates in Krasnoyarsk. Concrete mix is placed by the moulding machine equipped with the sliding vibrating dye. The sliding vibrating dye idea is employed in a moulding machine designed in Kiev.

It moulds elements in the form of hyperbolic paraboloids which are assembled into channeled vaults. The machine is supplied with a change vibro-template and can be used for moulding articles of different geometrical design. Harsh concrete mixes (water-content 0.38–0.45, placeability 40 to 100 sec.) are placed in fabricating shell elements. Seven-wire strands of cold-drawn high-tensile steel wire (rated strength 15,000–19,000 kg/sq. cm) are used as prestressed reinforcement in contour diaphragms.

Improvements in assembling spatial structures

The first shells in Leningrad were assembled on the floor level and placed in monolithic state into the desired position with the aid of elevators. The assembly of the shell of the Sports Palace in Tbilisi was performed by the suspended roof method without scaffolds, but this entailed greater consumption of concrete and reinforcement per 1 sq. m of the roof space. Barrel shells and some other shells are assembled without supporting scaffolding, which is another economic advantage. The evolution of improvements in assembly of the large positive double-curved shells is of particular interest, because they ensure the least consumption of concrete and steel per space unit. The assembly of such shells (18 m × 18 m to 36 m × 36 m) made of flat prefabricated slabs (3 × 3 m) calls for application of standard supporting scaffolds, which ensure the desired shape and stability during erection. Originally, independent cross-bar scaffolds were used; they had to be completely dismantled when placed in the adjacent position. Later, block telescopic (Fig. 2), then netlike scaffolds and, finally, rigid universal conductors were introduced (Fig. 3).

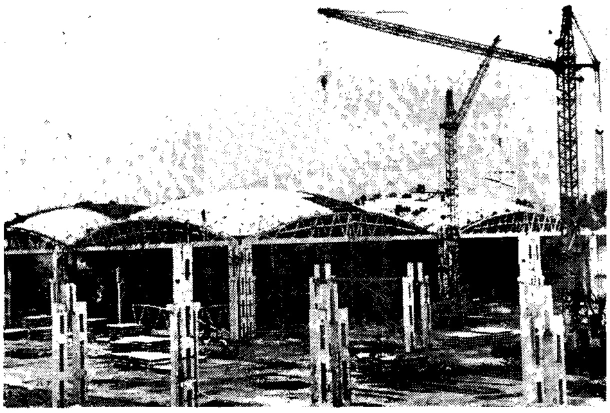

Fig. 2. Double curved shell erection.

The introduction of universal portable conductors has cut erection time considerably, because it has brought erection preparation time to the minimum. The use of universal conductors is effective only in case of their repeated utilisation, which may be ensured by the planned construction of a large number of identical shells. Depending on the type of the supporting equipment used, the terms of shell assembling change. For instance, the Leningrad building experience shows that assembling, and making monolithic, a 36 m × 36 m shell with the aid of independent cross-bar scaffolding take 20 days, whereas the assembly of the same shells with universal conductors is completed in 10 days.

All other operations connected with shell assembling (column, contour girder erection, etc. included) are performed by conventional means and methods. Conventional crawler or pneumatic cranes, tower, and gantry cranes are used. For assembling of the elements of spatial structures, shells are made monolithic by welding of the reinforcement bar ends of slabs and by subsequent concreting of joints by the method of pneumatic concrete by means of straight flow pumps. The quantity of concrete used for making precast shells monolithic, does not exceed that used for similar purposes in the case of ordinary flat-slab constructions, and it makes up about 14–15 per cent of the total roof volume.

New methods of attaining quality

Inspection. The necessity of complete quality inspection of all precast reinforced concrete shell elements has required the application of non-destructive testing techniques including electronic and acoustical, radiometrical and magnetic tests. The checking and measuring equipment is installed at the plants according to the technological scheme of precast reinforced concrete shell element production and it ensures complete operational quality inspection of all article during the process

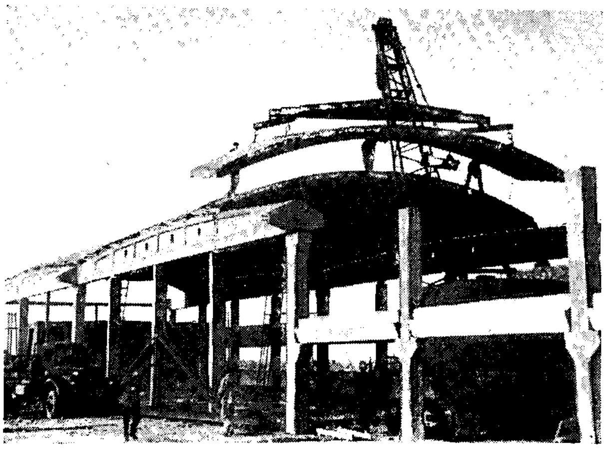

Fig. 3. Barrel shell erection.

of their fabrication as well as finished articles at the end of the line.

In addition to the stationary installations, the mobile laboratories are called to perform spot checks on the construction site. These mobile laboratories carry out quality checking of the prefabricated shell elements after they have been made monolithic.

Conclusion. To ensure a wide application of spatial structures a spatial structure development coordinating council has been formed under the State Construction Committee. Specialised erection organisations and departments at Scientific-Research and Designing Institutes have been set up as well. In Leningrad, Krasnoyarsk and Kiev experimental specialised organisations of the house-building plant type are being established, their responsibility being both prefabrication and erection of spatial structures. Several Research Institutes are working on the improvement of calculations, designs, fabricating, testing and erection techniques as well as perfecting the methods of technical and economic assessment of spatial structures. Instructions for designing and construction have been published. The Soviet experience accumulated in industrial and civil construction involving application of prefabricated reinforced concrete shells shows the following conclusions:

- precast shells are considerably rigid and earthquakeproof;
- as compared with flat slab constructions the present precast shells require less concrete and steel by 25—35 per cent and cut production costs by 14—20 per cent, while the similar figures for structures soon to be introduced are 35—40 per cent and 20—25 per cent respectively;
- further improvements in shell designs and extension of effective utilisation of shells, call for development of calculation techniques with application of electronic computers, which would take into account design features of prefabricated shells, material properties, selection of effective shapes of shells and methods of their erection. It is necessary that methods for modelling, as well as studying, long-term processes (creep, stability, etc.) required for complex configuration shell strength investigations, should be developed rapidly. It is necessary to perfect methods and equipment for testing constructions.

Reference

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Economic efficiency of industrialised structural designs of residential, public and industrial buildings in the U.S.S.R.

By P. Gorbushin, S. Lazarevich and B. Skorov (U.S.S.R.)

The main way towards industrialisation when erecting various buildings and structures is the factory production of details and complete elements of buildings and their mechanized erection at the site.

In the USSR there have been created favourable conditions for extensive development of the industrialised construction of residential, public and industrial buildings as well as various engineering structures. Technical progress in the field of construction in this country has reached a high level and fully meets all the requirements, ensuing from the industrialisation of construction.

The use of prefabricated structures is the backbone of the industrialisation of construction. In the decade from 1950 to 1961 the production of precast concrete structures and units in this country has increased from 1.3 mil. cu.m. to 39 mil. cu.m. and in 1964 it was as high as 54 mil. cu.m.

The Soviet system of planning ensures the proportional development of construction, building materials industry and production base of construction.

The most extensive application of industrialised methods of construction has been made in housing.

This report deals with economic advantages of industrialised construction as compared with conventional methods. The increased productivity of labour and national income are economic effects of the industrialisation of construction. It results in the reduction of labour and material consumption, weight of buildings and construction time.

The industrialisation of construction has, besides economic, some social effects; speeding-up of satisfaction of housing demands improvement of cultural and welfare services, provision with consumer goods, facilitation of the work of builders as well as raising of cultural and technical standards.

Structural designs

In this country standard designs are widely used in all the fields of construction. Standard designing ensures the improvement of quality, makes the design economic, reduces the designing time and costs. It creates favourable conditions for maximum unification of factory made elements and thus for the considerable reduction of their cost.

In 1963, 95.2 per cent of the total volume of public and cooperative housing construction were carried out as per standard designs. On the average 94 per cent of public buildings of mass construction such as schools, kindergartens and nurseries are constructed as per standard designs and, in some Republics, this figure amounts to 87–100%.

In 1963 45 per cent of industrial buildings and structures were constructed as per standard designs.

At present standard designing in industrial construction is directed towards creation of type-section and bays for various types of buildings in all branches of industry. This standard design method fits well for a great variety of production processes even within one branch of industry and for rapid changes to be made in the technology of production resulting from technical progress.

The planned development of national economy of the USSR creates favourable conditions for using most economic designs. Housing construction is usually based on designing big com, plexes, comprising residential and public buildings, traffic routes-water supply, sewerage, power supply, etc.

Industrial construction is based on designing combined industrial complexes, comprising enterprises, a system of access roads and railways, water and power supply and ancilliary premises in common use. Designing on the basis of big complexes in industrial and housing construction assists in introducing industrialised methods of construction and better utilisation of the technical base. Housing construction carried out in big complexes results in cutting down construction costs on the average of 6–8%. Construction of combined industrial complexes allows to reduce capital investments by 5–10% and the cost of construction works and erection operations by 8–15%. In the Angarsk industrial project the reduction of capital investments was as high as 23 per cent.

At present three main types of residential buildings are mostly used in state housing construction: brick, largeblock and large-panel types. In 1963 they made up 87% of the total volume of state construction. It should be noted that all main structural elements except walls in brick buildings, and all structural elements without exception in large-block and large-panel buildings are made prefabricated. The use of large-panel structures is the main trend in housing construction. Their percentage is constantly increasing: thus, in 1959 the figure was as low as 2%, in 1961 – 13.8%, while in 1965 it will reach 33% of the total volume of housing construction to be carried out by state and co-operative organisations. In large-panel construction a most wide use is made now of the three main types of buildings: 1) framed buildings: 2) buildings with load-bearing internal and external walls; 3) buildings with load-bearing cross walls. The latter type is gradually ousting the other two and buildings with load-bearing cross walls are becoming predominant.

Buildings with load-bearing cross walls may be of two design schemes: 1) with cross walls spaced at 3.2 m and 2) with cross walls spaced at 5.2–6.0 m. The latter allows for better planning and is more promising. However, the former type is at present prevailing. Large-scaled use of type design series makes it possible not only to reduce the cost of factory production of structures but also the cost of fabrication of equipment for house-building factories which in this case become serial.

Technical and economical data for various types of large-panel buildings vary but little. Thus, in respect of the cost and man-hours required the deviation will be within ± 2%.

Precast concrete is the main structural material used for large-panel buildings. The external wall panels may be of two types: sandwich panels and single-layer made of concrete on lightweight porous aggregate or of cellular concrete.

The construction of large-panel buildings as per standard designs with most rational planning allows to cut down the overall construction cost. In 1963 the cost of 1 sq.m. of living area in large-panel buildings was 13 per cent less as compared to brick buildings of conventional type. The cost of large-panel buildings is 6–7% lower than that of buildings with load-bearing brick walls and precast floors, roofs and partitions.

Large-panel structures for public buildings owing to their specific planning (large areas for separate rooms and large spans) are so far used only on an experimental basis. At present public buildings of mass construction are of framed type with load-bearing brick walls. Large-block school buildings are used on a large-scale. The study of public buildings designs has shown that the use of prefabricated structures and more rational planning envisaged for 1970 will allow to reduce the construction cost of public buildings on the average by 8 per cent, 3–4% of which will be saved owing to the use of prefabricated structures.

At present one-storey buildings with precast framework are prevailing in industrial construction. Columns, as a rule, are reinforced concrete; roof trusses of the span up to 24–30 m are made of reinforced concrete, while those of 30 m and above of steel. Crane girders may be both reinforced concrete and steel which depends upon the span and crane loads.

Multi-storey buildings are mostly of the precast concrete framed type with the column grid of 6 m × 6 m and 6 m × 9 m.

A wider use is made of large panels of 1.2 × 6.0 m up to 1.8 × 12.0 m size for walls of one–and multi-storey buildings.

Roof slabs for one-storey industrial buildings are made of precast concrete and have the size of 1.5 × 6.0 m and 3.0 × 6.0 m, though in some cases they have the size of 1.5 × 12.0 m.

The use of standard designs of bays and sections of prefabricated members creates favourable conditions for accommodating individual shops and even independent production units in one building, which, as estimated, will save 4–8 per cent in construction costs.

It is of paramount importance to decrease the weight of structural elements, when using industrialised methods of construction. According to the data of research institutes of the USSR, the weight of structural elements of residential buildings such as foundations, external and internal walls, floors and staircases make up nearly 55% of the weight of a residential building. The cost of these structural elements equals 50% of the total construction cost of a building.

The overall cost of horizontal and vertical hauling from a quarry or factory to a working place amounts to 20 per cent. Therefore, if the weight of main structural elements is reduced two times, the cost of a building will be 5 per cent lower.

The weight of 1 cu.m. of a multi-storey brick house is 440–560 kg and that of a large-panel building – 250–300 kg, i.e. two times less. In future the weight of residential buildings constructed by industrialised methods can be further reduced. The use of wall and roof panels in industrial buildings, thin-walled shell roofs, asbestos-cement sheets, mineral wool insulation and cellular concretes will ensure the reduction of weight and, hence, the cost.

Estimation shows that the development of production of improved prefabricated structures will result in lowering the weight of materials to be used in construction in 1965 by 25 per cent as compared to 1958 and, thus, in reducing the cost of construction products by 5–6 per cent.

Improvement of organisation of construction work

The state contract system is the basic organisational form of construction in the USSR. In 1964 87 per cent of the total volume of construction work were executed by state contractor organisations. Industrialisation of construction necessitates a wider specialisation. In 1964 52 per cent of the volume of construction work carried out by contractor organisations were executed by State specialised agencies.

During recent years in such cities of the Soviet Union as Leningrad, Moscow, Kiev, Minsk, Tashkent new organisational forms of industrialised construction were introduced, known as house-building factories. House-building factories produce complete sets of precast elements for residential buildings and are responsible for their erection at the construction site which is mostly executed directly from transportation facilities without intermediate handling operations.

The required man-hours per 1 sq.m. of living area in buildings constructed by house-building factories in 1961 were 26.2% less than those in a similar type of construction executed by civil engineering organisations, the construction time being considerably less.

The cost of buildings constructed by house-building factories is 3–10 per cent lower as compared to those built by civil engineering organisations. In 1963 34 per cent of living area in large-panel buildings were constructed by house-building factories. The expansion of factories, producing precast concrete details and elements of buildings may give a good economic effect. Thus, increasing the production capacities of factories two times (from 70 thous. sq.m. of living area to 140 thous. sq.m.) will result in the reduction of the prime cost of production by 6 per cent and of capital investments by 15 per cent. The reduction of the prime cost of prefabricated details and elements of buildings is essential for the economic evaluation of industrialised construction.

Two different methods of fabricating panels have been employed in practice; 1) Unit-flow line method and 2) Conveyor method.

Moreover, there has been developed in this country a vibro-rolling method of manufacturing panels which is being tried experimentally at factories.

A lower prime cost was attained when applying the unit-flow line method with the use of cassettes. This relates to Gyprostroy-industria cassettes, in particular. The prime cost of products manufactured by the vibro-rolling method is somewhat higher than that by the above method.

Progress in the industrialisation of construction primarily depends on the availability of the basic necessities, ensuring the production of precast concrete in such quantities that will meet the demands of our construction. At present the technical basis is created and 2100 factories manufacturing precast concrete products are working in the construction industry.

Increase of labour productivity and construction rates

The introduction of prefabricated structures has sharply reduced the amount of man-hours required and construction time. These two effects of the industrialisation of construction are, particularly, evident in state housing construction which is almost completely carried out as per standard designs and with the use of prefabricated structures.

The effect of the industrialisation of construction on the labour productivity in housing construction is evidenced from the following data on the total amount of man-hours required per 1 sq.m. of the floor area in residential buildings of various types. The data are given for 5 storey 4-section* blocks of flats with the total living area of about 2500 m^2.

Types of buildings	man-hours per 1 sq.m. of living area				
	Manufacture of reinforced concrete structures at factories	Construction of the building			
		Sub-structure	Super-structure	Total	Grand total
Brick	0.55	0.25	4.70	4.95	6.50
Large-block	1.35	0.25	2.90	3.15	4.50
Large-panel	1.55	0.17	2.18	2.35	3.90

As is seen from the table, the grand total of man-hours required for the construction of large-panel buildings is 29% less than those for brick buildings; the amount of man-hours required for the erection of the building is reduced by 53 per cent.

It should be noted that the prefabrication of structures for buildings with brick walls resulted in reducing the amount of man-hours required for the construction of such a building by nearly 30 per cent as against conventional methods.

The main law of the industrialisation of construction may also be seen from the above data: with the raising of the level of industrialisation, the quota of labour consumption required for prefabrication is constantly increasing against the total labour cost, while the overall construction costs are decreasing.

The same laws are characteristic of the construction of public buildings but due to a lower percentage of prefabricated structures used they are less conspicuous.

In industrial construction the amount of man-hours required for the construction of a building largely depends on the individual specific features of the design and dimensions of the building.

The construction of a one-storey building of 3–4 spans of 24 m by means of a crane of 5–10 tons lifting capacity and with the use of prefabricated structures is characterised by the following:

Floor area of the building, thous. sq.m.	10	25	40
Man-hours required per 1 sq.m.	1.4	1.15	1.10

Pre-assembling of erection elements will considerably increase the labour productivity. Thus the required amount of man-hours per 1 cu.m. of prefabricated concrete structures after their pre-assembling decreased two times, the weight being increased from 1 ton to 5 tons.

On the whole the labour productivity in the construction of the USSR has increased by 36% in 1963 compared as to 1958.

The reduction of construction time owing to prefabrication is

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* A section is called a part of a block with the flats in it, having an access from a common staircase.

more apparent in housing. The Code of Practice for 1962 specifies the time for construction of residential buildings: 8 months for 5-storeys 4–5 section brick houses and 6 months for large-panel buildings. The actual time of construction of brick buildings is not, as a rule, lower than the specified one, while the construction time for large-panel buildings was reduced to 4–3 months. In industrial construction a wide application of prefabricated structures allows to complete the construction of large power plants in 1.5-2 years and blast furnaces in 7–12 months.

Conclusions. Introduction of industrialised methods of construction contributes to the constant increase of labour productivity. In the construction of the USSR in the period of 1958–1963 the labour productivity increased by 36 per cent.

The accelerated commissioning of residential, welfare and industrial buildings results in raising the living standard of people: housing demands are met quicker, welfare services are improved, demands for consumer goods are met better, the work of builders is facilitated.

Pre-assembly of prefabricated structures, their unification and reduction of weight appeared to be advisable in all cases.

The practical results of the industrialisation of construction have shown the advantages of house-building factories. The volume of work done by them is constantly increasing. Along with that the increase of production capacities of factories manufacturing precast concrete products may be regarded as advantageous.

The industrialisation of construction is particularly efficient when it is concentrated into big complexes which ensures 7–8 per cent saving.

To facilitate the adoption of most economic design schemes for residential buildings, designs of individual members of a residential building and to more widely use efficient building materials a greater attention should be paid to the exchange of practical construction knowledge.

In this connection the CIB Secretariat might take upon themselves to annually publish 2–3 review issues dealing with the industrialised construction practice in different countries. The questions such as use of new building materials, good designs of joints between the external wall panels and methods of manufacturing structures with the relevant technical and economical data might be elucidated as first priority.

F 12

C. Grosgurin

A general scheme for prefabricated school buildings

By C. Grosgurin (Switzerland)

In Geneva we are entering upon a school building experiment which will go on for several years: the construction of a standard group of prefabricated school buildings, for the lower secondary school forms, suited to present pedagogic requirements. Although the execution of this programme is still in the opening stage, a number of initial conclusions emerge, which are worth setting forth.

How did the problem arise? As all other Swiss cantons, the Canton of Geneva is a small republic enjoying full autonomy in regard to education. In this respect, the canton authorities were faced as far back as 1960 with the problems created by a very substantial growth in population: a chiefly urban population of 270,000 inhabitants, with an annual increase close to 10,000 inhabitants. At the same time, an educational reorganisation was being considered, affecting the three school years following primary school (12—13 year, 13—14 year and 14—15 year classes), that is, the last three classes of compulsory (and free) education. This reorganisation led to the setting up of an "Educational Guidance Cycle".

This is an organisation gradually replacing all public education institutions corresponding to the last three levels in question, which included, for boys: the final years of school attendance as an extension of primary school and leading to apprenticeship; the "Collège moderne", giving access to secondary level technical schooling; the lower section of the "Collège de Genève", providing admission to schooling, leading to the various forms of "maturity" and further to an academical training. As regards girls, similar institutions will likewise be taken over by the "Educational Guidance Cycle".

The old system made it too obvious to schoolchildren that they belonged to such and such social class. Another drawback was that the system was no longer in keeping with the requirements of modern life with regard to educational guidance.

On the contrary, the educational guidance cycle will form what is termed a common stem, that is to say, pupils of both sexes, whatever their social origin, whatever education they intend later to receive, will be together in the same school. There it will no longer be a question simply of teaching them, but also of observing them, helping them and giving them the benefit of expert advice on educational guidance. As a rule, a child gifted for study, but whose home environment is unlikely to encourage it in this direction, should find the necessary support in the educational guidance cycle; arrangements are made so that the child may be transferred, in the course of the year, from a so-called practical section to a so-called general section, or from a so-called general section to a section called "Latin-Sciences".

As a result, an analysis of demographic progression and structure, jointly with a survey of the lay-out of developing residential areas, established the following fact: it will be necessary to complete in stages for the educational guidance cycle within the next four years, groups of school buildings distributed over a number of locations in the outlying districts of the Geneva area, within a circle, 50 miles in diameter. Such premises should be adequate for 4,000 pupils, allowing for the number of pupils who could be accommodated in existing, and still utilisable, school buildings.

This raises two points:

1) That of the optimum number of pupils per school group; for instance should two schools of 2,000 pupils be built, or 10 of 400?

2) That of the maximum number of pupils a class-room should contain.

There are two ways of looking at the first point: smaller and more school groups mean more confined recruiting districts; this has the advantage for school children of a shorter distance from home. On the other hand teachers of special subjects would have to make more journeys, often in a rush. Above all, fitting out of class-rooms equipped for such special teaching entails expenses that only full occupation of these rooms would warrant. This involves a rock-bottom minimum. Now, as has been noted, the same school has a number of sections, so that special teaching is diverse, ranging from the physical-chemical laboratory to manual work, and to cooking classes of domestic science. The optimum figure under consideration will also be affected by the solution of the second point: the maximum number of pupils a schoolroom should be arranged to accommodate. Pedagogues' answer to this question is that 25 pupils is a maximum, considering the necessary contact between teacher and pupils, but that a smaller number would surpass teaching profession recruiting possibilities. A three-pupil safety margin is to be recommended; so classes should be arranged for 25 + 3 pupils, a total of 28 pupils.

Finally, a school group will consist of 28 classes of 25 pupils (700 pupils plus spare room for 84), the word "class" being taken as meaning a group of pupils. The plan for a standard school will therefore consist of these 28 class-rooms, to which should be added a large number of specially fitted-out rooms. The importance of the latter should be stressed. Not including rooms required for a gymnasium, for teaching music, a conference hall for lectures, concerts, film shows, a library and offices, more space is required for special rooms (Physics-Chemistry, natural sciences and attendant practical work, drawing, workshops, geography, domestic science: cooking, laundry, needlework) than for theoretical teaching. The ordinary class-rooms/special class-rooms area ratio is 6—5.

A first conclusion emerges from these facts: ground plan treatment featured with small detached buildings should be eliminated; they may be convenient for primary schools, but they are not suitable for secondary schools where there are many internal communication lines. Furthermore, most special rooms are fitted with black-out equipment and do not require daylight from both sides—in fact this would be a nuisance—nor preferential aspect.

Finally, as the treatment concerns a standard school, it should fit, not just a particular plot of land, but various sites. The general design should therefore be made up of component parts which can be grouped and connected with each other, following different patterns according to the shape of the building ground, its aspect and approaches. Lastly the design will of course have to comply

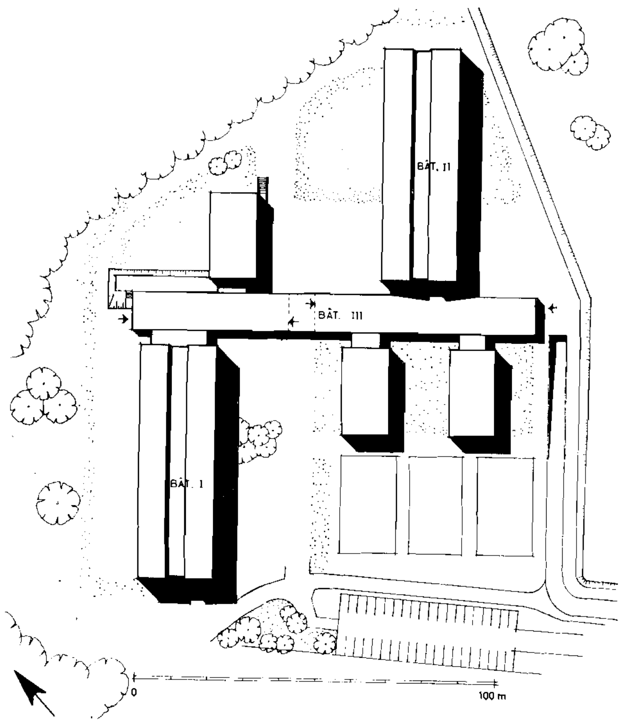

Fig. 1. General lay-out of Collège de Pinchat, in the course of building. Buildings I and II are the class-room buildings; building III is the link building. The 3 small buildings, like buds, are the gymnasiums.

with the basic requirements of a rational and industrialised building: it is, in the model we have evolved, a set of three types of volumes, each of which has of course a very geometrical outline. These three types, drawn on a modular plan, are:

1) A main class-room building, two-storied plus ground floor. The ground floor, designed for very free partitioning, contains either a rather large reserve space in the shape of an open porch, or the offices. Above, two class-room floors; the top one receives daylight from both sides, on account of a large central passage. A shool consists of two class-room buildings, which in cross-section show axial symmetry.

2) A gymnasia main building. The standard school contains three gymnasiums. Two have public shelters in the basement, and the third an auditorium with sitting room for about 280, complete with stage and wings.

3) A link-building forming the backbone of the general lay-out. The buildings under 1) and 2) are positioned as buds from the link-building. The groundfloor contains the entrances, pupils' separate lockers, as well as rooms appurtenant to the gymnasiums (changing-rooms, accessories, etc.). The basement is for bicycles (almost half of the school children come on a bicycle).

Apart from the stratagem consisting in placing side by side, to a number of grouping patterns, geometrical buildings built on three models, the architect must indeed waive part of his designing freedom. Does prefabrication, in the particular case, present such benefits as to warrant this surrender? I think so for the following reasons:

The first advantage is a lower cost of foundations and main walls. In this respect, the following are the relative prices per cubic metre built (worked out according to S.I.A. standards) at Collège de la Florence (Florissant district). This building experiment is prior to the educational guidance cycle group of schools but featuring in general the same sort of scheme and treatment. This group was built in stages, starting in the 1960–61 winter. The three stages became operational in September 1961, September 1962 and September 1963 respectively. The two class-room buildings were prefabricated. Building III (link, gymnasiums and auditorium) was built on traditional lines. In terms of 1961 prices, that is, without taking into account rises occurring in the course of the work, the prefabricated class-room buildings came to about Fcs. 128 per cubic metre. whereas the ordinary building cost Fcs. 159 per cubic metre.

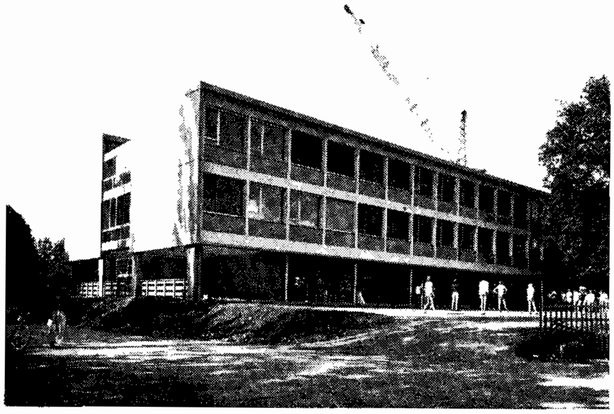

Fig. 2. The first of the completed main class-room buildings. The inter-axial distance is 2m70 (9 modules of 0m30).

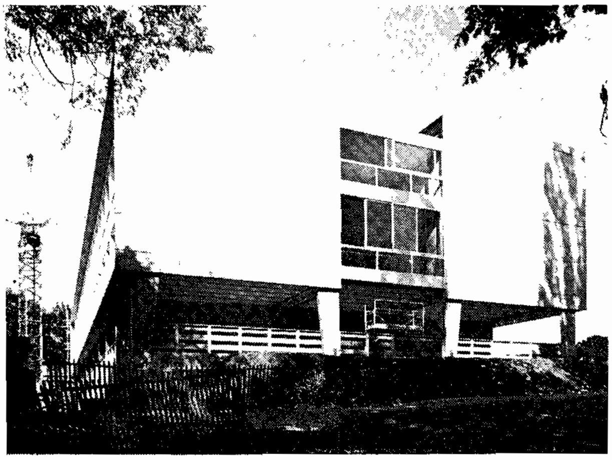

Fig. 3. The boxes formed by the slab components can be seen from below. The surroundings have not yet been arranged.

The second advantage is the speed of work. The first, and more urgent, class-room building of Collège de la Florence was completed in 8½ months, including the installation of the travelling prefabrication plant, component fabrication, erecting the main walls on a site-cast substructure, internal walls, finishing work and arrangement of surroundings. On the other hand, building III, of the traditional type, took nearly twice as long to complete, due among other things to time lost during the very severe 1962–63 winter. We find here one of the advantages of prefabrication: preparation goes on in winter whilst site work is at a standstill.

But, in my opinion, the main advantage of prefabrication lies not so much in the economy, still substantial, or in time gained, but rather in labour-saving, mostly skilled labour. It is surprising to note, when observing the erection of a building of approximately 10,000 cubic metres, that a gang consisting of a foreman and 8 men managed quite well.

Such are the reasons which prompted the builder (Department of Public Works, Geneva) to consider a prefabrication process applied to all the main buildings, including the gymnasia buildings. Building parts are cut into components not exceeding tons 2.5 in weight. The floors, mostly with a 7m span, are made of box slabs, with visible ribs on the ceiling. Nevertheless, prefabrication is confined to foundations and main walls and it is important to explain why.

The equipment of special rooms calls for important and greatly varying internal structural work, hence the difficulty of total prefabrication, since this and, generally speaking, any form of standardisation require basically mass production of similar components, of the smallest possible number of types. So many different types of partition wall components would be needed in a school of this sort to incorporate the electric and sanitary installations. It is obvious that such a number of them would be required that their mass production would be a major headache and would waste more time in design and building than would be required to build on traditional lines.

Moreover, in our problem, a type of construction is required that lends itself to possible alterations in the course of design, even of building, without such alterations causing delays. As a matter of fact, hardly a month elapses without the occupants (Public Education) having to face fresh requirements: a particular branch of teaching has to be developed, another restricted, additions to premises to accomodate sections not provided for in the original scheme: a centre for educational guidance and psychotechnical test advisers; a centre for pedagogic research and statistics; a centre for audio-visual techniques etc. On paper, one talks of a standard school, corresponding to a specific plan, and repetitive. In actual fact, the plan evolves and expands in the course of design and of building.

This is yet another reason for deciding to prefabricate foundations and main walls only. Internal structural installations are made on the spot and given different forms to meet a great diversity of requirements. But foundations and main walls should be designed so as to facilitate carrying out the installation. This is easily done by means of an unbroken system of horizontal and vertical casings providing a network for carrying the ducts for the various fluids. Hence the U-shaped columns and beams, typical of this system.

The point should be emphasised: in a building of this kind, channels and perforations are systematically ear-marked everywhere. This makes the erection of the elctric and water installations easy and quick. Contractors who have had this experience know that it is a time-saver. There lies yet another, unexpected but real, advantage of prefabrication.

F 13

R. von Halasz

Development trends in industrialised building with prefabricated steel-concrete members

By R. von Halasz (West Germany)

Existing construction principles of prefabricated members for large span constructions

Around about 1950 the following principles of construction have been developed which have been acknowledged by the majority of designers:

A prefabricated member made of B 600 concrete is always more economical than one made of inferior concrete, if the cross section is designed in such a manner as to warrant its full utilisation.

Workshop production is always more economical than production on the building site or yard provided that the transport distance does not exceed 50 km and that the production volume will be large enough; this fact results particularly from the possibility of combining in the workshop similar orders which are independent one from another.

It is economical to standardise some types of shed constructions, to organize production of these standard types and to produce in stock. The standardisation, which must be made after careful study of the market and after preliminary research of design, production and economy, will render possible the addition of experience and, therefore, a reliable further development.

Shed construction, skeleton structures for multi-storey buildings and other engineering structures are subdivided into the fewest components possible. These components can be as heavy as the transport and assembly facilities will allow. Nearly all building firms are today making use of modern equipment by which as large members as possible can be transported because it is more economical to reduce the number of working operations than to move a great number of lighter members.

The interconnecting of the members on the site can no longer be done by cast-in-place concrete (which would have to harden afterwards) with projecting reinforcement, nor by welding (which would require the necessary equipment on the site) but, after corresponding disposition of the static system, by hinges, by simple superimposing or supporting, possibly by simple bolting.

The trend of present development

The development characterised by the principles mentioned above has at present again been advanced. The following trends can be perceived:

Superseding of skeleton structures by slabs and shells: As is well-known, in house building, skeleton structures have been nearly completely superseded during the last 10 years. They have been substituted by building with large slabs. The reasons for this development are obvious: the inclusion of complete prefabrication, the integration of numerous working operations, the necessity of reducing the number of prefabricated parts which have to be transported. A parallel development takes place in industrial building. Here, it is the roof which requires the greatest share of the costs of an industrial building, which has to fulfil the most complex functions of a structural member (heat insulation, rain-shield) and which, therefore, has developed furthest. Up to now, the roof consisted of tie beams, purlins and roofing. By using *prefabricated shell-members with greater width and large span* the number of the necessary prefabricated members is reduced in the ratio of 40 : 1 up to 10 : 1. In Germany and in many other countries the HP-shells are known and widely used. Besides these folded plates are made everywhere. The characteristic feature of all these constructions is that they supersede the tie beams, purlins and roofing and that they span freely the hangars or sheds. Thus, they fulfil the tasks of bearing the structure, dividing the rooms, and roof sheathing. One can mention (besides many other types) the LIN-T-ribbed slabs of the Americans which can span up to 15 metres, in Germany the T T –ribbed slabs of Messrs. J. Rech AG, the ribbed slabs of the Inbau KG and those of the Stahlbeton AG in Zürich. Thus, the trend to load-bearing slabs in industrial buildings corresponds to that of building with large slabs in house building. This trend includes the integration of the functions of skeleton building and completion, concentration of nearly all working-operations in the fixed workshop, reduction of the number of structural members which have to be moved, and reduction of the number of connections.

From shell to folded plates: The *production methods* will have a very important influence on the future development of the prefabricated members with free span. Obviously production methods which require much labour or those which cannot be mechanised will be superseded by others with which parts can be made either by conveyor-line production or by automatic machines. For this reason, the development should proceed from shells to load-bearing slabs. In the past, shed buildings were typical objects for the monolithic steel concrete construction. When designers proceeded, from about 1940, to assembling shed buildings from prefabricated Vierendeel-beams, supported cranked frame-girders and smaller roof-plates, this represented only a transition from monolithic structures to prefabrication. From 1945 the main beams were designed as prefabricated prestressed beams and the range of application of prefabricated sheds was thus considerably extended. During the last years, however, developments have appeared which lead from the traditional shed building to load-bearing structures which consist of prefabricated slabs arranged side-by-side: the single members of these structures can be prefabricated in a very simple way.

The problem of side-walls. Curiously, the development of the side-walls is less clear than that of the shed roofs. In many of the recent constructions even now the wall skeleton, which consists of prefabricated columns and crossbars, is filled out with a great number of wall plates. Although, owing to smaller height and better accessibility, the disadvantage is not so serious as with the roof, one can foresee that here, too, the trend towards labour-saving large slabs will start as soon as designers can succeed in finding convincing constructions which will supersede columns and wall filling. It is necessary to develop walls which fulfil the tasks of dividing the rooms, of heat insulation, of supporting capacity, and of carrying wind loads all in one and which render possible the fitting of doors, windows, etc. as well as the mounting of installations. This problem can be solved, for sheds of moderate height, by plain flat prestressed plate-members which are clamped at their lower edges and stiffened by ribs. For sheds of great height, shells and folded plates with small height of section will be recommendable which warrant vertical flat boundaries of the working-room inside the shed. If such structural elements are produced in horizontal position in the workshop or near the site and are fitted with heat-insulating layer, inside and outside coating, doors and windows, pipe connections etc., the same advantages will result as are already known from the large-slab construction in house building.

The problem of production programmes for industrial shed buildings. Though there is no definite standard of dimensions officially prescribed, most factories have drawn up a type programme as they expect that buyers will prefer type-sheds if they can get them cheaper than individual production.

Special developments

A special development for shed buildings with great span is the rhombic lattice framework. It has first been used in 1953 for a sports-gymnasium with 40 meters span in Berlin-Schöneberg, then in 1954 for a cooling tower in Berlin-Mariëndorf, later on for an industry-shed in Berlin-Siemensstadt, since then at many other places.

Variations of the same construction have been known from the USA and other countries. A remarkable peculiarity of this construction is the fact that it is frequently employed though it is in opposition to the principles stated above (small number of elements, dry connections where possible). In the first of the buildings mentioned above the author has cooperated in statics and construction. The consumption of steel and concrete for this building with its free span of 40 meters was considerably smaller than it would have been for a monolithic shell and the costs of the auxiliary scaffold for the assembly were not higher than they would have been for the casing scaffold for the shell. The production of the simple plates, all of the same shape with rectangular section, was very economical, though their number was very great. Thus, sometimes structures can be economical though they are built-up from a great number of elements as these elements can be very economically made by mass production. To this special group also belong *Beams made of elements braced together*. Shed buildings, the columns and roof truss of which were made of a great number of identical elements which were braced together under stress, have already been used for some time. Connecting a small number of prestressed prefabricated parts will nearly always require more labour than the assembly of a great number of prefabricated members which have not been prestressed but which are braced together under stress at the site. This one prestressing at the site saves a great number of preliminary prestressing operations.

In the meantime, many bridge girders, highly loaded girders for shed-buildings etc. have been designed according to this principle idea. However, I believe that this development will be confined to special cases because, as mentioned before, this method is in opposition to the stated principles.

Columns of multi-storey buildings. The development in the skeleton method of building multi-storey houses, however, in every respect corresponds with the general trend towards large prefabricated members. Only very seldom the columns of multi-storey buildings are as yet built-up of different butt-ended parts; it is no rare thing to find columns, made in one piece, 30 meters in height. They not only simplify the erecting of the skeleton but also make it economical. The ceilings in multi-storey buildings for offices and shops are preferably built-up from large slab elements. Staircase walls are prefabricated as closed cases in the workshop even if their weight amounts up to 15 tons. Only with really exceptional conditions will composite constructions be chosen.

Conclusions. The recent development of industrial building with prefabricated structures of steel-concrete is characterised by the following trends:
From skeleton building, to building with large slabs
From shells to folded plates
From framework walls, to walls with large slabs
From subdivided skeleton columns, to columns all of a piece
From individual production, to standard type production
From separated fulfilment of functions, to integration.

F 14

R. Heckl

Prefabricated elements for agricultural buildings

By R. Heckl (Austria)

Agriculture, which is a highly productive branch of the economy, has the largest demand for buildings, both as regards building units per capita and the share of building costs compared to the total operating expenses. Therefore agriculture has a very great interest in building research and in the rationalisation of the building industry. However, the building industry also should pay regard to the fact that agriculture will be one of the industries with the largest demand for buildings for decades to come.

Without knowing and taking into consideration the characteristics of agricultural production, its building problems cannot be understood or solved. Building research, building design and the building industry find themselves in a difficult situation in as far as agriculture itself has not yet got any clear conception of its future trend and the resulting structural consequences.

The maintenance of agriculture as such is a vital question for industrial society. With less people working in agriculture, this industry must produce more. In this connection, agriculture is confronted with the following two tasks:

1. Rationalisation and mechanisation of the individual farms in order to cope with the necessary work with a minimum of labour.

2. General measures for adapting the structure of the farms and rural living conditions to the requirements of mechanisation and the standard of the industrial society.

In both cases, success depends on how far and how fast the building problems connected with the above tasks can be solved.

To judge from statistics, farms which are large enough to fall under the category to which the above applies, would seem to have undergone a far-reaching mechanisation in the leading industrial countries. However, if examined more closely, more than 90% of the existing machines only serve one sector of farming, viz. the work on the fields. On many farms, the work in the animal sheds must still be done by hand, as was the case in times of surplus manpower and consequently these tasks take up two-thirds of the total working time on the farm. This is the most difficult problem in farming, both as regards working technique and the financing of buildings. At least nine-tenths of the farms are dependent for their livelihood on stock-raising. Livestock answers for 60 to 70% of the sales profits of European agriculture; furthermore, through the supply of manure and the utilisation of waste material it has also a considerable influence on the size and stability of the profit on crops. The primitive remedy of giving up stock farming can only be applied in exceptional cases to a small number of farms and here also it may be problematical in the long run.

Thus the rationalisation and mechanisation of the work on the fields must of necessity be followed by the rationalisation and mechanisation of the work located to the farm-buildings. In the majority of cases, the existing buildings are obsolete, insufficient and unsuitable. Their modernisation and replacement is one of the most difficult problems in agriculture as well as for the building industry.

The investment requirements for new constructions as regards animal sheds, storage space, manure collecting plants and equipment correspond per head of cattle to the sales value of 6,000 to 10,000 kg of milk or 5,000 to 10,000 kg of wheat. In addition to animal sheds and storage space, each farm requires sheds for machinery and equipment which have to be assessed at 8 to 10% of the costs for animal sheds and stores.

Building in agriculture cannot restrict itself to farm-buildings, as it could not function without the necessary dwelling-houses. Dwelling-houses and farm-buildings together form the centre of the farm and must have an organic and rational relation to the production areas. From this relation arise the special tasks and methods of building in agriculture, which are basically different from those in industrial building and dwelling-house construction in the industrial society.

In this connection, the dwelling-houses in agriculture have to-day decisive sociological and technical functions, which the majority of the existing, out-of-date dwelling-houses cannot fulfil. A minimum of 500 m^3, or even better 650—700 m^3, of buildings per family farm is necessary. The modernisation of the existing old buildings and their replacement constitute a financial burden for the farm, which is even heavier in the case of small farms. In the case of farms of 5—10 hectares, dwelling-house costs comprise about 60% of building expenditure and building demand in agriculture, of farms of 10—20 hectares 45% and of farms of 20—40 hectares 35%; thus agriculture makes a considerable and immediate contribution to the total of dwelling-house construction.

Furthermore, all general measures towards an improvement of the traffic situation and the agrarian structure, improvements and land reclamation depend to a great extent on new constructions or simultaneous structural modernisation, no matter on what model agrarian policy is based. Between the two great wars, the aim was to establish as many people as possible in agriculture in order to overcome mass unemployment and the impending risk of famine. However, the necessary increase in the number of farms to the detriment of the large farms and through land reclamation was doomed to fail primarily on account of the impossibility of financing and constructing the required buildings.

The present aim, to have as few people as possible working in agriculture, is primarily due to the drift of labour into the towns and is secondarily dictated by considerations of economic policy. However, it would be wrong to believe that the building problem would thus be easier to solve, as the necessary concentration also requires extensive and quick construction measures, no matter whether the aim is to erect hygienic and fully mechanised family farms of 20 to 40 hectares or large farms on a capitalist or socialist basis.

In 1962, the erection costs of new dwelling-houses and farm buildings on a farm of 20 hectares amounted to DM 142,000 in the Federal Republic of Germany, i.e. about 7,000 DM per hectare. In order to equip West German agriculture (14.2 million hectares), with an average of 20 hectares per farm, with new buildings during the course of the next 25 years, an annual building volume of DM 280.— per hectare, i.e. 4 billion DM, would be necessary. The present building volume in West German agriculture amounts to about 2 billion DM. This implies that in the best of cases it would take about 50 years to equip agriculture with new buildings and thus the building volume would have to be doubled if the modernisation methods were to have any practical effect on the present total condition of agriculture. The prerequisite for this would be that 4 5% of the farms are modernised each year and that the time necessary for complete modernisation should not exceed 20—30 years.

The conditions are similar in all industrialised countries, and, as proved by calculations, the fulfilment of the building requirements in agriculture is not a problem which concerns only agriculture, but also the building industry.

The old type of agriculture with a surplus of labour was largely self-sufficient also as regards building construction. The building materials usually used comprised materials obtained nearby or produced on the farm, which had little or no market value, viz. mainly wood, straw and quarry blocks. All transport was effected by the farmer himself; the same was true for all unskilled work which, if necessary, was done with the help of neighbours. The size, shape and equipment of the buildings were standardised to a great extent and adapted to the simple requirements and customs. Drawings were not necessary; the technical life of 80—100 years could be fully utilized and premature modernisation for functional reasons hardly ever occurred.

The actual building expenditure of the old agricultural system, which had to be covered by the market value or capital reserves, therefore hardly amounted to 30—40% of the effective building value calculated on the basis of the prices on the building market, and the maintenance and renewal expenditure amounted to 1—2% per annum. Building in agriculture was not a part of the building industry and agricultural buildings were, in spite of their large share in the total amount of buildings (in Austria, for example, 163 million m^2 = 64% of the total building area), a negligible quantity, both for the building industry and building research and unfortunately also for agricultural science.

In connection with the change-over from wooden to solid constructions the situation began to change. Building in agriculture now became greatly dependent on the commercial building trade. The decreasing amount of labour available in combination with the increase in intensive farming decreases the capacity for self-help in agricultural building. At the same time, the demand for new buildings in agriculture increases for functional reasons as well as on account of the progressive obsolescence of the buildings.

This demand cannot be covered if the present methods of the commercial building trade are applied. It is not only a question of burdening agriculture with building costs, but also a question of capacity, i.e. of the building industry, as the latter is at present in a productive crisis. This critical situation is reflected in the relative increase of building costs in comparison with the building material costs, industrial products and especially agricultural products. The building trade can no longer cope with the present building demand. There is a great shortage of labour in the building industry and, in addition, it is hampered by the complicated wage situation and widely spread workplaces which depend on weather conditions and which are handicapped by transport distances, as well as by a split/up variety of often unclear building programmes and insufficiently prepared construction work.

Therefore also from an international point of view it would seem that the building trade must adapt itself to industrial economy in the same way as agriculture must adapt itself to the industrial society. However, this is equally difficult, as the production of the building trade, especially in connection with the building process on the site, is limited as regards rationalisation, mechanisation and industrialisation. Thus the customary work on the site constitutes the bottle-neck which in all industrialised countries limits the capacity of the building industry, and the possible building volume.

There is no doubt that an effective increase in the capacity of the building industry in all fields will only be possible by means of prefabricated construction. In connection with this, many jobs which to-day have to be carried out on sites which are often changed and frequently offer unfavourable working conditions, should be concentrated to a stationary workplace outside the building. Here complete structural units should, if possible, be prefabricated in series which later on could be assembled on the site in a simple working process which should also be a short one.

However, so far we cannot expect a noticeable reduction in building costs in the individual case employing prefabrication methods. The costs for element construction are so far not lower, but sometimes even higher than those for rationally effected buildings of another type. This is the main reason why building with elements has only developed hesitatingly which in turn has an unfavourable effect on the costs. It is theoretically correct that the advantage of element construction is not reflected in an immediate reduction of costs, but seen as a whole, in an increase of the capacity of the building industry, and seen individually in a simplification of the site job, especially with a view to the replacement of skilled labour by unskilled labour. Agriculture which cannot cover its increased demand for building construction by its profit, i.e. it cannot increase the price of its products accordingly, must interest itself primarily in the effective costs. For building in agriculture it is therefore important that element construction will make it possible for the still considerable capacity for self-help in building in agriculture to be activated on a new basis and thus to reduce the effective building costs. This is the only way in which agriculture can cope with its building tasks.

Element construction necessitates and the same time facilitates the primary prerequisites for rational and productive building, the planning on the basis of standards and types which were previously a matter of course in agricultural building, but which had been lost during the last few years.

In Europe, we have a magnificent example of the consistent development of the possibilities offered by assembly construction in agriculture which was given by the Netherlands. In connection with the reclamation of land in the Zuider Zee, more than 5,000 farms of 14–48 hectares each have been erected since 1927, and a further 2,000 farms are planned. The objection may be raised that the conditions prevailing there cannot simply be applied to normal agricultural building sites. However, the design and especially the development of the element systems in the polders of the Zuider Zee is such that the methods applied there and the experience gained are also of importance to future agriculture building activity in normal circumstances and contribute considerably to solving many problems connected with prefabrication in agricultural building.

In the simplest cases, the prefabrication of structural parts can be effected on the site itself. By means of the repeated use of equipment and moulds and of well established working methods with a minimum of skilled labour and a maximum of effect, cheapening, quality improvement and an increase in capacity can be achieved. The classical example of prefabrication on the site (field prefabrication) with subsequent assembly is supplied by wooden constructions. Very close to prefabrication on the site come also various rural concrete building methods such as the construction of silos and manure pits by means of steel moulds, making use of the extensive self-help capacity in agriculture (unskilled labour, transport, gravel supply) which has been a customary construction method in Austria for many decades.

The next stage in this development is to concentrate prefabrication in already existing workplaces, for example, those of the concrete products industry, whereby existing equipment and labour can be utilized.

The highest fully industrialised stage of prefabrication requires specialized stationary plants in favourably situated places which necessitate large capital investment and correspondingly large series. Prefabrication in stationary plants situated a long way from the site is doubly handicapped as regards transport: firstly by the transport of the building materials to the factory and secondly by the transport of the finished products to the site. These transport costs increase progressively with the weight of the structural parts; the same is true for the assembly costs on the site. Sometimes the transport of heavy and large elements to rural building sites is completely impossible. As at least 85% of the agricultural building volume is comprised of small building sites, the use of heavy assembly elements and subsequently of heavy assembly equipment is mostly not rational and cannot be carried out by unskilled labour. In such cases the use of cast in situ concrete is cheaper. Light assembly elements which can be placed without special training by 2–3 workers, facilitate the utilization of agricultural self-help. Particularly in building in agriculture, elements of up to 250 kg offer a better universal application, and in addition can be produced, transported and assembled at a cheaper price than heavier structural parts. Furthermore, Swedish investigations have shown that with light structural units a wider variation can be achieved with less elements than is the case with heavy elements.

With transport distances of more than 50 km, the use of heavy and medium-heavy elements becomes disproportionately expensive. Experience has shown that factories producing heavy and medium-weight elements must limit their sales range to 50 km and they will only have sufficient and easy sales possibilities in congested areas with a great demand for industrial building and dwelling-house construction. The demand for elements for farm-buildings can only begin hesitatingly, as the construction programme is as yet unclear and subject to discussion. However, as soon as the sales of elements for agriculture construction have taken a favourable turn, the market for light and medium-weight elements for building in agriculture will remain steady for many decades, while it is doubtful whether the present hectic cyclical boom for blocks of flats and industrial plant will keep up. Normally it will, however, be difficult to run to capacity a concrete products work for specific agricultural assembly elements if the sales range exceeds 50 km.

Thus it appears appropriate to design industrial elements in such a way that they can be used both for industrial construction and in building in agriculture, or else to design agricultural buildings in such a way that at any time elements from current production can be used. Therefore the current offers of the relevant industries for prefabricated elements for sheds, workshops, fences, canalisation and paving with setts should be examined to find out whether these elements can also be used for building in agriculture. These elements must be catalogued and described in detail, so that the planners will know what kind of suitable elements are available. It is not the building elements which must be adjusted to the plan, but the plan must be adjusted to the building elements available. In this connection, the catalogue issued by the "Associazione Italiana Prefabricazione" would seem to constitute an excellent model.

Universally applicable elements for sheds without supports are of special interest for agricultural construction. Heavy wall elements in the form of large slabs which are used for dwelling-house construction in the towns have hardly a chance in building in agriculture, not so much because of the transport and assembly difficulties, but for functional reasons. Dwelling-house and animal shed construction make high demands on the heat insulation of the wall elements, but in each case for quite different reasons. In animal shed construction the requirements as regards resistance to aggresive moisture are especially great; so far, these requirements could not be fulfilled, particularly by the light-weight slab construction systems offered. In addition, no saving in construction costs could so far be achieved with these elements, so that the conservative solid wall construction is at present preferred in the majority of cases for agricultural buildings. Thus the progress made so far is that large-size, light-weight wall elements, and blocks in heavy and light-weight concrete are used as far as possible with a view to adapting the principle of assembly construction. Particularly in animal shed construction, these elements are erected as non-load bearing filling-in work of a portal frame. In animal shed construction, the best protective function combined with the highest possible resistance when saving plastering on the inside and outside can, according to Austrian experience, be achieved with sandwich walls in heavy concrete with a core of light-weight slabs in wood-wool. In this connection, large-size wall elements can be prefabricated on the site in order to save moulds.

England is leading as regards offers for industrially prefabricated reinforced concrete hall roof trusses which are suitable for building in agriculture not only from a functional point of view, but also because of their favourable prices. An old agricultural type of building, the so-called Dutch barn, was used as a model for the industrial shed: the Dutch barn consists of a shed roof supported by brickwork piers. The English concrete products works offer the standardized truss elements and purlins in reinforced concrete for spans of 4.50 to 18 m. The distance between the trusses amounts to 4.50 and 5 m. The wall brackets which can be supplied range from 1 ft. to a maximum height of 22 ft. = 6.60 m. The static system and the division of the English trusses into at least 4 elements are of interest in this connection; with normal spans of up to 12 m and a maximum weight of 800 kg per truss element, this makes possible relatively easy transport and assembly. A variety of combinations of full and semi-trusses makes possible saddle-roof gable widths of up to 30 m.

With English hall roof trusses, the roof pitch amounts to 22° 30″ and is thus suitable for corrugated asbestos cement sheets in all climates as well as for small interlocking roofing tiles in concrete. Only with such a greatly applicable roof pitch is it possible to achieve a general spread of prefabricated trusses, as corrugated asbestos cement sheets represent the most widespread and most suitable large-size assembly element for roof covering and wall facing; the minimum roof pitch should be 15°, or even better, 20°. The small interlocking tiles are also old-established and genuine assembly elements. They make possible extensive self-help and in a wet climate they are far more general particularly in building in agriculture, and can be used in a simpler and safer way and can be repaired more easily than flat roof systems which today are often pushed into the foreground in connection with suggestions for assembly construction.

As far as uniform portal-frames are concerned, the English model may be recommended. However, in Central and Northern Europe we shall be compelled, for reasons of costs, to use combined trusses, i.e. a shed system with a roof construction combined of wood or section steel and wood with reinforced concrete wall brackets or solid walls. The wall brackets can be prefabricated on the site or cast in situ. The wooden trusses are prefabricated either as nailed board trusses or glued boards. In Austria, welded trusses in section steel with wooden purlins are especially competitive for corrugated asbestos cement roofing, while galvanized steel trusses and light metal trusses are too expensive for agricultural buildings. A shed constructed entirely of wood is the cheapest, but for several reasons this type is hardly used any longer for barns. The American pole-barn is of special interest as the simplest shed construction. This pole-barn is not built of round timber poles, but of prefabricated reinforced concrete poles. This barn has been described by Schalow as the most economical shed construction in East Germany.

Several elements for shed equipment are particularly suitable for building in agriculture and for prefabrication in large series. Once again the Netherlands give an example of possible simplifications in constructing portal frames and walls in combination with handy prefabricated elements. Also in this connection an immediate reduction of the total building costs is not noted; on the other hand there is no increase in costs. The Dutch example shows, however, that a better planning and a better adaptation of the shed without supports to various purposes and sizes of farms is achieved; furthermore, it is possible to dismantle the construction later on, if necessary.

Modern fodder conservation and manure utilization which necessitate ensilage silos and manure collecting plants represent typically agricultural building tasks. They offer great possibilities for prefabrication on the site as well as for industrial prefabrication and assembly construction, as such plants can only be erected rationally as concrete assembly constructions. One of the most effective means of intensifying the work on a farm and rationalizing it on a very simple constructional basis is the trench silo, particularly in connection with a concrete feeding-yard. For this purpose simple and tested as well as handy assembly units prefabricated in concrete products works are available in almost all countries. The reason why they have not yet been able to compete successfully with cast in situ concrete and prefabrication on the site is to be found in the costs, particularly the transport costs, a fact which again emphasizes the necessity for further development in the use of elements in building in agriculture. The use of prefabricated elements in agriculture will only succeed when a dense network of element producers has been established.

In the construction of tower silos, wood has so far competed with cast in situ concrete and concrete blocks. Until recently, semi-assembly methods using serial formwork have proved superior when properly organised. In connection with certain conservation methods based on hermetic sealing, metal assembly silos on high concrete bases with mechanical bottom discharge have been in the foreground. However, for reasons of cost and partly also for functional reasons, these silos cannot compete with concrete silos on family farms. The concrete assembly silo (stave silo) which is widespread in the USA, consisting of handy reinforced concrete staves, is not very successful in Europe. At present tests are being carried out with precast silos consisting of large-size reinforced concrete rings and asbestos cement elements. The so-called hay towers are all-assembly structures in asbestos cement elements, which are used for drying, storing and the mechanical discharge of finely chopped hay.

Dwelling-house construction comprises at least 40% of the building demand and building expenditure in agriculture, but does not represent a specifically agricultural building task, especially since on modern farms the dwelling-house is basically detached from the other buildings. In the future it will be hardly different from any other rural family house. In dwelling-house construction the tendency towards a simplification of the construction procedure approaches complete prefabrication. In this connection we do not wish to nor can we deal with the possibilities of prefabrication in agricultural dwelling-house construction, especially as the development and industrialisation of housing construction has at its disposal means and possibilities which far exceed those of agricultural building. Therefore agriculture must carefully observe the development of non-agricultural dwelling-house construction.

Finally, I should like to return to the starting point. In spite of extensive rationalisation and mechanisation, or particularly on account of these, agriculture remains the branch of the economy which has the greatest building requirements. The building demand in agriculture can only be fulfilled if a combination of the most modern and of the oldest construction methods is made, viz. if agriculture makes use of assembly construction with prefabricated elements in combination with self-help and neighbour assistance.

Concrete and wood offer the greatest variety of possibilities for prefabrication and self-help, where concrete includes in the widest sense all cement-bound building materials, from simple concrete made of natural aggregates via light-weight concrete with various aggregates and fillers to asbestos cement. Hollow blocks in fired clay are very often used in the form of prefabricated elements in agricultural reinforced concrete constructions; today, wooden building elements will only be economical if used together with concrete building units.

A report on prefabricated elements in agricultural building is thus necessarily a report on concrete elements in building in agriculture.

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G. Herholdt

Industrialised precasting and erection techniques for housing construction in East Germany

By G. Herholdt (East Germany)

This paper seeks to outline the path taken in the German Democratic Republic to industrialise housing by giving a brief description of the precasting methods, the plant, and the site techniques.

Basic principles

Of all the new dwellings built during 1963 in the GDR, 77% were erected by industrialised techniques. The most important among the new systems devised are the large block system for precast units of 800–2000 kg weight, the precast skeleton system for units weighing 2000–5000 kg, and the large panel system for precast units of 5000 kg.

The highest degree of factory prefabrication, the greatest productivity, the shortest erection periods, the lowest consumption in building materials, and the best quality of finished buildings are achieved with the large panel system. This is also borne out by the following data:

	Traditional brickwork	Large block system	Large panel system
Productivity in average hours per dwelling	1800	990 (including prefabrication)	755 (including prefabrication)
Average time required for erection	10 months per block of 40 flats	7.5 – 8.5 month per block	5.5 months per block
Weight per cubic metre enclosed space	380 kg	364 kg	323 kg

Up to 1960 4- and 5-storeyed blocks of flats were erected from precast units. Today, 8-, 10- and 12-storeyed buildings are also being built from precast units weighing 2 and 5 tons. Designs for 16-storeyed blocks of flats in the large panel system have been prepared, and projects for buildings with more than 20 storeys are at present in the drawing board stage.

Due to the switch-over to industrialised building methods it was possible to cut the average cost of a flat by roughly 30% over a period of six years (1956–1962). The amount of hard manual labour has been reduced and productivity has been raised considerably. For instance, the amount of labour required for precasting wall units in factories has been reduced from originally 8 hours per cubic metre of concrete to 3.8 hrs/cu.m. and, in some cases, even to 1.25 hrs/cu.m.

Whereas wall and floor units weighing 0.8 and 2.0 tons were formerly precast in fixed forms, they are now manufactured with slip-form pavers operating the long-line method. The large panels, complete with windows, external finish and internal finish, are manufactured in highly mechanised tilting forms and vertical multi-moulds.

Standard designs for concrete panel factories including all technological data and machinery plans are available to ensure efficient production methods and low investments. These factories are designed to produce all the elements required to erect a complete building.

By erecting 31 factories for concrete panels in the GDR, 26 of which are partially open-air plants with an annual output of 500 dwelling units, it was possible to introduce the large panel system not only to cities with particularly large construction programs, but also to many other parts of the country.

Apart from the panel factories there are another 20 concrete plants operating the slip-forming process to produce wall units and prestressed floor slabs. Each of these factories can turn out 43,000 cubic metres of precast walling or 23,000 cubic metres of prestressed floor slabs per year.

The transition the GDR's building industry is undergoing and which, in the field of housing, is marked by the wide-scale introduction of the large panel method, is based on standard designs for the buildings as well as their structural components, on off-site factory prefabrication, and on series erection on the flow-line principle at the site.

The following three criteria characterize the development of the precasting industry in East Germany:

(1) Mass and series prefabrication of standardised structural units based on the Modular Building System;

(2) Application of standardised production techniques, i.e. standard sets of equipment and standard processes for all operations involved;

(3) Specialisation, concentration and cooperation among concrete factories in order to supply contracting organizations with all the components required for a project.

The Modular Building System referred to under (1) comprises the entirety of all coordinating principles for designing versatile and interchangeable structural components, groups of components, sub-assemblies, structural sections and complete buildings for various functions and uses.

According to the principle laid down under (2) the following two basic types of precasting methods are at present being employed in the GDR:

(a) Fixed-form methods, i.e. single-mould method, vertical multi-mould method, long-line slip-forming method;

(b) Flow-line methods, i.e. trolley-mounted single-moulds, single-moulds on vibrating tables.

There are two definite types of precasting plant according to criterion (3), i.e.

(a) specialized plant for mass producing certain types of units only;

(b) integrated-type factories for supplying the complete assortment of components needed for erecting a standard-design building.

Precasting techniques

The precasting method to be chosen for a specific structural component depends on the type of loading the unit will be subjected to when in position as well as on the grade of concrete and the type and amount of reinforcement necessary. In sandwich panels the properties of each layer have also to be taken into account.

Due to their sandwich structure external wall panels, for instance, are best cast horizontally. Different types of external finish can easily be applied to the panels using the same horizontal mould. Thus rendering, architectural concrete, exposed aggregate, ceramic finishes etc. allow for a wide range of decorative treatments.

Structural units composed of clay products, such as hollow tiles, or insulating slabs sandwiched between layers of concrete, are, for technological reasons, also produced horizontally. All external wall panels are cast horizontally in the GDR as these units, when in position, take chiefly loads in their own plane. Therefore there is no need to incorporate flexural reinforcement in them. That, however, means that they have to be tilted up into the vertical position by means of rigid forms. Tilting moulds have been designed to meet the requirements.

Internal wall panels using lightweight concrete whenever thermal insulation is called for, and dense concrete whenever high strength is called for, can be precast both vertically and horizontally. Vertical moulds are superior in that no auxiliary means are necessary to tilt them afterwards.

The cross-sectional shape of a unit is also of importance for choosing the precasting method. Right-angled and comparatively thick units can be cast vertically with little difficulty. Thin, ribbed units, however, are more suitably cast horizontally.

Floor slabs can be precast both vertically and horizontally. They are subject to similar conditions as internal wall panels, only that due to their being reinforced there is no need for any special tilting mechanism.

In the GDR the vertical multi-moulding method has been adopted for manufacturing internal wall panels and floor slabs. The panel factories in the GDR therefore consist of the two technological lines outlined above, i.e. the horizontal tilting moulds and the vertical multi-moulds. These are complemented by a department for precasting special elements such as stairs etc. The single-mould method on vibrating tables was developed for precasting prestressed concrete for floor slabs.

Another extremely productive precasting method employed is the long-line method using slip-form finishers. This method allows for large units either non-reinforced, conventionally reinforced, or prestressed to be produced continuously in various sizes and for differing purposes.

Of the two machines constructed in the GDR, slip-form finisher Model G 1 is particularly designed for open-air casting with air-curing, while Model G 2 is more suited for operation on heated casting lanes for high-early-strength concrete. The range of units to be precast with the G 1 plant comprises plain concrete units of 800 – 3000 kg. The dimensional stability and the grade of finishing (single-layer concrete finished on one side) meets the requirements for dry construction. The annual output for one technological line turning out internal wall units is 30,000 cu.m. concrete or 158,000 sq.m. walling. The productivity is 0,5 hrs/cu.m. Solid prestressed concrete floor slabs 140 mm high can also be cast on the G 1 plant.

The G 2 plant produces both solid and cored prestressed concrete floor slabs for housing and industrial projects as well as external wall panels for industrial buildings. The productivity for industrial floor slabs is 1.59 hrs/cu.m., and for housing floor slabs 1.71 hrs/cu.m.

Flow-line scheduling

Large-scale introduction of precast concrete and the setting-up of a highly mechanised concrete products industry call for industrial methods of organization on the construction site.

Drawing on international experience gained in adapting the flow-line principle to building operations a method called the Rapid Flow-line Method was devised in the GDR. With this method panellized blocks of 40 flats can be erected in 4.5 months.

The basic principles of the rapid flow-line concept are as follows:

- reduction of the construction period for residential blocks
- continuous and uniform work over a long period
- overcoming the time-lag between structural erection and final finishing by carrying out both simultaneously
- carrying out as many processes as possible at the factory
- minute detailing of all technological operations
- mechanisation of all principal processes
- organization of all operations on the principles of cyclic work.

In order to apply this method to any construction job a detailed technological project has to be worked out beforehand, the ultimate goal being to achieve the shortest construction period both from the technological and economical point of view.

Conclusion. Conventional building methods proved to be fully inadequate in coping with the continuously rising volume of construction work in East Germany. The only feasible solution to this problem therefore was to industrialise building. The first steps were to switch over to prefabricating all structural units in highly mechanised and well organized factories capable of turning out top-quality units with the most economical use of building materials. That this path was correct is borne out by the positive results achieved in the course of industrialising housing.

For achieving maximum economy in industrialised building it is of the utmost importance not to consider prefabrication, mechanisation and flow-line erection as individual elements, but rather as one integrated process.

By continuously improving and perfecting present methods it will eventually be possible for the building industry to catch up on the high degree of industrialisation already attained in other branches of the economy.

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K. Holbek

Canadian use of precast concrete units

By K. Holbek (Canada)

In the continuous efforts by Canadian builders to keep actual building costs down, by the Canadian architects to look for better buildings materials, and in the day-to-day fight for profitable markets in the highly competitive construction field in Canada, the precast concrete industry was born and has come of age to a degree where it now occupies a substantial part of the over-all building material market, all within a little more than a decade.

The demand to reduce manpower requirements at the site, to decrease the overall construction time and to make construction efficient throughout the year, notwithstanding the comparatively long and severe Canadian winters, led to a national market for precast concrete in the early fifties, served mainly by a few pioneers who started specialised firms in this field. Some of these pioneers have built their firms into substantial plants to-day, others have fallen by the wayside but their place has been taken by new firms, in many cases offsprings of firms already established in the building industry and having the necessary funds to start and maintain a proper precast concrete set-up.

The development of precast concrete units, however, has been hampered by several factors which undoubtedly are common in varying degrees in many other countries. Peculiar to Canada are the widely scattered isolated market areas covering not more than half a score spread from the Atlantic to the Pacific. All these different areas are governed by different Provincial and/or Municipal building codes, most of these with no provisions for precast and/or prestressed concrete and only recently has a national building code comprising this item been developed, but the speed by which this has been accepted across the country is most encouraging.

Another factor holding back the development of precast is the complete lack of standardisation of even the simplest building components, and modular construction is practically unknown in Canada. Some manufacturers have standardised sections on a local basis only, as described later.

Furthermore the Canadian construction practice of bidding jobs based upon architects' drawings and specifications still leaves plenty of opportunities for substitution of material and consequently does not encourage extensive special pre-bid research, testing, mock-up or investigation for specific jobs. Also by limiting the engineering and production time between orders and deliveries the advantages of prefabrication are diminished to some degree.

Most of the specifying authorities cannot specify special processes or systems, either from an engineering or production basis, but must keep the bidding open for all the different manufacturers with the result that all the details, joints, connections, handling and erection, which are often the key to an economic solution, do not fit any particular manufacturer, and changes and substitutions at this stage normally do not improve the picture.

Although the National Research Council has done a tremendous amount of research and work towards making the construction industry an all-year round operation, it is only recently that this research has included prefabrication. The same can be said about the cement companies but fortunately there are recent developments towards more applied research in the field of precast concrete. Sporadic research in this field is also carried out at the Universities. As this research becomes more generally available the results will appear at the educational level thus making the designers of to-morrow more familiar, not only with the advantages of prefabrication but also with the discipline it enforces on designers.

Last, but not least, the strongest deterrents against prefabrication to day are the so-called "hidden taxes" on the materials at the manufacturing stage. In Canada provincial taxes vary from Province to Province, up to a maximum of 6% and recently an additional 11% Federal Sales Tax was imposed. The initial effect of this was to penalize prefabrication compared to on-the-job manufacturing by the general contractors thus emphasizing the climatic cycle operations of the construction industry. Some improvements have been negotiated but this problem is not easy. It helps, however, to explain the complete non-existence of some precast products in Canada which have been precast in Europe for decades.

The precast concrete industry in Canada has developed a product range which can be divided into two main categories:

1) Standard products made from standard permanent forms with some adjustments for variations in height, width, etc. the use of which is promoted by extensive sales literature covering all physical and design criteria in easy-to-read table form.

2) Custom designed products to suit the individual jobs.

Among the precast standard products the main items are:

- Flat Hollow Core Slabs varying from 16 in. to 48 in. in width, and depths from 4" to 8" with spans up to 30 ft;

- Double Tees also called Twin Tees, Wing Slabs, etc. varying from 4 ft. to 8 ft. in width and from 12 in. to 24 in. in depth, giving spans up to 75 ft;

- Single Tee Slabs or Lin Tees varying in width from 4 ft. up to the Giant Tees of 10 ft. width in depths from 8 in. to 54 in. providing spans well above 100 ft.

In the second group the main products are precast beams and columns, special structural shapes like arches, folded slabs and particularly all architectural concrete panel work.

Most plants are producing products within both groups and most jobs involve products from each. In the field of standard products the technological changes in the production, combined with a broader acceptance of these standard products, have resulted in a "big volume" approach to these items, with a consequent competitive price range and fairly standard quality controls.

The second group of products has been helped over the last few years by the increasing average size of the jobs which, to a casual observer, appear somewhat bigger than individual jobs in Europe, outside of Government developments. Consequently custom features, like special designs and forms, can be kept to a manageable portion of the overall cost.

The most significant development in the precast concrete industry during the last few years has been the ability of the industry to make their products fulfil several purposes simultaneously, that is in combining architectural and structural qualities and incorporating as many of the services as feasible.

The highly competitive marketing of the precast concrete has developed many ingenious solutions to specific jobs by using standard structural units for architectural purposes and vice versa (the use of panel walls for structural purposes). This development was partly caused by a selling philosophy rather than a design approach. (See figures 1 and 2).

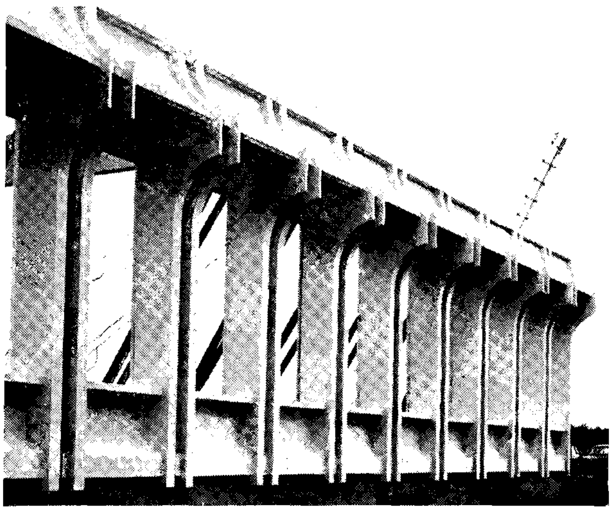

Fig. 1. Load carrying, insulated, one storey office wall panels

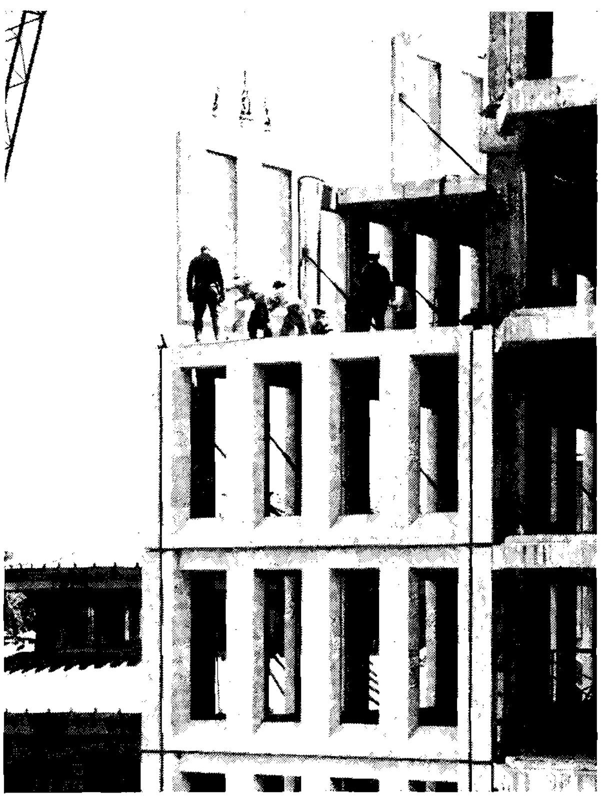

Fig. 2. Window-wall panels used as outer bearing wall for precast floor units at McGill University Arts Building.

This development has been highly successful on outstanding individual jobs and as designs improve with respect to weather resistance, insulation, moisture control etc. the technology developed may eventually lead to some standardised and modular design throughout the country.

This development is especially apparent in the institutional, industrial and commercial field where Canada is now catching up with the European practice especially in the architectural treatment of panels and the increasing sizes of these panels.

The main reason for the trend towards larger panels is to cut handling and erection time but although great strides have been made we are a long way from the mechanised erection of most European countries.

In areas other than institutional, industrial and commercial, such as the housing field in all its aspects, from single dwelling to multiple dwellings, prefabrication is practically unknown in Canada. This is partly due to the factors mentioned earlier in this paper as affecting prefabrication in general but also due to the availability of traditional wood and a consumer resistance against buying prefabrication which the layman still considers synonymous with uniformity in appearance.

Since the war the percentage of multiple family dwellings of the overall dwelling construction has remained constant at about 25% and both types of dwellings have mostly been built by individual small to medium-size contractors, thus making all efforts by the precast industry towards standardisation, planning and development of reasonable size projects rather frustrating.

There are, however, signs that the 25% is going to increase and as bigger developers also appear to be interested in this market we may be entering a construction phase similar to the European practice over the next decade or two.

As an indication of the growth of the precast industry, it is interesting to note that more than twenty companies from coast to coast, representing 90% of the precast concrete industry have been able to form the Canadian Prestressed Concrete Institute and in less than two years have produced a 500-page handbook of precast prestressed concrete covering the Canadian codes, explanations and comments on same, particular design applications and graphs, typical specifications and plant requirements, and last but not least a considerable amount of connection details based upon a design philosophy which should help the future designers towards a better understanding of the proper application and detailing of these all-important connections.

It is exceedingly difficult to cover any particular development of the precast concrete industry or to draw any conclusion of any advanced design or technology not previously experienced or solved by the precast industry in other countries, mainly because the precasting technique is still so much on a custom-designed and custom-made basis as described above.

Although the industry has produced jobs across the country of outstanding design, production or erection qualities which have created considerable interest also outside its border, we still consider ourselves on the receiving end of any research developments and find an easier task in listing the technical and economic problems yet to be solved. Undoubtedly some of these problems are common to other countries and it is possible that in many cases solutions have been found but communication between the national research organizations, or between the individual companies and their national research bodies is not yet functioning smoothly enough.

Here again the highly competitive nature of the construction industry and the young age of the precast industry combine to make most firms ignore any long-term or complicated research, and the research and testing departments of these firms have been tied down to day-to-day production problems urgently demanding solutions because valuable time and production costs were involved.

Therefore the industry has yet to face the need for a broader and more forward looking research, and it is the writer's opinion that this must be done by the industry as a whole either as direct participant in such research or at least as a guiding participant or coordinating factor among the existing research facilities such as the National Research Council, the Cement Industry and all the many new University facilities.

Among the more important technical problems facing our industry to-day are:

1) Insulation of wall panels suitable for present-day humidified and air-conditioned high-rise buildings;

2) Actual stress deformations due to temperature changes with the wide and rapidly changing range experienced in the Canadian climate;

3) Earthquake criteria for design of precast structures;

4) Improved low-cost joint details with a minimum of maintenance and site work;

5) Additional testing of connections to determine ultimate strength and to develop design criteria.

Some of the above problems have undoubtedly been solved in other countries but many of these solutions are not suitable for the severe construction problems in Canada caused by the great distances, remote construction sites and the severe winter conditions.

As a typical example it is worth noting that connections between precast elements in Canada must be bolted and /or welded. Any casting on site without protection and heating is impractical for nearly half the year and consequently cannot be considered at the design stages when timing of the job is uncertain.

The Canadian Prestressed Concrete Institute is now seriously considering this connection problem and will probably enlist the help of several university facilities and research programs to complete their program, which entails extensive testing of recommended standard connection types.

If the Canadian precast industry should make strides in solving any of the above listed problems it may be able to convey these results into research papers useful for other countries or research bodies and we are looking forward to the day when the exchange of research and development techniques in our particular field is a two-way street, both for collection of results by others and publication of our own research achievements on a broader basis than is presently the case.

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F. S. Howell

The concrete house project of the housing commission, Victoria, Australia

Special techniques of production and erection

By F. S. Howell (Australia)

Without doubt the greatest incentive to industrialisation in building is a ready market for the products of the factory and in this regard Victoria has been particularly fortunate. In the war years home building slowed almost to a halt so that with the return of Service personnel, together with an influx of migrants, a desperate housing shortage created the ideal situation for the introduction of new materials and techniques for home building. Although the Concrete House Project was established to assist in reclaiming slum areas the several years of high demand for single homes were put to use in finding ways to overcome the awful monotony generally associated with mass produced houses. Means were found to create some twentyfour variations in external appearance using the same ground plan to standardise factory production for all but two wall panels. Siting a house side on or end on, varying the pitch of the roof or the type of roofing, using sometimes a large scenic window and on others a window wall produced a fascinating variation in appearance but left such items as plumbing, electrical layout and internal joinery, fibrous plaster ceilings, and timber work and internal painting standard for all the variations.

Since this time the building industry in Victoria has gradually caught up with the lage in housing and, because Australians prefer conventional building materials for their homes, the output of single houses from the project is decreasing progressively. The spare capacity is now used for production of multi-storey flats so essential for replacement of sub-standard dwellings in decadent areas of the metropolis.

The lessons learned about and techniques developed to handle such problems as the cost of materials handling; means of reducing on site labour; the economic limits of manufacturing to fine tolerances; construction of high density housing without inducing claustrophobia; and how to gain help from the technical resources available in a community, form the subject of this paper. Some note is also taken of the effect that climate may have on the degree of industrialisation adopted.

Effect of climate on building construction

Inhabitants of countries which suffer from the effects of very cold winters without having the benefit of cheap power or fuel have become accustomed to living in thick walled dwellings to gain the advantage of insulation. This type of structure would become uneconomical if combined with a structural steel frame and the natural development has been from masonry block construction to solid load bearing wall panels often cast in factories during winter months when on site work becomes impossible.

On the other side is the picture of America, a land of abundant natural resources and where the climate within buildings is generally controlled by air conditioning or alternatively at least the winter chill is reduced by space heating. This country in terms of its size and population has shown small tendency toward industrialisation of building on the load bearing masonry wall principle so common in Scandinavian countries.

Australia, lying within the temperate to tropic zone has had a tendency to follow the lead of America—perhaps because it also has sufficient ore deposits to satisfy its need in steel production.

Victoria, unlike the other States in Australia, however, has a Concrete House Project which has been required to tender for the supply and erection of shells (including precast concrete floors, stairways, etc.) in load bearing wall construction. Tenders have been submitted in competition with both steel framed and cast on site concrete framed or load bearing wall construction and the ground floor plans have been as identical as feasible in each system of construction.

The load bearing precast concrete wall system developed by the Victorian Housing Commission in conjunction with the Concrete House Project, Consulting Engineers W. P. Brown and Associates, Engineering Staff of the Melbourne Univeristy, and with the very strong support of the Division of Building Research, C.S.I.R.O. under the Chief of Division Mr. Ian Langlands, has been shown very clearly as the most economical system to date for construction of multi-storey flats in Victoria.

This information is submitted as a very real fact worth consideration by other communities who have the problem of investigating and developing means to provide economical high density housing for their people.

Materials handling

In any heavy construction industry the cost of equipment and labour for handling materials is a very large element in the total cost of manufacturing the product.

Early in the life of the Concrete House Project this element was not so critical as it is now because output was mainly single houses with concrete walls three inches thick. Steel casting tables 30 feet × 10 feet were laid out in six long lines with roadways between for delivery of materials. Some sixty tables were laid out for casting wall panels and the balance of the factory area was occupied in manufacture of chimneys, stairs and small porch slabs in concrete; precutting of roof and floor timbers; the making of cement roofing tiles; and with storage racks for air curing concrete walls. The main labour force was engaged in casting wall panels and this involved a series of gangs moving up and down the rows of tables stripping formwork, cleaning and oiling forms and tables, re-setting forms, placing reinforcement and a miscellaneous assortment of bolts, sockets, conduit and water pipes. These were followed by a powered concrete spreading machine with the concrete delivered from a central mixing plant by a road transporter. Finally gangs engaged in vibrating and surface finishing operations trailed behind.

Examination of the layout showed that some ninety men all walked almost a kilometre each day carrying bundles of tools, bags of bolts, nails, etc.; they stopped and started work at a different point in the factory each day and so lost time in walking to locker and wash rooms. Worst feature of all though was that a wide range of materials had to be organised and transported to continually changing delivery points, and it became obvious that a totally new layout would be necessary to manufacture components for multi-storey flats with any degree of efficiency.

Accordingly a production line system was introduced for the casting of wall panels. Casting tables for wall panels are now placed on trolleys which can be attached to a conveyor moving at an average rate of one metre per minute but capable of small rate adjustments either way. Tables move past a series of fixed stations where steel forms and table surfaces are cleaned, then oiled; side and end forms are placed and fixed down; window and door forms are similarly fixed; steel reinforcement is placed and welded at critical points; conduit for electrical wiring is fastened and water pipes (hot and cold) are tied and bolted accurately at outlet points. Each table has then reached a point where inspectors check all items prior to concreting. After inspection the casting table is lifted onto a mobile vibrator trolley which passes the table under a concrete spreading machine located beside the concrete mixer and having a series of pneumatically operated gates to control the discharge of concrete at window and door openings. After some hand levelling of the concrete the trolley with the casting table and its load of concrete are all subjected to several seconds of medium frequency and fairly high amplitude vibration. Finally the table of concrete, still on the vibrating trolley passes under oscillating screeds, which are also vibrating, to produce a nearly level surface requiring a minimum amount of hand finishing. The loaded table is then transferred to curing positions—three and four inch thick walls to be air cured for ten days after removing from the casting table at one day old; four, six and seven inch thick load bearing walls for use in high rise flats are shortly to be cast in the production line and then be taken for steam curing to minimise storage area occupied in the factory. The production operation outlined has been treated in some detail but the reason why may be appreciated if the gains won from the change are listed. Briefly, a twentyfive per cent reduction in labour force can achieve the same output as previously; men now have fixed start and finish points each day; materials are fed to fixed stations and can be stored adjacent to work areas; more room is available in the factory for the extra production of concrete floor slabs required in multi-storey flats, i.e. less floor area is taken up by roadway.

The production line does not have the capacity to manufacture floor slabs as well as wall panels so that a modified form of the old system is in use. However, best use has been made of available space and complete sets of cast in situitems are stored beside each casting table. In addition a new concrete plant has been installed to feed direct to skips which can be moved by tractor across the factory if required or by overhead crane along any of the four work bays.

The general principle has been adopted by the Project that where possible slabs are made near to the maximum economic size. An upper limit of five tons (English) including lifting gear is about the mark at present and this allows reasonable economy in handling equipment. However, the rule is often modified because it is also considered desirable for floor slabs to be made room sized so that joints between slabs can be hidden under walls. This assists in providing dimensional tolerance as well as making easier the operation of levelling up floor slabs. The general rule of size is mentioned because once again each product made has to be handled several times and it will cost very nearly as much to hook on and lift a two ton slab as it does for the same operation on a four ton slab if one uses equipment capable of handling the larger size. Therefore the larger the products the fewer the number of lifts and the lower the cost of materials handling provided secondary problems such as exposed joints or special transport fees for over-wide slabs do not act to offset savings.

The use of light weight aggregate in place of dense basalts can also save substantially in materials handling costs because larger sized components can be manufactured. This reduces the number of transport and craneage operations required between manufacture of components and completion of erection of the building. The number of on site joints to seal and weatherproof can also be reduced if larger components are used.

Reduction of on-site operations

The actual cost of the shell of a multi-storey dwelling will probably only be around one third of the total cost of the dwelling. To save ten per cent on the cost of a shell can sound very impressive but the overall savings of some three per cent may not be attractive enough to a client for him to accept the repetition generally necessary to make industrialised building a paying proposition to the builder.

It must be realised that any architect can save substantial sums on a large scale housing development if he can do as was suggested earlier in this paper, i.e. standardise the internal layout so that bulk buying is possible for such items as windows, joinery, doors, cooking and washing appliances, toilet suites, baths, basins, etc.

To gain the greatest benefit from industrialisation calls for a determined effort to manufacture elements which require the minimum of on site work to complete the building once the elements are in position.

The Victorian Housing Commission has found it economically worth while to install standard aluminium framed windows which require no painting and which can be installed from inside in multi-storey buildings. These windows in combination with exposed aggregates on the sheer faces of buildings and together with copper joint flashing cast in walls and floors have eliminated the necessity for scaffolding (other than safety rail) or for external painting except on balcony access faces which are readily accessible. These innovations have been introduced successfully right to the top floor of a twenty storey block of precast flats now in the last stages of erection. Since this type of housing is intended for slum reclamation areas close to industry it is the policy of the Commission to use a lively coloured, rounded, river gravel for exposed aggregate faces because this material does not gather grime.

All electrical, gas, and hot and cold water pipes are cast into wall or floor elements in the factory. Copper waste assemblies are made up in the factory in lengths of one floor height and including soil stacks, ready to drop in place in the duct provided. Pressed steel door jambs are cast into walls and doors arrive on site from the manufacturer already hinged and pre-painted. Similarly cupboards arrive from the maker primed and undercoated only needing one visit by the painter. However, perhaps the most successful development introduced by the Project has been that of casting floor slabs upside down in the factory. After turning over they are lifted into place on the walls so that the broomed finish is ready as a ceiling to receive paint and the top surface is fit for the laying of vinyl tiles after slabs have been stitch welded and joints grouted. No levelling screed of concrete is used on floors and erection is a totally dry process except for grouting up of vertical joints and of joints between walls and floors.

Manufacture and erection to fine tolerances

When the Housing Commission decided to embark on a programme of high rise flat construction using precast concrete elements their Consulting Engineers W. P. Brown and Associates prepared a specification for factory manufacture and field erection which laid down tolerance limits never before attempted by the Concrete House Project. These limits were briefly as follows:

Manufacturing Tolerances for precast concrete elements

i) Wall Panels
    Length and height Minus 1/8″ Plus 0″
    Thickness Plus 1/8″ Minus 0″
ii) Floor Slabs
    Length and breadth Minus 1/8″ Plus 0″
    Thickness Plus 1/8″ Minus 0″

Erection Tolerances for precast concrete elements

i) Floor slabs level to plus/minus 1/8″ about the floor datum level.
Joints in floor slabs are flush to plus/minus 1/16″.
ii) The lean of any load bearing wall does not exceed 1/8″ in its own height and the centre line position of any wall does not deviate from the theoretical centre line by more than 3/16″ in the full height of the building.

These tolerances have been achieved throughout the erection of the first twenty storey block now nearing completion but they called for purchase of specially selected steel forms, methods of protecting forms after stripping to prevent damage by dropping and very careful supervision by foremen and inspectors in the factory. It also called for the full time employment of a qualified surveyor on site to maintain floor levels, wall set out and verticality. A combined handrail scaffold and locating angle was used on each floor to set perimeter walls to line and similar steel angle positioners were used to locate internal walls. The overall result of achieving these fine tolerances has been that, except for extreme weather conditions for two months of the winter, the erection rate achieved overall has been higher than that expected from crews erecting four storey walkup structures. Extra cost of factory production and field set out is being won back by absence of holdup from ill fitting components. Further gains in time will be made by finishing trades because the structure is so true to line and level and positions of fitments are accurately located.

Development of high rise flat construction in Victoria

Industrialised housing for structures above one storey in height has been developed by the Victorian Housing Commission in a period of ten years. In 1954 a four inch thick precast concrete wall was tested to destruction and the results of the test were encouraging enough for technical staff to plan a full scale test on a three storey precast concrete structure to determine to what height the Commission might build in four inch wall construction. The test result indicated construction up to at least five stories could be undertaken if high quality products were manufactured and joints were strengthened. Commission then proceeded to build two, three and four storey structures in areas reclaimed to eliminate sub-standard housing.

Late in 1962 a full scale test to destruction of a prototype flat was carried out under the control of W. P. Brown and Associates in conjunction with Technical Officers of the C.S.I.R.O. The report of conclusions drawn from this test indicated that flats similar in design to the prototype tested could be built with four inch thick walls to a height of eight stories provided particular care were taken in packing of mortar between walls and floors to prevent high stress concentrations and provided care was exercised by building to close tolerance in line and level. An eight storey block of flats was then offered to tender which was won by the Concrete House Project using a system of precast concrete walls four inches thick and cast in situ floors. This combination was used mainly to demonstrate that it was possible to manufacture and erect walls to the fine tolerances specified by the Consulting Engineers. After the successful completion of this structure the Commission called tenders for construction of a twenty storey tower block containing one hundred and eighty flats. Alternative structural designs were prepared by Consulting Engineers but each design adopted a common ground plan. The Concrete House Project submitted a bid for the supply and erection of the precast concrete shell and the Contractor who accepted this quote and the design which accompanied it was successful in winning the tender by a substantial margin.

The Commission now has designs in hand for the construction of twelve storey blocks of flats, one in the shape of a three legged star and another as a tee in plan. These together with twenty storey tower blocks and a proportion of walkup units will be built in redevelopment projects to provide variety. At this stage the industrialised system has proved more economical than framed or in situ load bearing wall structures and the Project will be fully occupied in manufacturing precast concrete components for slum reclamation projects.

Conclusion. Although Victoria is only a small state occupying an area a little larger than England and having less than ten per cent of the population of that country it has been demonstrated that industrialised building is an economic system to use for redevelopment of decayed metropolitan areas in Victoria. The same conclusion could apply to many other small communities particularly where labour costs are high.

Any industrialised system should make careful analysis of methods and costs of materials handling before commencing manufacture of housing components.

Continued efforts should be made to reduce on site labour to a minimum to produce dwellings at the best price.

Manufacturing and erecting multi-storey building components to very fine tolerances involves greater capital outlay which may be recouped by reduction of costly delays on site which are caused by ill fitting components.

Prefabricated large span prestressed concrete components for industrialised building

By G. F. Huyghe (Belgium)

The modern building technician must face new and ever changing problems, for example,

- ever increasing beam span;
- smaller beam section to reduce deadweight responsible for higher concrete stress and, therefore, stricter material quality control;
- continuous pressure to cut down time allowed for completion of work despite related labour shortage;
- higher heat insulation standards and more modern effects;
- minimum building maintenance to meet labour shortage and costs;

The development and applications of new techniques is the answer to many of these problems.

Noteworthy examples are the development of prestressed concrete, prefabrication and introduction to the building trade of lightweight concrete (specific weight 1.7). There is no doubt that this material will also be used in Europe in the prefabrication of prestressed concrete component units.

In the course of the last twenty years a wide and varied use has been made of prestressed concrete. As a result of the Symposia of the Fédération Internationale de la Précontrainte, specialists are kept fully in the picture with new applications all over the world. A particular example is the great advance in prefabrication in factories of medium and large span building components. The process applied is prestress by adhesion. High elasticity steel wires or strands are stretched between two abutments approximately one hundred metres apart. The shuttering having been placed in position, concrete is cast around the wires. The concrete hardens; then the wires are cut. These tend normally to recover their initial length, but concrete adhesion prevents slip and the concrete is under compression.

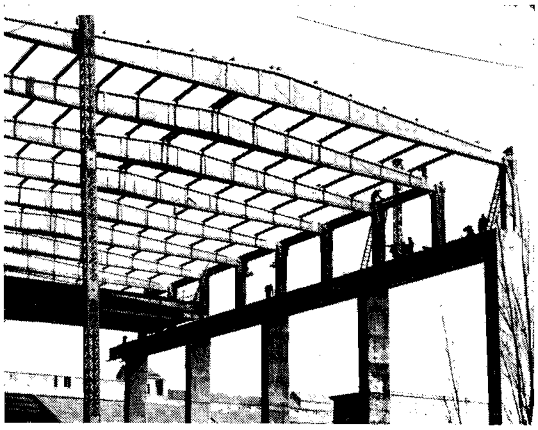


Fig. 1

Factories applying this process are becoming more and more mechanised, particularly in regard to placing of cables and of shuttering, as well as to producing and casting concrete. As production is not dependent upon climatological conditions and each manufacturing operation is submitted to very careful study, it is possible to turn out component parts as planned, weeks ahead. The finish of these building components is of the highest possible standard as a result of inspection carried out by trained personnel. Concrete steel is carefully checked and controlled several times a day. Its compressive strength is measured over sufficiently large quantity of blocks to obtain broad-based statistical values. Measurements and deformation of component units are checked. Discrepancies in measurements and deformation in excess of marginal allowance are detected and such parts, not up to acceptance specification, are scrapped. Transport and assembling are also planned. This technique meets to-day's requirement, that maximum beam span should be greatly increased by the use of prestressed concrete (fig. 1).

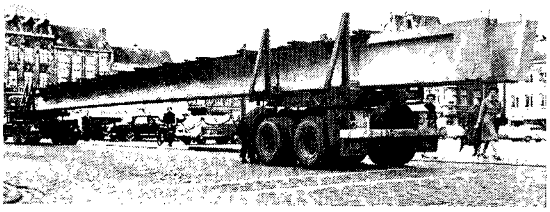


Fig. 2

The maximum length for road transport of beams made at the works is approximately 40 metres (fig. 2).

Beam section has been reduced to a minimum. By using light aggregate concrete it will be possible to obtain even lighter component parts, with the advantage of providing improved thermal insulation. Mechanised manufacture of prestressed concrete components also solves the labour shortage problem in the building trade. Jobs as factory workers or with the assembling gang are more popular than such crafts as masonry, concrete work or shuttering. Moreover, factory workers have a better output than site labour and their standard of work is always improving. Shops are heated in winter, thus avoiding discontinuance of manufacture in freezing weather. Assembling of components is a quick operation and presents no problem. Further use of prefabricated building parts will make it possible to obtain further improved hoists and transport material. With two cranes approximately 100 tons can be hoisted per day (beams of roughly 15 to 30 metres, pillars or wall component parts). A 140 by 100 metres warehouse (see fig. 3), made of 200 tons of pillars, 2,300 tons of beams and 1,400 tons of wall components, requires about two months to complete assembly.

There remains one problem to be solved which depends not only on manufacturers, but concerns much more building technicians and architects who make use of these building component parts: standardisation. In effect, the more standardised the building component parts, the simpler the preparation of plans, moulds for concrete and steel, attachments and connections, and the lower the cost price. By means of such standardisation building components will in the future be made for stock when demand is slack and thus subsequent orders can be filled quickly from this stock. In Belgium one-storied buildings (shops in industry, garages, large departmental food and grocery stores, warehouses) are often built with precast prestressed concrete components. Concrete presents the advantage over building with metals of requiring no maintenance. This is an important feature when the high cost of upkeep of buildings and the related labour shortage are considered. A new development in Belgium is the precasting of pillars (fig. 4), which are still being erected on a sitemade base. Precasting this base too is being contemplated.

Another development is the use of TT-shaped units for walls (fig. 5), which gives a building a modern appearance. Now that it is accepted that a factory building need not inevitably look ugly and be devoid of architectural outline, this TT profile is in great demand.

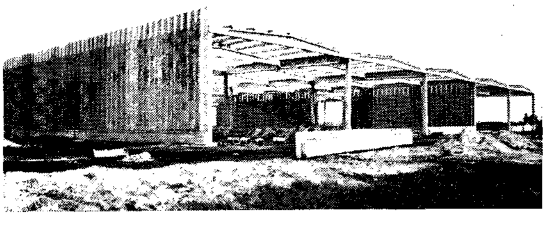


Fig. 3

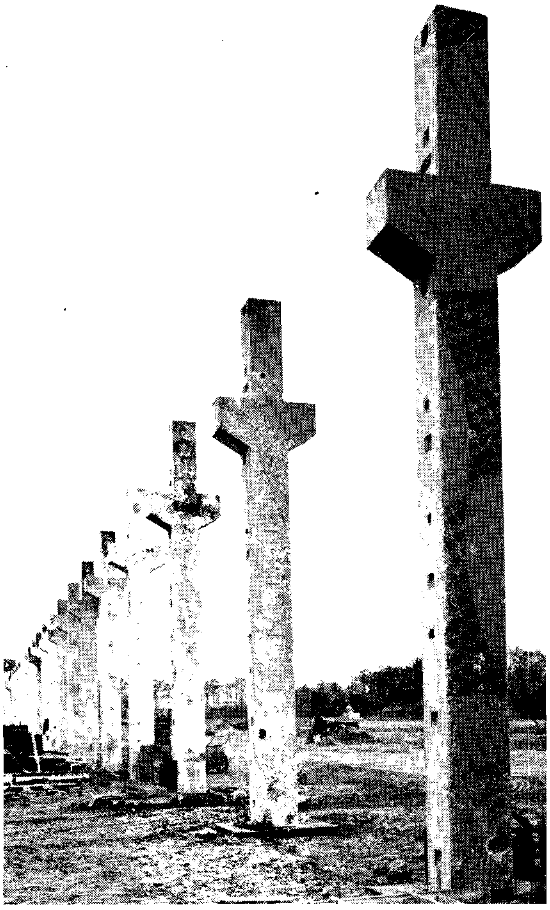


Fig. 4

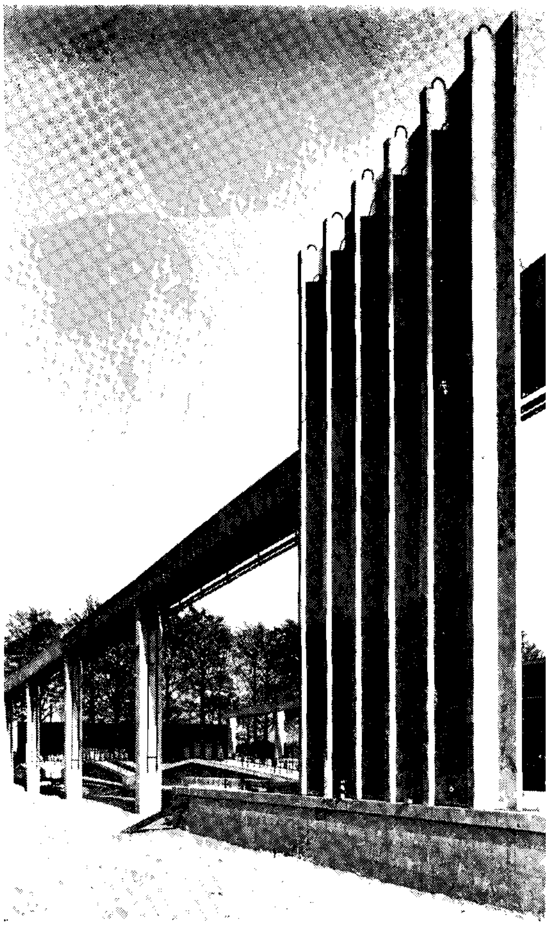


Fig. 5

The TT units may optionally be provided with an insulating layer. A further stride in building prefabrication has been made in Belgium with the erection of multi-storied structures.

This, however raises a major problem, connection. There is no question of assembling components as in one-storied buildings or of piling up floors as one would place tables one on top of another. Such a structure would take very little horizontal stress. Furthermore, it would comprise numerous joints, that would open and close under the effect of temperature, thus causing a large number of cracks in walls. Suitable connections should therefore be devised for each particular projected building. The first principle is to have as few connections as possible by making larger component units. This, however, implies the availability of sufficiently powerful hoists for placing such components in position.

The second principle is to decide on one of the two following solutions:

a) connections allowing of no deformation. Such is the case with connections where concrete is cast after placing the component parts in position (fig. 6) or when these parts are soldered to one another on the site.

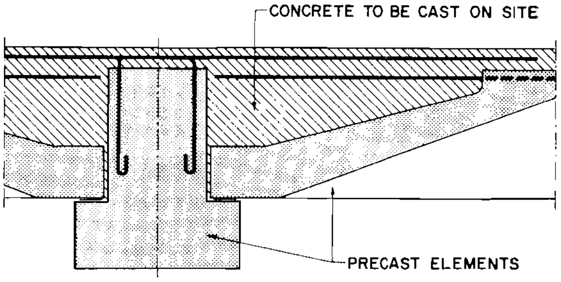
b) provision for an open joint between the component parts; such joint should even be decorative. It can then be filled with a plastic material adhering to the two rims.

An example of multi-storied building is given in fig. 7, which illustrates a parking design. It will be noted that the connections between floor component parts and beams are of the type shown in fig. 6. Connections between front façade beams and floor components are simple supports, as well as for the beams resting on the pillar consoles.

In such a case precast façade components should be provided for, as in the parking project shown in fig. 7. If masonry were resorted to, there would be a risk of cracks in the walls. The use of consoles is naturally out of the question in non-industrial buildings. In this case an attempt is made at more or less novel solutions, in which U.S. standardised connections are used: (Connection details for Precast, Prestressed Concrete Buildings — P.C.I. — Chicago).

Figure 8 illustrates a connection between a border beam and floor components and also a beam-pillar connection.

These are but a few examples. Nevertheless, European specialists should get together in a common effort to standardise a number of connections to complete the U.S. range and which would possibly better meet European needs and practice. Precasting of prestressed concrete building parts is still in the initial stage of development, but will make good progress in Europe, as it did in the United States. However, it is necessary that building contractors should bear in mind this development and provide themselves with sufficiently powerful hoisting equipment. Also, technicians and architects should manage to standardise and establish standard measurements for buildings. Building designs should, from the initial stage, be considered in terms of precast components. If concrete works are able ultimately to offer good quality component parts, with less designed rational connections, industrialised building will eventually be achieved in various fields: multi-storied structures, schools, hospitals, car parks, warehouses, sheds and factories.



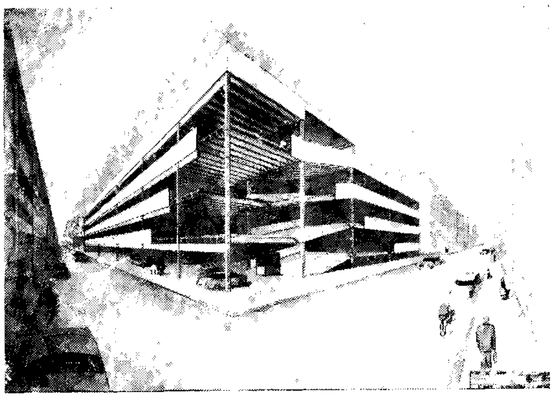


Fig. 7

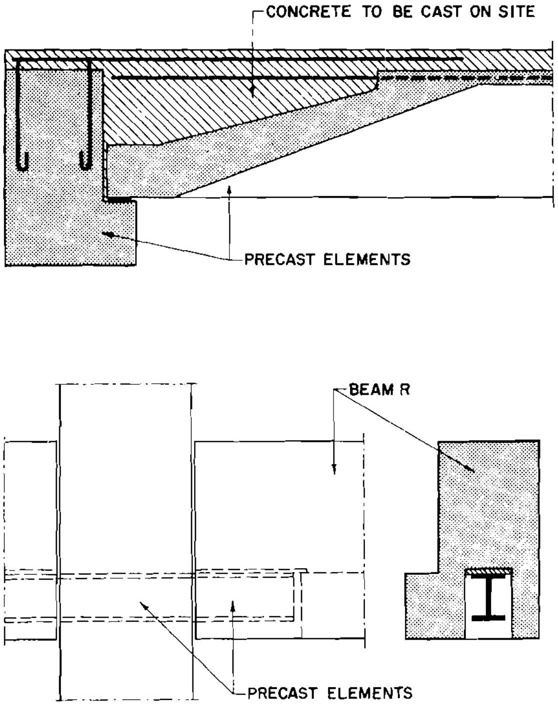

CONCRETE TO BE CAST ON SITE
PRECAST ELEMENTS
BEAM R
PRECAST ELEMENTS

Fig. 8

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K. N. Kartashev

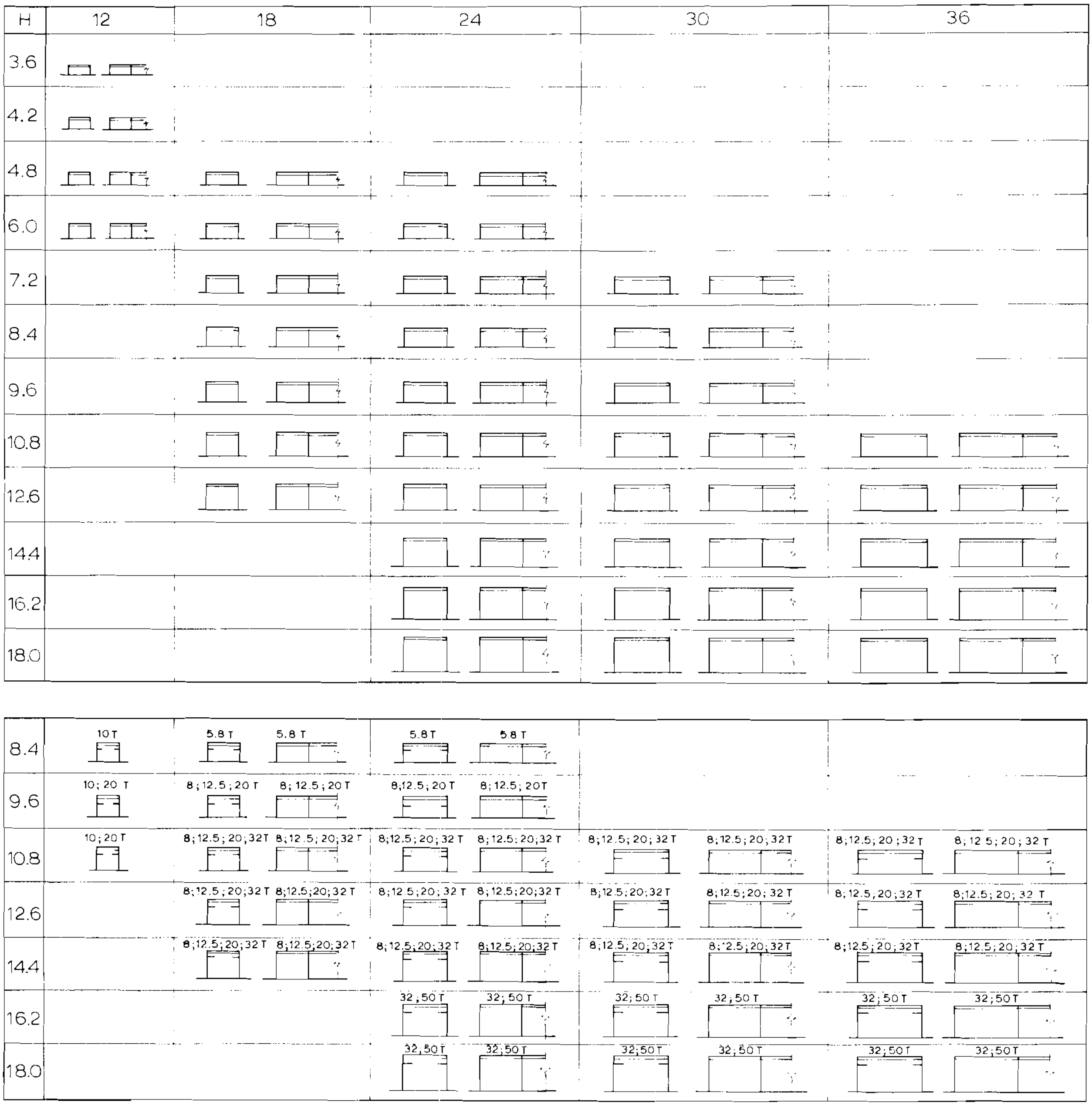
Interbranch unification of industrial buildings as a basis for their industrialised construction in the U.S.S.R.

By K. N. Kartashev (U.S.S.R.)

The volume of construction in the USSR including industrial construction is constantly increasing. It necessitates the introduction of new progressive space-planning and structural designs of buildings and structures for increasing labour productivity and speeding up construction rates. To carry out the actual volumes of construction and erection work in the USSR a powerful building industry has been created. The building industry as well as the other highly developed industries must be provided with the unification, typification and standardisation of applied design and materials. Otherwise it would be extremely difficult to arrange a mass-scale machine production of precast building and structural members and to secure their cost reduction.

At the present day the construction site is often turned into the erection site. The average percent of the prefabrication in buildings reached, in 1963, already about 67% and in some cases the largest buildings were almost entirely erected of prefabricated reinforced concrete members. For example a recently finished transformer-producing plant of 76,000 m^2 area with spans up to 36 m and two tiers of overhead cranes (of 100 and 250 tons capacity) in the middle span, was fully erected of prefabricated reinforced concrete elements, 62% of which were prestressed.

The work on the unification of industrial construction which had already commenced in 1932, is very complicated and labour-consuming. In the USSR there are more that 100 groups of industries each combining a large number of different plants. Every plant has sometimes dozens of shops with different production processes. The attempt to adapt buildings to all the various requirements of the abovementioned shops would lead to the necessity to build each of them by an individual design.

Fig. 1. Dimensional schemes of cross sections of singlestorey buildings with spans of 12, 18, 24, 30 and 36 m; 1. buildings without cranes and with a suspended handling equipment with capacity from Q — 0.5 to 5.0 tn; 2. buildings with bridge cranes with capacity Q = 5, 8, 12.5, 20, 32 and 50 tn.

At the first stage of unification the values of basic dimensions (spans and spacings of columns) for buildings of all industries were fixed as multiples of 3 m and standard column grids were introduced. Due to this measure a certain order in the design and on the site was created, but nevertheless the number of types and sizes of precast elements remained excessively large.

The study of a great number of designs of single-storey buildings which were built before 1961, has shown that there are similar dimensions of spans and heights in buildings that find wide use in various industries. At the same time some dimensions and their combinations are met very seldom. For example, buildings of small height with large spans or buildings of big height and small spans are seldom designed. The values of height and span dimensions are already conditioned by the presence of overhead cranes, as they cannot be less than certain values.

In 1962 the dimensional schemes of cross sections of single-storey buildings were specified as obligatory for use in all industries, combining the span column spacing, height (to the bottom of roof load-bearing structures), type of the handling equipment and its capacity (fig. 1).

A number of rarely occurring combinations was excluded from use. Simultaneously a reduced number of values of various parameters for mass-scale construction was adopted. Thus, for example, only 5 values of span dimensions (12, 18, 24, 30, 36 m) and 12 values of heights for shops without cranes and values for shops with overhead cranes were adopted for use.

Designs of multistorey buildings have been studied also, resulting in approval of dimensional schemes of cross sections (fig. 2) for three- four- and five-storey buildings for mass-scale construction. Certain schemes are specifying an increased height of the ground-storey as well as the upper storey, with an overhead transport or bridge crane without intermediate supports. At the same time precast structures were unified. For example the sizes of floor slabs of 1.5 × 6; 3 × 6; 1.5 × 12 and 3 × 12 were adopted. The roof structures of small spans are girders, of the large ones- trusses. For a 18 m span, taking into account the unification of structures throughout the whole job the use of girders and trusses is both allowed. For wall panels two lengths – 6 and 12 m and height dimensions of 0.8; 1.2 and 1.8 m are specified. The dimensions of window panels are coordinated with those of wall panels.

Taking into account the mass-scale production of standard structures, they are designed with great care and are subjected to preliminary comprehensive tests. To help the organisation of production, drawings of steel forms are supplied together with the drawings of standard structures. Standard production lines for manufacturing the unified precast structures are applied in the designs of factories of precast reinforced concrete structures. The application of interbranch dimensional schemes significantly reduced the number of building types, raised their flexibility and reduced the number of types and sizes of precast structures by 2–2.5 times (in comparison with the subsequent stage of unification).

Increase of mass production of articles reduced their prime cost by 15–20 per cent; that affected such articles as large floor and wall panels and prestressed roof trusses in the first place.

However practice has shown, that the work carried out on unification was insufficient and the number of types and sizes of structures on sites is still large, hampering their industrial production.

Taking into account transition to a higher stage of unification, volume unification was laid down. A part of building called a "unified type section" was accepted as an element of unification. Such a section consists of one or several parallel bays of identical width and height with an identical handling equipment. The section size is usually taken equal to the distance between expansion joints.

All the dimensions of a section are established jointly by builders and production engineers and conform to the process requirements of the given industry, for which they are being worked out. The section, independently of it, is erected of unified structural members.

Column grids and section heights are fixed in an attempt to facilitate the possibility to block the buildings and to obtain a

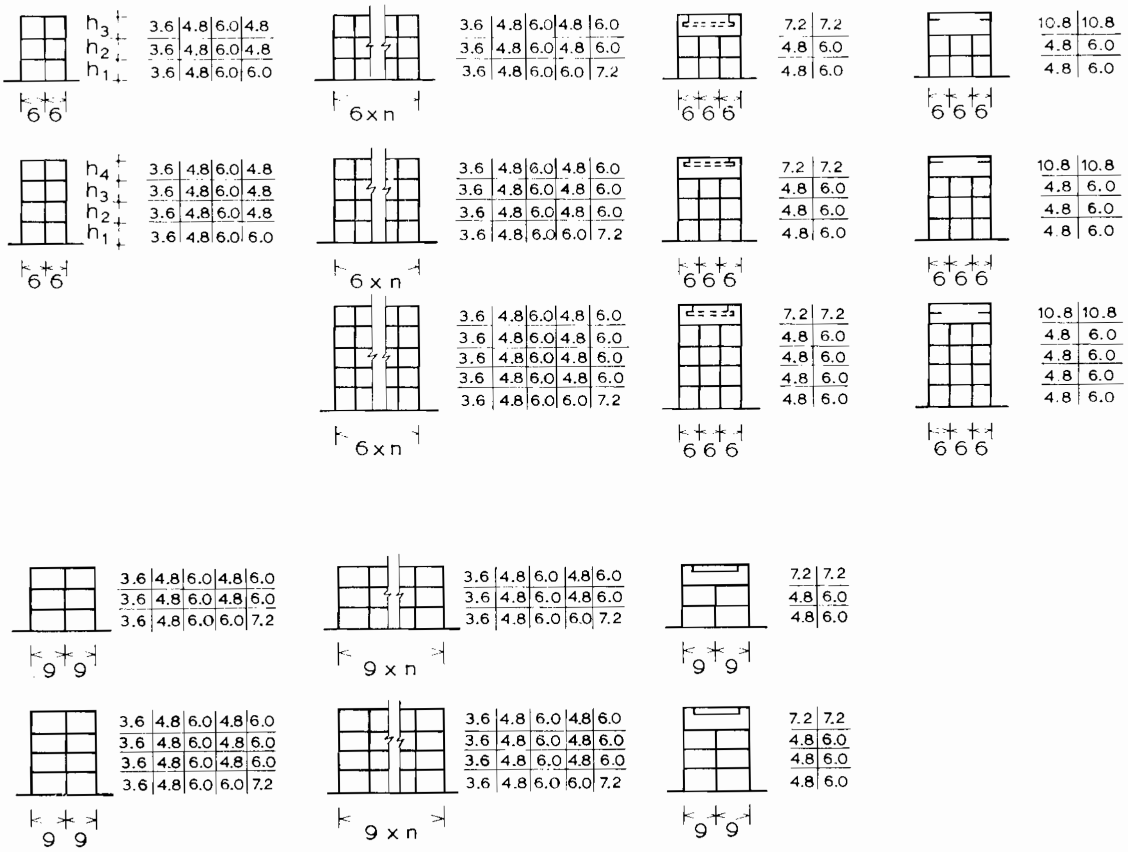


Fig. 2. Dimensional schemes of cross sections of multistorey buildings; 1. of buildings with a column grid of 6 × 6 m, 2. of buildings with a column grid of 9 × 6 m.
Note: the adopted floor heights of each cross section are shown to the right.

flexible building which allows a free placing of equipment. This is particularly important in view of continuous modernisation of the process in conditions of a rapid development of techniques, when equipment is regrouped and renewed. Various types of buildings can be erected of unified sections. The building of a mechanical shop, having in the lower part four sections with a column grid of 24 × 12 m, has two sections of 72 × 144 m and the other two 72 × 72 m. The assembly bay adjoining this part of the building has two sections of 72 × 24 m with a 6 × 24 m column grid.

There is a series of factories turning out one-type mass-scale production, for which complete parallel process lines occupying the whole bay of a building are being developed. The building industry factories in particular belong to this type of production.

For these factories, unified standard bays of 18, 24 and 30 m span, with the length multiple of the length between expansion joints have been worked out. In such standard bays of 18 × 144 m, 28 different process lines producing precast reinforced concrete structures were accomodated and in bays 30 × 360 m all the factories of the asbestos cement industry are successfully disposed.

Not only constructional but also process drawings for unified standard bays have been worked out, the possibility of joining one bay to another with different process lines being foreseen.

To this purpose in these bays the delivery of concrete, output of finished articles, supply of steam, water etc. are provided at the same places. Large factories are easily completed of such unified bays without any alteration of drawings.

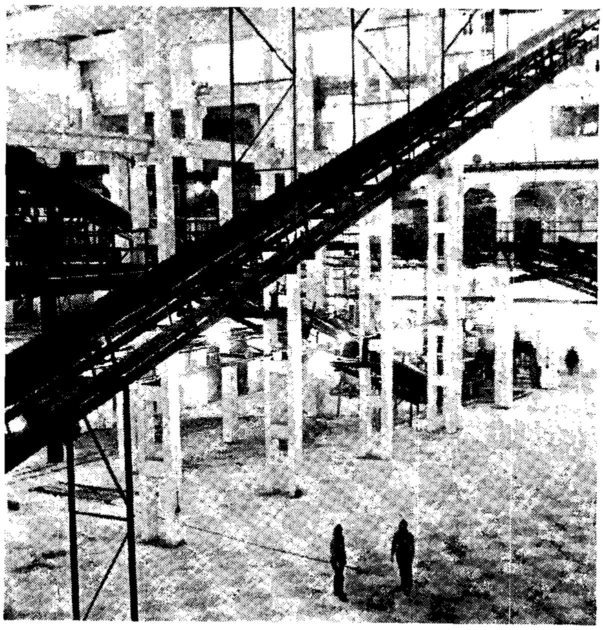


Fig. 3. Interior view of a pavilion-type building for the chemical industry prepared for installation of equipment.

Unified sections for buildings of various industries have different sizes. Thus, for example for some chemical plants instead of multistorey buildings formerly used, pavilion-type buildings (fig. 3) of one and two-span sections with 24 and 30 m spans and 18 m height (to the bottom of load bearing roof structures) are applied. In such buildings the equipment is placed on the floor level on seperate foundations or on the sectional steel and reinforced concrete multilevel frames. In both cases the building structures are free from process loads owing to which they can be made lighter.

Securing the independence of construction and process parts of the shop gives great advantages. The building can be erected without final design of the technology being determined. The change and modernisation of the equipment can be done without any alterations of structures. Such pavilion buildings are also being successfully used for nonferrous metallurgy works, certain factories for the food industry and others.

A large number of various food industry enterprises is being built in every settlement. These enterprises were divided in three groups: for small towns with population up to 50 thousands, for medium ones with population from 50 to 200 thousands and for big cities with population over 200 thousands. For these three groups standard sections of 24, 48 and 72 m wide with column grids of 12 × 6 m and various lengths were worked out.

A series of seperate production units can be accommodated in long buildings of a width equal to the section width; these sections are being easily blocked over the length of the building.

Amalgamation of production units in a group of enterprises ensures the reduction of the construction cost, simplification of their administration and reduction of operation expenses. Different enterprises can be accommodated in similar sections. All the unified buildings of the food industry can be erected of only 30 types and sizes of precast reinforced concrete members. Standard sections were worked out for a number of industry branches (chemical, machine-building, building materials, building industry, food, light industry and others) allowing better organisation of mass-scale fabrication of precast structures, a speeding up of the erection of buildings, to simplify the design and to provide a reduction in construction cost.

At present, type sections for industry branches, not yet included in this work, are being worked out.

The work on the unification of industrial construction is not completed at this stage. At this time unification of industrial structures (hoppers, silo, water-cooling towers, tanks, water-towers, galleries, tunnels, retaining walls and others) is being developed. The number of types of these structures as well as the number of types and sizes of the component precast elements out of which they are erected, is greatly reduced.

The next stage of unification is the unification of general layouts of enterprises and their subjection to definite unified principles. Unfortunately the conciseness of the report does not allow to consider this problem, but as practice has already shown this work gives a considerable economic effect.

Basic reflections on the economic area of influence of prefabrication plants

By L. Komoli (Austria)

The considerations detailed below are limited to the field of prefabricated large-sized elements for building construction, using panel building methods. They are valid only in a limited manner for prefabricated elements for industrial and civil engineering works. An attempt is made to deduce valid rules for the area of influence of prefabrication plants depending on the relationship of site and plant.

So far, the area of influence of a prefabrication plant of the kind in question has generally been identified with a circle, the centre of which is the prefabrication plant with a radius amounting to between 30 and 50 km. There are hardly any exact data on investigations concerning this problem. All data furnished so far have been too general to be considered as a genuine basis. For determining the area of influence of a plant, which is identical with mastering the long transport distances still considered economical, a number of factors have to be considered.

These factors, or termini, have at present to be taken from the field of industrial production in its general sense, to which industrial prefabrication in building construction belongs, as there are no basic termini at present for the special case of prefabrication in panel building. They are the criteria for determining the location of an industry. The most important location factors are the following:

1.) Orientation of supply, i.e., the choice of site with regard to procuring the necessary raw materials.

2.) Orientation of sales, i.e., situating the plant within the sphere of the customers.

3.) Orientation of transport, i.e., the dependence of the site on the general traffic situation.

4.) Orientation of labour, i.e., consideration of procuring labour taking qualitative, traditionalistic and wagepolitical factors into account.

5.) Orientation of agglomeration, i.e., the massing of similar plants in one location.

For the present investigations, orientation of supply and transport only are of real interest and fundamentally influence the choice of location. Orientation of sales, on the other hand, is certainly an ideal case which must be of secondary interest even if a plant is placed in the centre of a large building site because a production plant in the industrial sense must be correctly orientated beyond the completion of a single special task, however large that task may be. This seems to be one of the large initial difficulties in the planning of works for prefabrication. Up to now, the general trend aimed at placing the production plant near the sales area, that is, efforts aimed primarily at immediate direct sales, ignoring the fact that such an orientation can only meet a single special case. The fact that so far nearly all field factories which had been erected for the execution of one special order were kept going after completing the first building task shows that these deliberations can only be correct to a certain extent. Therefore the problem must be viewed differently when adopting considerations of industrial manufacture.

An industrial manufacturing site has to be erected which not only produces for a certain, however large, single object, but which has to be in a position to satisfy a widely scattered demand. A plant of this kind, which may well plan its manufacturing programme but not the location of its possible future customers, not even speculatively, must therefore be guided by supply and transport possibilities. Orientation of sales is only considered in as far as it would be senseless to erect a manufacturing plant outside the sphere of possible sales. In view of their existence, orientation of labour and agglomeration may be neglected in the present deliberations.

In the following description it is assumed that a plant is so erected that its position with regard to raw materials needed is favourable. In ascertaining, under these pre-conditions, the economic sphere of influence of the plant, it is necessary to commence with an analysis of the transport of the finished products.

Consideration must be given to the fact that in transporting large-sized wall elements regional by-laws governing transport often enforce certain limitations. These regulations not only differ from one country to another, but may also vary from area to area in one and the same country. In any case, these regulations constitute secondary conditions which must be adhered to and which only allow, in very special cases, the full use of the load capacity of these vehicles.

Furthermore, each transport vehicle can execute, within the process of one working shift—including limited overtime—only a full number of transport cycles. When analysing the cost of transport it can be seen immediately that the kilometres to be covered, as well as the driving times, are only of secondary importance. The figures given so far, including the 30 to 50 km already mentioned, do not take into account the longitudinal profiles of cross-country drives to be covered and traffic difficulties which unavoidably occur in town driving.

To reach exact driving parameters in each individual case, transports have to be computed in their entire process. For this investigation, the recently published book by Ledderboge: "Berechnungsgrundlagen für Fertigteiltransport" ("Bases of Calculation for Prefabrication Transport") was very valuable. For town runs, however, the most meticulous theoretical pre-investigations are no substitute for test drives to ascertain the approximate time limits in town traffic.

Driving times for a driving cycle generally consist of the following factors:—

t_{load} = Time for loading and shunting within the works

t_{full} = Time for full load driving from the works to assembly site

t_{unload} = Time for unloading and shunting at assembly site

t_{empty} = Time for noload drive from assembly site to works

t_{div} = Summarising diverse unforeseen time losses

t_{full} and t_{empty} are to be determined from the longitudinal profile of the route and parameters of the traction engine.
To simplify matters, we can generally assume that

V_{1i} = speed at load drive

at the respective drive section L_i/km/h

V_{2i} = speed at unload drive on the same drive section L_i

$$T_1 = (t_{load} + t_{unload} + t_{div}) + \Sigma_i \left(\frac{L_i}{V_{1i}} \times 60\right) \text{full} + \\ + \Sigma_i \left(\frac{L_i}{V_{2i}} \times 60\right) \text{empty}$$

On signifying the shift time with t_{sh}, nT_1 must be approximately the same as t_{sh}, where n has to be a full number.

$$nT_1 \cong t_{sh}$$

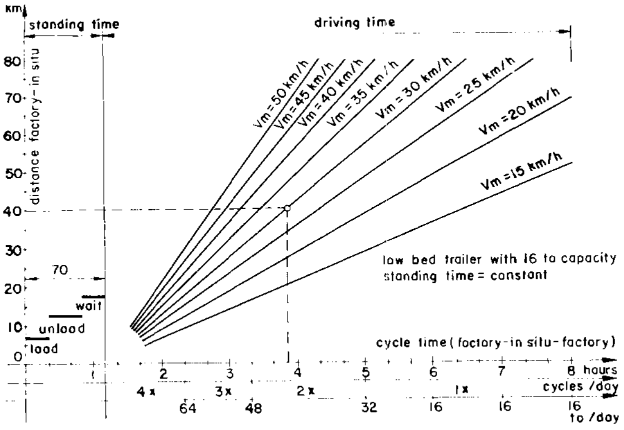


Fig. 1. Dependence of cycle time and cycle number on the average driving speed.

In Fig. 1 the times $t_{load} + t_{unload} + t_{div}$ are given under the term "standing time", giving the dependence of the number of cycles on the driving speed at various distances from the works.

In Fig. 2 the theoretical as well as the actual limit for "n" transport cycles is shown according to figures based on test drives. Criteria for the actual cycle limit in a certain area with the same traction engine are given by the longitudinal profile of the road (gradients, drops, narrow stretches, curves, etc.), by traffic (density of traffic, crossings, speed and other traffic limits, detours, etc.) and by road conditions (pavement, surface smoothness, etc.).

Thus, for one and the same standpoint certain distances, which have to be arrived at according to the above-mentioned deliberations, can be favourable. In addition, by a certain number of cycles, for example 4 cycles, 3 cycles or 2 cycles per day, widely scattered distance ranges arise within which only the same number of cycles can be performed.

The logical conclusion is that the ideal set-up for the isolated investigation of transport performances from the works to the assembly site would be the continuous threeshift service as this would eliminate the impeding boundary condition that within one shift only full cycles can be accomplished. But because of other reasons this cannot always be recommended.

If, on the one hand, by the present investigations the connections of transport performances are made clear, it is of importance in judging the area of influence to find out the costs of such transports. To calculate these costs, no instructions have to be given as it can be assumed that they are generally known. Referring to the relation of costs which are common, for example, in Austria, these costs amount to between 1.7% to 4.2% of the costs of the finished products and are thus within tolerable limits. The costs only increase considerably if the distances grow so large that within one shift only one load and one noload drive with the respective standing times can be performed. In this case they are double the peak value and reach under the same circumstances as quoted above with approximately 8%, a very considerable strain (Fig. 3).

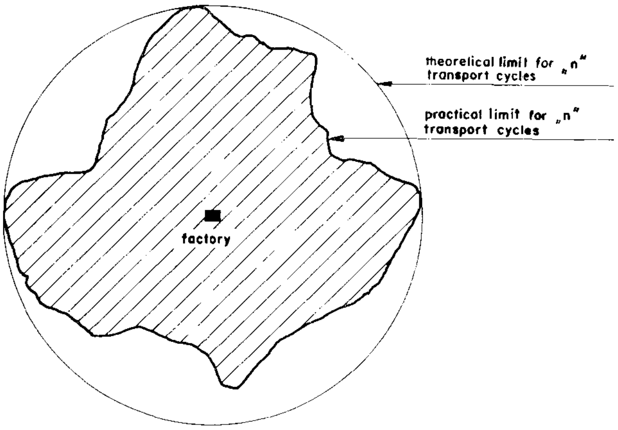


Fig. 2. Practical and theoretical area of influence for 'n' transport cycles.

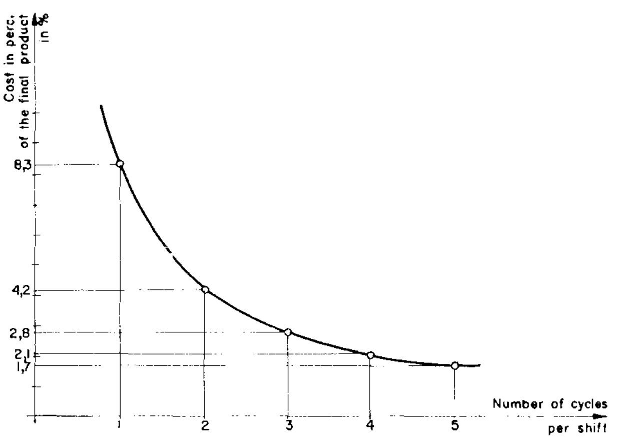


Fig. 3. Dependence of transport-cost-charge of the final product on the number of cycles.

This is true for the standard construction of an apartment. In the case of higher demands on the equipment, the share for the cost of transport sharply decreases and is generally of the order which is likely to be within the exactness of calculation.

In conclusion it may be said that, apart from the given demand, the decisive influence in the choice of a site for a factory for large-sized building elements is firstly the possibility of procurement of raw materials and then the actual number of cycles of transport vehicles from the works to the consumers. The number of cycles required can perhaps also be reached by fixing the outward and return journey of the vehicles above the normal shift time necessary for the assembly of the prefabricated parts.

Problems inherent in the calculation of constructions with large prefabricated components

By B. Lewicki (Poland)

For a construction to be an economic proposition its particular components should be designed in such a way that maximum use is made of their strength, provided, however, that no deformation occurs beyond the safe limit. All the components of a building are not calculated. In many cases, whether it be jointing, or anchorage or reinforcement of some elements, their design is based on building principles usually supported by extensive experience. Such principles also exercise an unquestionable influence on the economy of the adopted building solution.

It is proposed, in this paper, simply to set forth, in general terms, the methods for calculation of structures made of largesize prefabricated components.

Calculations for buildings in which large prefabricated components are used are effected according to the general rules applied to concrete and reinforced concrete constructions (e.g. floor slabs). However, particular attention in such calculations is paid to:

– *the determination of wall strength.* This leads accordingly to working out the required strength of concrete and has a bearing on the quantity of materials to be used.

Moreover, it is essential in some cases, to check by calculation:

– *the jointing of components*, particularly as concerns two walls placed side by side, one of which bears the stress of the floor loads, and the other just its own weight, or where two bonded walls are made of materials of different deformability.

– *wind bracing*, with due regard to the fact that buildings made of large components are always lighter than buildings constructed in the customary way.

– *the deflection of floor slabs, under the effect of a lasting load.*

The wall strength is determined in two sections: half-way up storey height (section 1 – 1) and at right angles with the top edge on which the floors rest. The static diagram used in calculating section 1 – 1 consists either of a rod hinged at both ends, or of a slab resting freely on three or four edges. This assumption is undeniably a simplification of the actual stress to which the wall is subjected. Such simplification falls short of what is required; in effect, in some cases, the breaking load calculated according to this diagram has a probably lower value than the actual force. But no adequate experimental basis is as yet available to prove the case for another and better diagram.

It is assumed in calculations that the load is applied to the wall with an eccentricity e_0, equal to the sum:

$$e_0 = e_{a1} + e_{a2} + e_s \qquad (1)$$

e_{a1} = "accidental" eccentricity due to heterogeneity of the material; preliminary tests indicate that this value ranges from 0.03 to 0.10 times the thickness h of the component, depending on the kind of material and on the manufacturing process.

e_{a2} = "accidental" eccentricity caused by geometrical defects in the course of manufacture and of assembly. Its value is within the same range as that of e_{a1}.

e_s = "constructional" eccentricity determined in relation to loading conditions of the wall, following the general laws of Statics.

The eccentricity factor e_{a1} and e_{a2} are always taken into account in the calculations. But, in the case where the wall is symmetrically loaded, i.e. axially ($e_s = 0$), a diagram is resorted to, relative to a rod (or slab), where the load is applied with an eccentricity $e_0 = e_{a1} + e_{a2}$. This method is fully borne out by experience.

The breaking load, for the static diagram under consideration, is worked out as follows:

$$N_u = bh\,R\varphi\,(e_0, \lambda; E_0, \gamma) \qquad (2)$$

bh = area of the horizontal section of the component (b = width, h = height of section).

R = compression strength of concrete or, in some cases, tensile strength.

λ = slenderness ratio of the component.

e_0 = original eccentricity of applied force.

E_0 = original deformability modulus of the material.

γ = ratio between height l of panel and its width b (γ is taken into account in the calculations in case the vertical edges of the slabs are stayed).

In this formula the effect on the value of the breaking load of eccentricity, of the slenderness ratio, of the deformability modulus of the material and, as the case may be, of the way the wall is shored, is expressed by the function φ.

There are also simplified calculation methods, following which the force N_u is expressed by the following formula:

$$N_u = bh\,R\varphi_1\,(e)\,\varphi_2\,(\lambda, E, \gamma) \qquad (3)$$

φ_1 is replaced with a simplified formula (assuming a rectangular distribution of the strains in the section) or with an empiric formula.

φ_2 is also in a simplified form or is replaced with coefficient tables.

The strength of the wall in section 2 – 2 is given in the formula:

$$N_u' = bh\,Rm_{ap} \qquad (4)$$

$m_{ap} \leqslant 1$ is an experimental coefficient that depends on the way the floors rest; this coefficient may reach a value $m_{ap} = 0.5$.

For the values of N_u and N_u' worked out in this manner the safety factor is checked:

$$\left.\begin{aligned} s_1 &\geqslant \frac{N_u}{N} \\ s_2 &\geqslant \frac{N_u'}{N} \end{aligned}\right. \qquad (5)$$

N = actual load applied to the wall panel under consideration.

s_1, s_2 = respective safety factors determined in function of the material and specific conditions.

Calculations are made for the case where adjoining wall components bear different loads or where they are made of materials of different deformability. The method of calculation is based on the assumption of equal deformations

$$\varepsilon_A = \varepsilon_B \qquad (6)$$

Proceeding from this principle the value of the load N is worked out which, to meet equality (6), must be transmitted from one component to another through the assembly.

In the case of a building with several stories, stresses are transmitted from one wall to another through the anchorage. It is therefore necessary to know also the distribution of stresses in the less strained wall B. Taking into account that wall B is jointed with the upper stories, the differences in stress between the two walls decrease in the lower stories. These assumptions have served to work out calculation formulas applied in practical cases.

The object of calculating wind bracing is to work out the amount of deflection f_b of the building as well as the value of internal forces occurring in wind bracing walls.

Deflection should meet the following requisite:

$$f_b \leqslant \frac{h_b}{2000}$$

h_b = height of building.

The accurate calculation of f_b value for a wind bracing wall with openings presents many difficulties. In practice, simplified methods are resorted to. These are based either on the widely applied diagram with cross-bar deformation confined to the length of a tie beam (de Kacner-Lewicki) or on the multiple bracket diagram, in which bracket reactions are replaced with tangent stresses (H. Beck, R. Rosman, R. Baehre and E. Ericson methods).

In the case of constructions with large prefabricated components, checking the amount of deflection on floor slabs is all the more essential as floors currently used are of the light type and not thick, and as the kinds of steel used have a high strain limit (it is expected that steel with a strain limit equal to 4,200 kg/sq. cm will shortly come into use).

Floor design is on the right lines as long as the amount of deflection under the effect of a lasting load meets the following requisite

$$f_{\infty} \leqslant \frac{1}{200}$$

In our calculations application is made of methods which are a development of the Soviet Mourachev method.

There are other methods known in Poland: that developed in Germany by Leonhardt and that developed in America by Winter and Yu.

An essential requisite for the advancement in design of buildings is the knowledge of the actual conditions in which they are stressed, particularly with regard to:

- the wall stress diagram; transmission of the load of floors and upper stories, degree of floor and wall attachment.
- the stress diagram of the building under the effect of horizontal forces, with due regard to the result of errors in assembling.
- the effect of lasting loads on the strength of walls and floors, taking environmental factors (moisture, temperature) into account.

Such problems require experimental research. This calls for large-scale international cooperation, and CIB Commissions W23A and W17 are taking a prominent part in this field. It is for this reason that they have created considerable interest.

Tendencies of industrialisation in conventional building methods

By P. Misch (West Germany)

In this paper the author tries to outline trends of development towards industrialisation in the German building industry, but confines himself to conventional building methods.
This means that this paper does not concentrate on precasting (factory built housing) one of the major features of industrialisation, though the importance of precasting has considerably increased over the last years in West-Germany.

Industrialisation

The word "industrialisation" in this context is only partly correct, especially if one considers the mass production of one and the same product, as typical for an industrial process. The building industry will, in comparison with classical industry, necessarily always remain at a disadvantage in many respects. It will never be able to mass produce for the market or influence the market. Long term planning of capacity is very difficult for the building industry. In complete contrast to classical industry the consumer will always define the product, the date of delivery and where the "factory" (the site) shall be installed – this installation becoming a part of the product.

Therefore the building industry has been called the industry without factories in the early fifties. But as consequence of the adoption of some typical features of other branches of heavy or light industry (called "classical" industry here) especially through the progress in mechanisation and rationalisation (increase of productivity through mechanisation and organisation) in Germany the building industry is to day often called "the industry of mobile factories". The trend towards industrialisation lies in the tendency towards investment in light and heavy machinery, equipment, and building components to break down the continuous construction operation into a series of identical steps with a view to "mass" production of these parts of the construction project with a minimum of skilled manpower.

Progress of industrialisation in general

The origin of the building industry is the trade, the work of the skilled man with his tool. Up to a certain extent each machine used in building construction is an (oversized) tool. All attempts towards increase of productivity through increased mechanisation are very difficult as the "tools" to be used on any one building site depend largely on size, type, and details of the individual construction project. With all this in mind (and much more should actually be said if space would permit) the progress of the idea of industrialisation seems quite remarkable. Figure 1 gives a rough idea of the increase of productivity over a period of ten years. The bottom line gives the number of man hours worked (1954 = 100) the top line the total volume of building and civil engineering construction the middle line the volume per manhour. The same tendency is supported by other figures. One production unit (1,000 DM turnover) required 293 manhours in 1950, but only 164 manhours in 1960 (prices adjusted acc. to the official index).

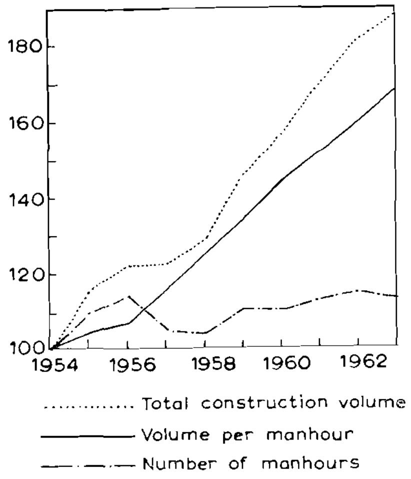


Fig. 1. Increase of productivity in the building industry

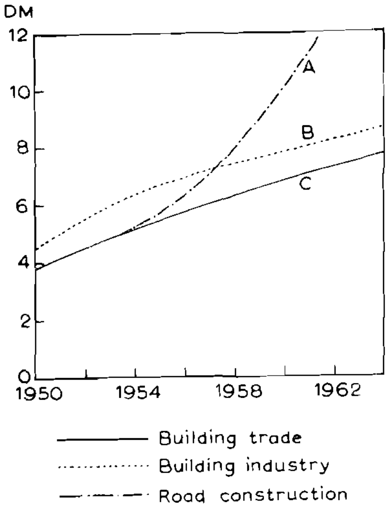


Fig. 2. Turnover in D Mark per manhour

The turnover per manhour is shown also in figure 2 (adjusted to a different price level, proportions remaining the same). The degree of mechanisation is reflected by table 1 giving the tons of machinery per worker (in Germany).

TABLE 1. Tons of machinery per worker.

1950	1952	1954	1956	1958	1960	1961	1962	1963*
0.70	0.89	0.98	1.24	1.51	1.78	2.0	2.25	2.4... 2.5

* estimated

The highest rationalisation in construction has undoubtedly been achieved in earthwork because of its suitability for the heaviest equipment. A comparison between the construction of the Suez Canal (1860/1870) and that of the Managil Canal (Sudan 1957/1958) exemplifies this (see table 2).

TABLE 2. Comparison between construction of Suez Canal (1860/1870) and Managil Canal (1957/1958)

	length km	earth-work m³	Time of construction	Number of european workers	Number of local workers	equipment
Suez Canal (1860/1870)	125	35 Mill.	10 years	22,000	19,000	60 primitive dredgers
Managil Canal (1957/1958)	134	28 Mill.	2.5 years	100	600	32 caterpillars 32 scrapers graders etc.

Time of construction was reduced to 25% number of workers to 1.6%. Equipment used at Managil cost 18 Mill. DM plus 9 Million for maintainance and repair.

A great step towards industrialisation has also been taken in road construction, where apart from earthwork also the laying of the pavement offers identical conditions on different sites thus lending itself to the use of standardised heavy equipment (see curve C in figure 2).

Concrete

The progress in general building may not be quite as conspicuous but it is well worth while to assess the present status of concrete construction and to try and draw some conclusions for future tendencies. It should be recorded here that the development of concrete construction was in itself a major step towards industrialisation in comparison with the conventional brick-and-timber building method.

The making of concrete, its placing and compaction, is a repeated operation which lends itself to rationalisation. Man hours calculated to day are 40% or less of those used 20 years ago. In *1943* the official frame tariff for building trade and industry (in one German region) quoted as a basis for piece-rate calculation: 5.5 to 6.7 manhours for making, placing, compacting, and curing of 1 m^3 of concrete in well defined parts of construction. *1958*: 2.5 manhours (or less if tower crane used) for the same type of work. Obviously the making of concrete has been mechanised to the fullest extent possible through the development of equipment for batching and mixing stations in sizes usable for the small site up to the automatic mixing plant for big sites. Transport has been improved by the use of tower cranes, and shovels for placing are nearly "redundant" in our day.

Transportation of concrete on the site is a decisive factor, e.g. for one and the same site (a 24-storey-office-block) the lift shaft was concreted with a tower crane, the floors with pumps. Pumping only required 1.1 to 1.2 h/m^3 for the top floors, compared with 2.2 to 2.4 h/m^3 with crane which in this example was a little underdimensioned.

TABLE 3. Development of Ready Mixed Concrete.

year	Number of factories	Concrete produced in m^3
1957	8	166 000
1958	11	405 000
1959	40	1 200 000
1960	80	3 200 000
1961	120	4 500 000
1962	200	8 000 000
1963	270 approx.	10 500 000 approx.

Ready mixed concrete is another example for the replacement of hand work by investment in machinery. The development of ready mixed concrete in Germany is shown in table 3. About 20% of the cement used by building trade and industry is consumed to day, in the form of ready-mixed concrete.

Reinforcement

The tariffs for bending, tying, and placing of steel do not show a decrease of man hours per ton over the period considered above. On the contrary they show a considerable increase. This is due to the fact that steel diameters used to day are in general smaller than those of the early forties. More rods have to be handled per ton. It seems that the possibilities for industrialisation are limited in this field. Bending on central yards is done by a number of contractors. Prefabrication of reinforcement cages (i.e. one step further) has certain possibilities but with the bulkiness of these comparatively light cages it will more or less be limited to site fabrication because the economy of transport is doubtful.

Formwork and centering

It therefore seems that the efforts towards industrialisation and economisation will have to be concentrated on formwork and centering. It is hard to quote statistical figures. But undoubtedly the use of formwork panels has brought improvement. Panels are to day in common use wherever possible whilst 20 years ago only a small number of contractors had detected their advantages. Adjustable formwork girders and props have helped towards rationalisation. Man hours per sq.m. of formwork required to day are possibly about 20 to 30% below the figures of 20 years ago.

But apart from general improvements the most important thing in this field is preplanning. Spectacular savings of manpower are possible if the building operations can be broken down into repeated steps permitting to leave as large as possible units of formwork and centering intact. The re-use of centering plus formwork from bay to bay of a long bridge, or the step by step operation of the cantilever method in bridge construction may serve as examples.

A 5-storey-warehouse (90 × 30 m) with mushroom columns (on 4 × 5 m centers) constructed with two rolling formwork- centering-trolleys brought a manpower saving of 40 to 50% on formwork alone. The general advantage of this method was not only the multiple re-use of the formwork (without carpenters) but was the fact that concrete was poured three times a week, all operations were repeated a great number of times, and unproductive waste of energy and working time reduced to a minimum.

Formwork devices such as the above have proved their effectiveness in all construction projects which can be adapted to similar procedures. North-light-roofs and other industrial halls, parking garages etc. can be quoted as examples.

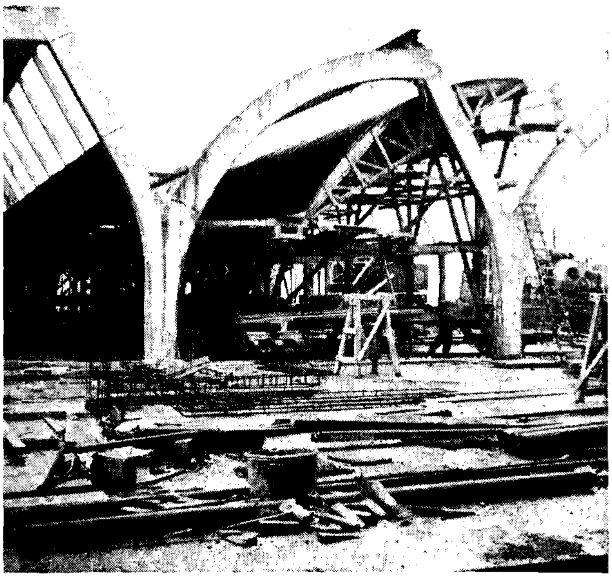


Fig. 3. Northlight shell roof with formwork travelling northward

Figure 3 shows a northlight shell-roof with formwork and centering travelling northward after being lowered a few centimeters (a temporary steel truss supporting the shell edge), Figure 4 shows the same principle. The formwork travels south here. Its upper portion turns around a pin. The 20 bays of this hall (each 60 m long with columns on 15-m-centers) were built in halves, so that the travelling operations of one half could be carried out while the concrete set in the other half. Only one carpenter was required during the operations for the usual minor repairwork. The same principle was also applied to a forded plate construction of a hall 40 × 140 m^2 using 4 formwork-trolleys (7.80 × 17.40 m^2). Had time permitted 2 would have been sufficient.

A different principle is exemplified in figure 5. The ground floor of a large industrial hall was built in 30 × 40 m bays re-using the formwork 50 times. The side forms for the girders carried also the load of the floor on top and the whole was assembled without nails or screws, and after stripping the whole centering bay was slid to its next position on rails.

It should be noted that the use of part prefabrication (columns and girders precast, floors in situ) may also lead to a saving on centering (floor formwork suspended from girders).

All these endeavours tend toward the abolition of the classical carpenter's tools. The initial investments over and above the needs of a classical method has brought about savings in manhours per sqm. of formwork of about 40 to 60% in all cases cited above.

The preference now given in Germany to sliding (or climbing) formwork, also for lift and staircase shafts of multistorey buildings which, with their many openings, were hardly considered the proper field for this method a few years ago, may also be traced back to the tendency discussed here. The lift slab method is another example where formwork and centering for the floors of a construction project are practically reduced to nil. The floors (or large proportions thereof) are cast on top of each other on the ground and then jacked up into position using pre-erected columns for climbing. To date this method has been used in Germany in a limited number of cases only. The above examples are typical for industrial building where the contractors have a comparatively strong influence on design but they show the importance of preplanning in general. Professor Rüsch, Munich, has even suggested drawing up a special syllabus for the preplanning engineer at technical universities with view to his importance for the economy of building. One of his main tasks should be to plan the way of construction and the installation of the site, so that as many repetitive steps as possible are obtained.

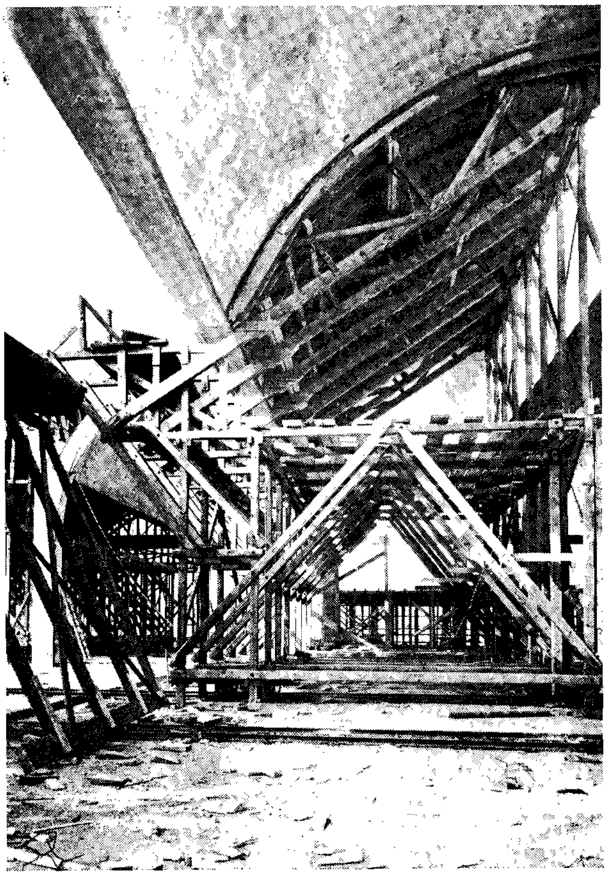


Fig. 4. Northlight shell roof. Formwork travelling southward

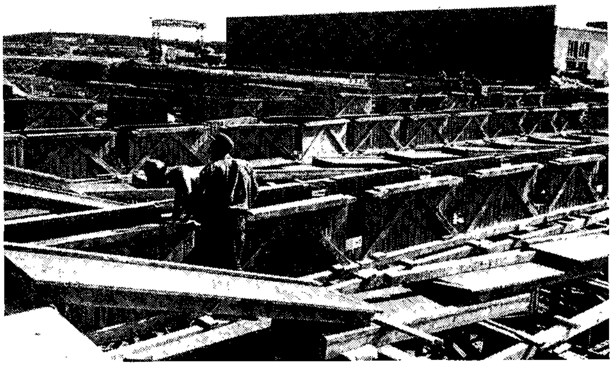


Fig. 5. Groundfloor of a large industrial hall constructed with load carrying formwork sides.

Prime condition for an efficient preplanning on the other hand is the open-mindedness of the designer. The author is of the opinion that the idea of prefabrication may in future tend to fertilize the idea of industrialisation of conventional in situ construction. The rule that a close cooperation between designing architect, engineer, manufacturer, and contractor is necessary for a construction project with prefabricated elements, has meanwhile been universally accepted. If the same rule is employed for conventional building this might prove highly advantageous for the overall economy and quality, bearing in mind that in many cases a monolithic construction has serious advantages over an assembly of prefabricated parts.

B. Obretenov

Improving the organisation of labour in the assembly of industrialised house-building

By B. Obretenov (Bulgaria)

One of the main features in the development of house building during the last several years is its rapid industrialisation. This industrialisation aims chiefly at cutting down the time for the construction of the house, and at facilitating the labour of building workers. With the gradual industrialisation of house building, the construction site has been relieved of some of the works that up to now used to be performed at it, and required much skilled labour, and has thus been transformed into an assembly site. With a view to building comfortable and cheap houses, the specialists in construction are faced with a number of important problems in the field of designing, perfecting the technology of building processes, and improving the organisation for the execution of construction work. The execution of industrialised construction, as a new form of house building, calls for corresponding new forms of labour organisation. In this connection, the improvement of the organisation of labour acquires an important significance, its cause being the special place which manpower occupies in its production process. This is a basic and leading element directly affecting production and it also sets in motion all other means of production.

The basic task in improving the organisation of labour is therefore to cut down consecutively the quantity of manpower involved and to improve the working conditions. The problems of the organisation of labour are related to those of the organisation of production. In many cases these problems are interwoven, and it is very difficult to draw any line of distinction between them. The main difference, which we must make and keep in mind when considering questions about the organisation of labour, is that, while the organisation of production affects the entire process of collective work, the organization of labour deals only with those aspects of the production process, which are directly connected with the application of manpower.

Organisation of labour at the work-site

Some of the most important questions concerning the organisation of labour in construction are: the question of the adequate deployment of the work force, the sequence of execution of the separate operations, and the differentiation of the functions between the different categories of workers who carry out the building process. These are some of the important conditions required to obtain a higher productivity of labour. In order to find a correct solution to these problems, one must first study the structure of the construction process. During the assembling of members in prefabricated house construction, this condition proves absolutely necessary. Here the working process is carried out with the help of heavy and expensive machinery. If one does not know the structure of the assembling process, this may lead to incorrect organisation of labour, to inadequate and incomplete utilisation of mechanisation, and, hence, to a rise in the cost of the building project. For the investigation of the structure of the assembly process, very good results can be obtained by applying the method of technical standardisation of labour. Thus, by analysing the structure of the assembly process, we can establish the duration of the separate operations, and determine which of them are performed with the help of machines and which are performed manually, and find ways for the most expedient use of all machines with a view to cutting down the cost of assembly. From the investigations carried out in this country over the assembly process in large-panel house construction, it can be seen that the duration of the different assembling operations of a wall member is as follows. (see table).

No	Type of operation	Time in min.	%
1.	Hooking the member	0.9	5
2.	Conveying the member	2.1	12
3.	Setting it in its designed position	13.0	72
4.	Releasing the member	0.3	3
5.	Return of erecting mechanism to its initial position	1.5	8
		Total 18	100

This shows that we must seek in Item 3 above, the basic reserves for reducing the assembly cycle, and the engagement of the machine. In practice this can be achieved by constructing and using appliances for this purpose, with the help of which the member can be fixed, in order to speed up the release of the erecting mechanism. In this way the cost of assembly will be cut down.

This concept of "assembling the members" in the broad sense of the word means to set them in their designed position, to make the necessary weldings, and to pour concrete or cement into their vertical and horizontal joints. As its definition indicates, this assembly process is a complex construction process which is accomplished through the simultaneous and successive participation of several workers of different categories. The productivity of their labour will depend to a great extent on the adequate determination of the different categories of workers and upon the proper differentiation of their functions.

The main group of workers taking part in the execution of the assembly work is the assemblers group. This group comprises 4 or 5 men who with the help of the erecting mechanism, set the member in its designed position; they also center it, level it vertically and fix it temporarily.

Besides this group, crane mechanisms are also engaged in the assembly. Depending on the type of hoisting mechanism, their machinists may be one or two in number, who perform all functions connected with the control and maintenance of the machine during the assembling process. All electric weldings on the metallic parts of the joining ends of the elements are performed by a specialist welder.

The last assembly operation, that of pouring concrete or cement into the vertical and horizontal joints of the members, is performed by two workers, either manually or in a mechanised way. With this, all assembling operations of the different members are completed, and the building can be handed over to other workers for the execution of the finishing works. The proper organisation of labour requires some special demands from the workers engaged in the assembling of members, with respect to their special training. All these requirements are contained in a special Manual, in which is shown what grade of qualification the assemblers should have. Thus, the assemblers are divided into four groups—from IV to VII.

It is very important to determine properly their number and the grade of their qualification. An assemblers group can attain their highest production capacity when the workers comprising it are fully utilised according to their specialty and qualification. Moreover, the number of its workers should be such as to allow the erecting mechanism to be used to its full capacity. When establishing the special skill and qualification of the assemblers, we take into consideration the provisions of the Manual, where it is shown to what group a worker belongs with a respective skill and grade of qualification. As already indicated, there are four categories of workers taking part in the assembling process, depending on their skill. The basic production group to perform the assembling work in large-panel house construction is the assemblers group. The number of its workers, as well as their qualifications are determined in accordance with the operations they have to perform. On the basis of the accepted technology for the execution of the assembly and the type of erecting mechanism, the various duties of these assemblers are determined in the following manner:

1. One group foreman—an assembler of the VII qualification group, who conducts and is responsible for the erection. Together with the engineer in charge of the construction site, he measures off the axis of the building, determines the spot where the members have to be set, lays the cement under the members, takes part in their erection by performing the responsible duties of their centering and vertical levelling.

2. First assembler—worker of VI qualification group, who assists the group foreman in measuring off the axis of the building and establishes the places for positioning the different members; he delivers the cement for making the levelling blanket under them. Together with the group foreman he takes up the elements and participates in their vertical setting and centering. He releases the hook from the assembly lugs of the members and, together with the foreman, takes part in fixing the assembling devices when such are used. Second assembler—worker of the V qualification group, who takes care of the delivery of the cement dosator to the building floor, transmits the signals given by the foreman to the crane driver. After the members are positioned, he takes part in their vertical levelling by means of the support provided, and looks after the safety of the work within range of the crane.

Third assembler—a worker of the IV qualification group. His operating place is on the construction site below—near the members stored for assembling. He attaches the hook of the erecting mechanism onto the lugs of the members. Besides the assemblers, there are also the crane engineers, who take part in the assembly. This is either one or two machinists, whose qualification depends on the erecting mechanism driven.

All weldings of the metallic parts where they touch are done by a worker having a special VI group qualification. The last operation is that of pouring concrete or cement mortar into the vertical and horizontal joints. It is done by two concrete workers of the IV and I qualification group respectively.

These are the main functions performed by the different workers participating in the execution of the assembly process. The timely and high quality execution of this process requires all efforts of the separate workers to be properly co-ordinated. In practice this can be achieved by placing all workers under the sole command of their group foreman. Such a group is called a complex group, and it does the whole assembly work. In our practice we have made experiments to compose assembly groups of different grades of complexity. With regard to their labour capacity, best results can be obtained when such a group is composed of workers of each skill. The distribution of the renumeration earned is to be made on the basis of their working hours and their respective qualification group. The analysis made on the structure of the assembly process and the functions performed by the workers of different categories during its execution enables us to design the numerical and qualification composition of the assembling group in the following way:

Assemblers group
Assembler 1 – group foreman
I Assembler 1
II Assembler 1
III Assembler 1
Total: 4
Mechanist group
Mechanist 1
Assistant mechanist 1
Total: 2
Concrete workers group
I concreter 1
II concreter 1
Total: 2
Electric welder: 1

When working in two shifts, the work force should double its numerical composition.

The personnel thus shown is the minimum necessary for proper operation. From these computations, made according to the labour consumption norms necessary for the execution of the different assembly operations on a single housing block, it was determined that the relation thus established between the workers of different specialities, who were engaged in the execution of the assembly work, is correct.

The question about the proper numerical and qualification composition of the assemblers group is one of the most important questions in the field of labour organisation. Other relevant questions to be considered are the most rational instruments and appliances to be used in the erection of elements, and the technical safety of labour, but these are not dealt with here due to lack of space.

Canadian practice in wood frame construction

By R. A. Orr (Canada)

A typical and traditional home in Canada is of wood frame construction. The wood frame home could best be described as a structure with a wood floor platform on horizontal wood joists; a wall structure of vertical members called "studs" with a sheathing skin; a roof of horizontal joists and sloping rafters with a sheathing skin; all of which are assembled on a perimeter foundation of masonry or concrete.

Buildings of wood frame construction are successfully used in every part of Canada, where climatic conditions are most extreme. Temperatures range from −40° F to 100° F with variations in excess of 60° in 24 hours; snow loadings range from 10 to 60 lbs. psf; winds reach a velocity of up to 105 miles per hour; and annual rainfalls range from almost none up to 60 ins. per year. Wood frame construction is used economically in both single and multiple family units, in densities of from 1 to 25 units per acre, with height limitations of 3 storeys, or approximately 28 ft. Performance and practice codes employed today in wood frame construction have been developed primarily from a continuing study of acceptable practices and experience. Building techniques of wood frame construction utilize the versatile qualities of timber, and the uniform standards of timber production in Canada, to meet the market demands.

Since the 1940's wood frame construction has been adapted to large scale production and prefabrication. Prefabrication of wood frame construction has been used extensively to produce residential and commercial buildings to meet markets over a wide geographic area. This type of prefabrication lends itself effectively to economical production for small as well as the large markets and to the control of design standards. Mechanisation is not extensive or elaborate in the "prefab" factories. Rather, prefabrication leads to greatly increased productivity through improved materials handling, job layout, and supervision in the plant, and by imposing order at the job site.

The operations of 'Engineered Homes' are typical of this type of operation, and the company's finished products are typical of contemporary wood frame homes. Engineered Homes is an integrated home building operation involved in construction, prefabrication and land development. Prefabrication of wood frame components is centralized, for the entire Western Canadian market, in the Calgary factory. The 54,000 sq. ft. factory building is located on a 6 acre site which provides full yard storage for all materials. Geographic market areas of this factory are Saskatchewan, Alberta and British Columbia with an economical delivery radius up to 800 miles.

Production of the Calgary factory varies from 800 to 1,200 housing units per year. Additional production could be achieved with existing plant facilities. Sales are made throughout the market area from a selection of approximately 60 basic plans with many architectural variations available for each individual plan.

The design function

The design of the company's basic housing plans is premised on these four primary considerations:

- market demand for variety of non-repetitive home production;
- code limitations and inspections over a broad geographic area;
- transportation;
- availability of skilled on-site labour.

Standard component system

Engineered Homes has adapted a standard component system to meet these requirements. This component system is co-ordinated through the practice of grouping together of structural members (or parts) that will remain constant throughout various architectural designs, structural designs, costing and production. This grouping of components constitutes the essential basis of all design and serves as the key to efficiently and economically producing a quality product while offering the wide scope of variations demanded by the consumer market.

Component assembly. In the assembly of the finished component the size of each of its individual parts is restricted in all dimensions. The component itself is restricted in at least two of its dimensions with the variable dimension being the length in plan. Generally, all finished components are designed and sized to work from (or be accommodated within) 4 ft. bearing or take-off points, i.e. a 4 ft. modular grid is used. By way of example, the plan shown in Fig. 1 is designed through the assembly of 15 standard factory-produced components. Included in these standard components are:

- standard floor joist component, varied in 16 in. multiples;
- stairwell component, fixed in plan;
- standard exterior wall component, varied in 16 in. multiples;
- standard interior wall component, varied in 16 in. multiples;
- window components, five types varying only in elevation, fixed in plan;
- standard roof component, varied in 16 in. multiples;

The exterior wall component (elevation 8′0″; thickness 4″; length in 16″ multiples) serves as an example to illustrate material use: parts are 2″ × 4″ vertical studs, 7′8″ long, at 16″ centres; 3/8″ plywood exterior sheathing; 2″ × 4″ horizontal plates at top and bottom. A standard exterior wall of 8 ft. length is considered as 5 standard 16 in. increments, plus two half increments of 8 in. at each end.

Design Plans. Complete production, erection and finishing of the homes is achieved using four plans, namely: basic set of architectural and detail plans; floor joist plan; stud plan; and roof plan.

The success of an individual plan, in terms of economical and efficient production, lies in the effective architectural design application of basic components, supplementing these with the required number of variable components. The plan "template" is first established by determining the fixed components (i.e., windows, doors, stairwells and flues). Basic components are then laid out on even or part multiples of 4 ft. length. Variable components fill between fixed components to complete the plan.

A standard cross-section is used in all designs with fixed vertical height and varying house width. Finishing details and schedules are applied to the basic plan. The joist plan, stud plan and roof plan are simple line drawings, each showing the code number of all parts for production purposes. Dimensions are shown to locate the fixed components such as stairwells and fireplaces on the joist plan, and doors and windows on the stud plan.

The factory production function

Deliveries of components from factory to site are scheduled to assure a continuity of site work from foundation to final finish with no loss of man hours. Components and all materials are generally shipped in four packages,

(1) Floor package.
(2) Framing package (walls and roof).
(3) Internal finishing package.
(4) Exterior and site improvement package.

Systematic delivery of factory-built prefabricated components facilitates the accurate scheduling of site work and a greater degree of site supervision. The progress of one hypothetical home, from purchase to completion, through the four shipments scheduled, would follow this pattern:

Floor package – Components of the beams used to support the floor joists are cut to exact required length, carefully coded for the guidance of site assemblers and strapped in bundles for ease of handling. Floor joists are precut and coded in accordance with assembly blueprints. These components, together with the sub-floor material as required for the plan, complete the first shipment to the site. The first shipment is scheduled to arrive on completion of the perimeter foundation.

Superstructure package—wall and roof material – Interior wall studs and plates are precut to required length in the factory. Studs and plates are assembled on jig tables using a prepared

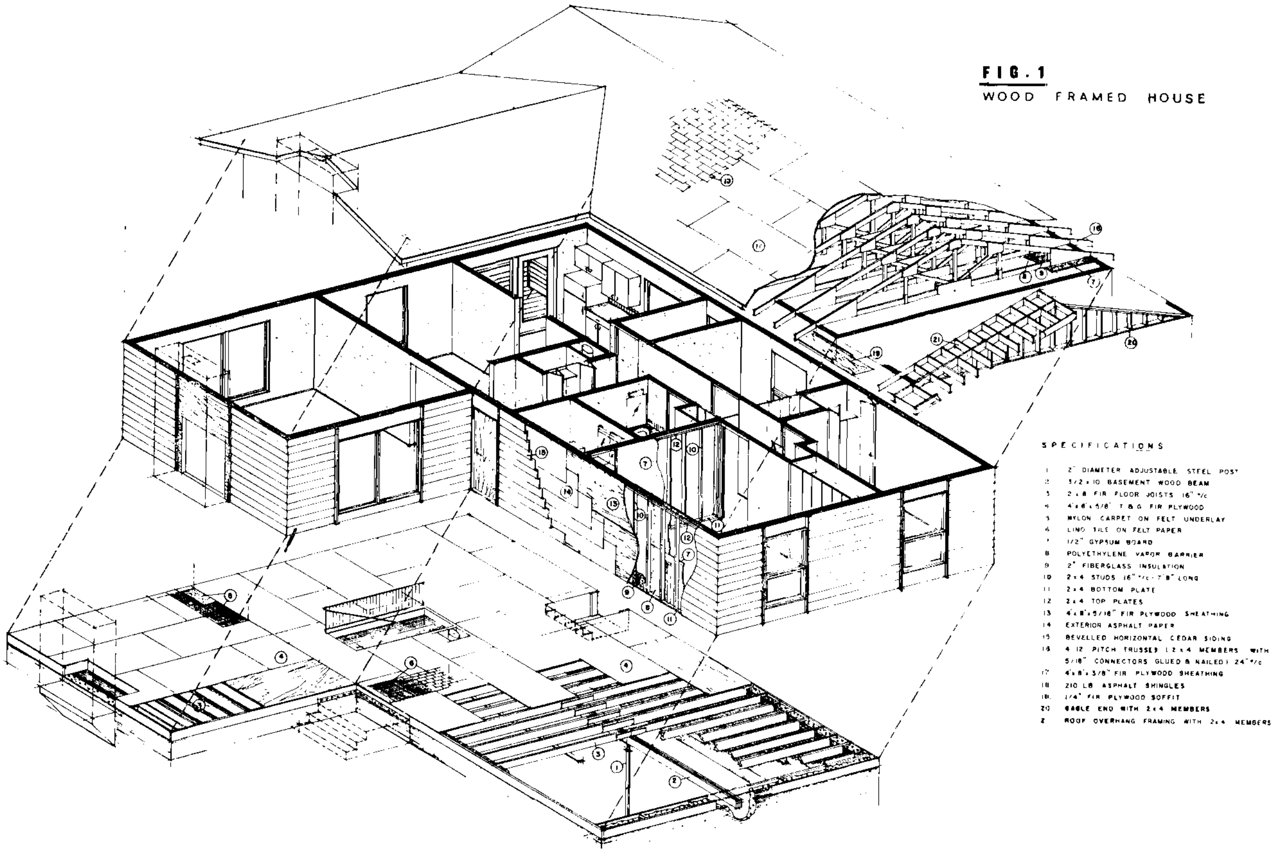


FIG. 1
WOOD FRAMED HOUSE

SPECIFICATIONS

1	2" DIAMETER ADJUSTABLE STEEL POST
2	3/2 x 10 BASEMENT WOOD BEAM
3	2 x 8 FIR FLOOR JOISTS 16" o/c
4	4'x 8'x 5/8" T & G FIR PLYWOOD
5	NYLON CARPET ON FELT UNDERLAY
6	LINO TILE ON FELT PAPER
7	1/2" GYPSUM BOARD
8	POLYETHYLENE VAPOR BARRIER
9	2" FIBERGLASS INSULATION
10	2 x 4 STUDS 16" o/c - 7'8" LONG
11	2 x 4 BOTTOM PLATE
12	2 x 4 TOP PLATES
13	4'x 8'x 5/16" FIR PLYWOOD SHEATHING
14	EXTERIOR ASPHALT PAPER
15	BEVELLED HORIZONTAL CEDAR SIDING
16	4/12 PITCH TRUSSES (2 x 4 MEMBERS WITH 5/16" CONNECTORS GLUED & NAILED) 24" o/c
17	4'x 8'x 3/8" FIR PLYWOOD SHEATHING
18	210 LB ASPHALT SHINGLES
19	1/4" FIR PLYWOOD SOFFIT
20	GABLE END WITH 2 x 4 MEMBERS
21	ROOF OVERHANG FRAMING WITH 2 x 4 MEMBERS

template to assure speed and accuracy. Fixture backing plates, provision for plumbing, heating, etc. (as dictated by the home plan) are built-in to wall sections. Exterior wall studs and plates are precut and assembled on a jig table template in the factory and exterior plywood sheathing is nailed to the stud wall.

Windows, sashes and frames are purchased in complete sets, which are then completely assembled in the window section of the plant. Hinges, fasteners and weatherstripping are affixed to all movable window units. Completed units are then framed as required with jacks and studs to form a "window wall" which in turn is integrated into the complete wall section.

Doors are completed, according to blueprint specification, in hte door section which carries out all necessary work, including glazing where required. All provision for locksets, hinges, weatherstripping, and decorative glass are completed prior to shipping. Exterior door units are finished in the factory for nailing into wall sections at the site. Protective primer coats are applied to both exterior and interior doors in the factory.

Roof trusses, prefabricated completely within the factory, are ready to be set on wall sections at the site. Method of manufacture, employing accurate patterns for each truss design, makes it possible to hold members rigid while gussets are glued and stapled into position. Gussets are attached to both faces. Where plans and specifications require rafters and ceiling joists in lieu of roof trusses the following procedure pertains: rafters and ceiling joists are precut, coded and bundled, in the same manner as floor joists, to ensure simplicity of erection at the site.

Roof decking is bundled at the factory in accordance with requirements of the individual plan. Gable ends are completed in the factory in the same way as exterior wall sections. Precut studs and joists are framed on a jig table then sheathing is applied to one side. Soffits, manufactured in a separate section of the factory, are precut to size and prime coated to protect against the weather.

Vapour barrier paper, insulation and interior wall finishing material are installed at the site following erection of all wall sections. Roofing material is installed following completion of roof decking.

Interior finishing package – Counter tops, as required for kitchen cabinets and bathroom vanities, are produced in the factory's finishing shop which prepares all interior finishing items called for in the plan. Prefabricated kitchen cabinets, available in a variety of sizes and finishes are included in the Interior Finishing Package. Site workers need only position the cabinets and secure them to the wall. Interior stairs are cut and assembled.

Interior doors, together with frames, are shipped in a knock-down package for site installation in interior stud wall openings.

Exterior finishing package – Exterior finishing items such as plywood panels and fencing are included in the final shipment.

Supplementary plumbing and heating packages – Various other finishing packages are available, such as plumbing, electrical and heating, all custom designed to suit individual floor plans.

Labour Content in manufacture of packages – The direct production time for the packages required to construct the home shown in Fig. 1 is:

Package 1 – 6 man hours
Package 2 – 100 man hours
Package 3 – 30 man hours
Package 4 – 7 man hours

Total – 143 man hours

This manufacturing plant employs approximately 80 men in direct labour.

The site assembly function

The following abridged description of site labour indicates the direct man hours required to complete the home shown in Fig. 1:

Preliminary site work – Excavation, forming and placing of concrete footings; and setting wall forms.

Package 1 – Placing floor joist components; applying floor sheathing components; pouring concrete wall and backfilling. Direct labour to complete the above—4 man crew, 185 man hours.

Packages 2 and 4 – Are delivered to the front of the backfilled foundation aboard a detachable flat deck trailer unit (40′ × 8′ wide). Components are loaded at the factory in order that they will be erected on the site. Erection commences with hand placement of components and application of materials in the following sequence: three exterior walls; all interior walls; front exterior wall; roof trusses; roof sheathing; and exterior finish. Direct labour—6 man crew, 160 man hours.

Interior finishing – The interior of the home is completed by applying 1/2 in. gypsum board to the stud walls (horizontally), using sheets varying in size from 4′ × 8′ to 4′ × 16′, depending on most economical cut for room dimensions. Gypsum panel joints are mechanically taped in a three coat application. Direct labour—4 man crew (2 boarding and 2 taping), 90 man hours.

Mechanical installations (plumbing, heating, and electrical) are done at this time—102 man hours.

Package 3 – Is delivered and installed in the interior of the home. Direct labour—2 man crew, 60 man hours. The home is decorated and floor covering installed–130 man hours.

The complete construction schedule outlined above can be done in approximately 20 working days but in practice the actual scheduling is done on a 60 day to 120 day basis for economical reasons. This type of scheduling allows a distribution of the work force over a series of homes so that the total labour force is kept to a minimum of crews. A 60 home project is quite reasonably scheduled for completion in 120 days with the completion of the homes coming one per day, after 60 days.

Conclusion. Wood frame construction does not lend itself to highly mechanized production. The productivity gains of the component manufacturing system are primarily achieved through the orderly provision of materials, jobs and supervision to the worker both in the factory and on the site.

The percentage of factory prefabricated components in the frame structure itself has remained quite constant in Canadian prefabrication for the past ten years. Gains in efficiency have been made largely by reducing the number of parts; by the simplification of components and by the manufacturing of individual items in the home (i.e., cabinets, doors, windows and mechanical items). Where lumber supplies are not economically available there is an application of the research that has been done to replace standard frame parts with factory manufactured structural parts, e.g., laminated beams, plywood box beams, stress skin panels and foam core panels. The discipline required to design using a standard component system has certainly never inflicted a limitation on the architectural results of manufactured homes. Rather it has enhanced the results as evidenced by the significant number of design awards won by Engineered Homes. It is the writer's opinion that increased productivity in both design and indirect labour could be achieved through the introduction of a standard module into the designing of the wood frame house. Ideally this module would be based on the metric system. Adoption of 40 or 50 centimeter stud spacing would require primarily that sheathing manufacturers produce products in dimensions appropriate to the metric system. Application of such a system would mean that any given home model could then be conceived, drawn, componentized and priced, right from the plan, without time consuming conversions in feet, inches, square feet and board feet.

With the technical knowledge and public awareness in the housing field there are many innovations and processes being attempted which are designed to increase productivity and lower costs of home manufacturing but wood frame construction remains difficult to equal for structural adequacy, versatility and low cost production.

The inherent contradictions of the closed systems of prefabrication and the future trends of evolution

By M. Párkányi (Hungary)

The industrialisation of building basically changes the whole aspect of architecture. The process itself was set off by standardisation, but it is only for the last decade, when the new structural systems appeared in industry, that it has begun to shape architecture. The approach towards industrialising building, met the unanimous approval of contemporary architects; since without up-to-date techniques architecture can not be kept on an up-to-date level. Seeing however the architectural results, deriving immediately from the adaptation of structural systems, they want to go further. They are looking for new methods, which—without compromises on the account of industry—can produce better architectural solutions.

The architectural efficacy of structural systems and its scale

The essence of the problem in architecture is whether from standardised units, we can assemble buildings which, though structurally unified, are different in function, distribution and aesthetic appearance. As the factory-made units of building themselves can not be shaped, the shaping of the building can only be based on their *additive* quality. Thus, when evaluating the available structural systems, the architect can only scale their efficacy from an architectural point of view, on the possibilities offered by the system to create various assemblies. Consequently the architectural efficacy of the structural systems can most suitably be scaled by the *number of variations* possible.

The open and the closed systems of prefabrication

The tasks of architecture today are solved by two great basic conceptions all over the world. The one sets out from the modern possibilities of metalworking and particularly from that of steel, and keeps the assembly of the units on the level of the assembly of machines. Because of the unrivalled structural endowments of steel, this conception has never stressed uniting elements into one large unit. Instead, it strived to maintain the principle of component and was the first to realise in architecture the open system of construction. It met first with success in industrial architecture, by creating large undivided spaces, relatively independent from the function.

The other conception experiments with different forms of stabilized and reinforced, natural or artificial materials which can be found anywhere, but first of all with reinforced concrete. The essence of this technique is pouring concrete into large moulds, either in the factory, separating manufacture from the site, or taking manufacture itself to the building-site and basing the whole operation on in-situ manufacture. In both technologies, it strives to produce and to assemble large elements, possibly on maximum degree of readiness, and maintaining the principle of coach-work in production, it establishes the closed systems. Availing itself of most favourable facts of manufacturing flats requiring small, divided spaces to a given function, it unites the manufacturer and the contractor into one body and with the building activity it actually meets its own demands.

Satisfying architectural requirements

The decrease of the available manpower, observable all over Europe and the requirement to meet the ever-increasing demand in housing as effectively as possible, inevitably directed the progress towards the closed systems. From the point of view of satisfying social requirements it turned out to be the most effective tool on governmental level, and in the forseeable future it marks one of the basic methods of building activity. If we want to make further progress towards industrialised building, we have to demand better architectural efficacy from the structures applied to building dwellings. As the number of variations depends first of all on the structural systems, the sizes of the units of the system chosen will be of vital importance. The way of the more efficient architectural solutions leads through the units. It is not indifferent whether the structural system operates with plane or space units and whether these units are of medium size, of parameter-size or even larger. The increase of the sizes of the units namely decreases the flexibility of the structural system, and this again leads to the decrease of the architectural efficacy. This paper analyses the architectural efficacy of the closed systems through revealing their inner contradictions and on the basis of the conclusions tries to outline the possible further trends of evolution.

The inner contradictions of the closed systems

Panel systems. The panel building method, one of the most widely spread practices in contemporary industrialised housing is based on the slab as a principle of construction. Its basic units, namely the large panels, are slabs of parameter size in two directions, constructed with different methods, of ceramic or of hydraulic materials, with reinforcement. This is regarded as the leading idea for manufactured houses. Thereby however, the architect has to adapt himself to the severe restrictions of the structural system. He has to accept that these plane-units can only be jointed along the edges, can only have openings on the surface, etc. The architect uses these slabs to produce cells, more accurately said: boxes.

Seeing that his units, the floor and wall panels, are of parameter size in both directions, the boxes constructable will automatically be of parameter size in three directions. The number of variations designable on the basis of the structural system will depend on the sizes (range of sizes) of the spans and widths of the floor panels. The claims for creating varied plans for dwellings will strengthen the tendencies towards increasing the spans. The tendency towards increasing the span, whilst maintaining the slab as principle of construction is one of the inner contradictions of the panel-building method.

Space-unit building method. The space-unit building method, the other endeavour in contemporary industrialised housing is based on the box as principle of construction. The architect here uses factory made, stiffened space units: boxes. He regards this as the starting thought for industrialised housing. He accepts that these space units can only be jointed at points and along lines, and uses these boxes for assembling the building. Seeing that his elements, the space units, are automatically three dimensional, and what is more, are of parameter size in three directions, the minimum reasonable growth in dimension starts with the parameter-size. The tendency towards increasing the sizes of the parameters, whilst maintaining the box as principle of construction is one of the inner contradictions of the space-unit building methods.

The further trends of evolution

The tendency towards technical progress intensifies the inner contradictions of the closed systems. The original process, which with panel constructions only meant to manufacture elements in the factory and assemble them on the site, has turned into manufacturing complexes of elements, transporting them to the site and assembling them. The architectural efficacy of the structural system goes on decreasing.

The limited architectural efficacy of the closed systems averted our attention to looking for newer methods. We wanted to establish a basically new building method, with new principles of construction, in which the reinforced constructions applied to housing approach to steel constructions on the level of assembly. We examined if we could derive solutions of jointing from reinforced concrete technology which are similar to those of steel constructions *in principle.*

The tissue-structural, cellular building method

We established an open system which puts the emphasis on the elements and leaves the final result, the building open. In this building method, instead of putting the emphasis on the usual manufacture of the frame, we manufacture the elements of the *surface*. We came to the conclusion that we have to transform reinforced concrete technology in a way that instead of the panel, the profiles – so well proved in steel structures – should mean the most favourable form of manufacture for the elements.

The building material is reinforced concrete, but with this technology the weight of structure can be reduced extremely significantly, from one-third to one-fifteenth. We developed a specific, *complementary* building method, i.e. we adapted that variant of modern technologies which combines the factory production of the elements and components with a kind of technology of pouring.

In order to achieve small weight and proper structural rigidity the *cellular* form of structure proved the most practical. When constructing the system we first manufactured the final surface and then we elaborated the forwarding of the thin concrete to this surface. If the concrete meeting this surface required ribs, then we formed the negative of the rib in the surface-element.

For the manufacture of the surface elements we of course chose a material of low specific gravity. Gypsum showed the most suitable, so we determined the form of the concrete by the form of the gypsum elements. The concrete itself meets the gypsum in the phase of pouring, when as a consequence of the moisture-absorbing capacity of the gypsum, the concrete poured in, gets immediately stabilised. It freezes on the gypsum.

Thus in this structural system we determined the *tissue* of the concrete by the negative channel-system of the gypsum elements, and determined the form of the structure by the *cells*.

The construction of the modular spaces required for the dwellings was based on the *additive* quality of the elements. With the new technology, founded on new principles of construction we succeeded in multiplying the architectural efficacy of the structural system.

Economics of the prefabrication of single elements in conventional house construction

By S. Peer (Israel)

With regard to prefabrication in house construction, two main groups may be distinguished:

Total prefabrication of the whole structure.

Prefabrication of single elements in conjunction with conventional construction methods (masonry or in-situ concrete).

The economic aspects of total prefabrication versus mixed structural methods under equal technical preliminary conditions have not been sufficiently studied. But even should such a comparison show that total prefabrication is the most economical solution – now or in the future – it is obvious that most houses will still be constructed by conventional methods, especially in small countries, where projects are normally not large enough to provide suitable objects for total prefabrication. In these circumstances, efforts to improve conventional construction methods should continue.

Through the increasing use of machinery in conventional methods, only unskilled manpower is saved, while the ultimate construction capacity remains dependent on the output of the skilled labour available. New construction methods are thus called for, with a view to minimising skilled labour requirements and permitting increased use of unskilled manpower.

One of the possibilities offered by the increasing use of cranes in conventional construction is in-situ prefabrication of single elements, whose production on the spot is complicated, costly and requires more skilled labour. This method is practicable even on the smallest sites. These considerations have led the author to study the economic aspects and limits of in-situ prefabrication of single elements[1].

Possibilities of prefabrication in conventional construction methods

As a rule, prefabrication of the following elements is possible in a building with masonry walls:

Basement: exit stairs; windows; light shafts; and cantilever beams or slabs for entrances.

Upper stories: lintels over openings with revolving shutters; lintels over openings without revolving shutters; reinforced concrete slabs for balconies; landings and stairway slabs.

In addition to the above, every building comprises other complicated elements, requiring much skilled labour, and it may prove economical to prefabricate them. (For example, prefabricated concrete supports replacing masonry columns built of cavity bricks).

Further possibilities for improving conventional construction methods are offered by the use of precast slabs, available on the market in a variety of designs. Use of prefabricated sanitary-installation elements is possible, and light precast cladding elements and partition panels may also be considered.

Procedure

The comparative analysis of the economic aspects of prefabrication of single precast elements was carried out by means of detailed work studies.

In comparing the labour requirements in prefabrication versus on-the-spot production, the following processes were taken into account:

- Preparation (mixing) of concrete
- Production of element
- Assembly of element
- Use of cranes.

For comparison of the costs, the following items were considered:

- Labour
- Materials
- Means of production
- Preliminary installation costs.

In determining the economic limits of prefabrication, the running-in factor was taken into consideration.

Organisation of prefabrication process

Each building site under study was provided with a simple platform of 2″ uncut timber boards supported on joists and serving as lower part of the formwork. The weight of the elements was fixed according to the lifting capacity of the available crane, so that certain elements, such as balcony, and stair-way slabs, had in certain cases, to be produced in two parts.

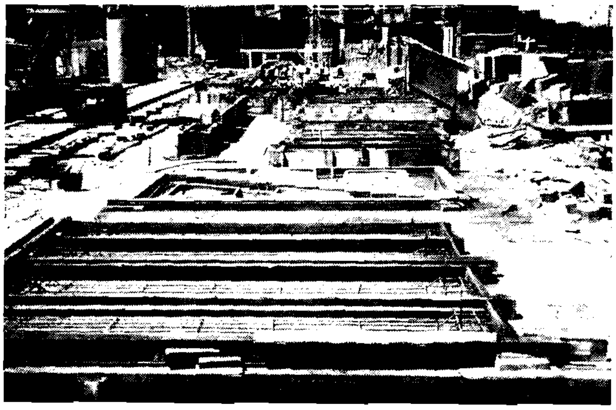


Fig. 1. Platform with formworks for prefabrication of single elements in conventional house construction.

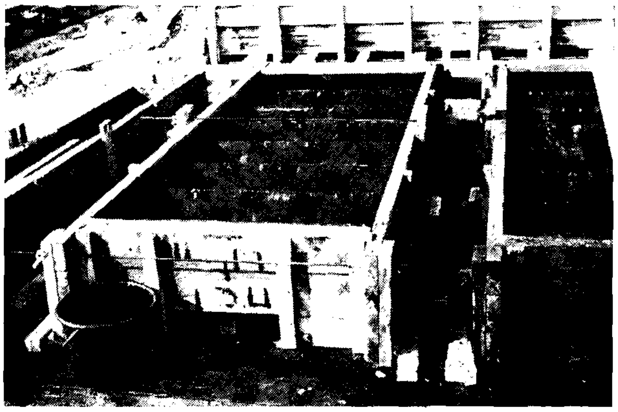


Fig. 2. Formwork used for prefabrication of flight slab.

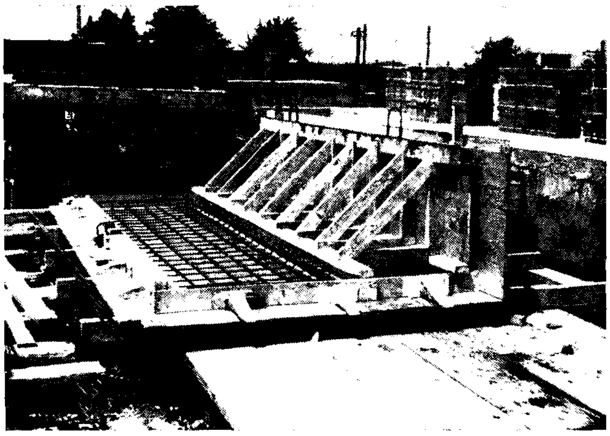


Fig. 3. Formwork used for prefabrication of balcony slab with balustrade.

The formwork, rather simple but stable, consisted of partially-planed 2″ boards, except that for architectural concrete plywood (ordinary or impregnated) was used. The expensive practice of nailing was replaced by wedging. The height of the formwork was in accordance with the measurements of the elements to be produced. An illustration of a platform with different formworks is given in figures 1, 2 and 3.

Results

Results are summarised in table 1, comparing on-the-spot production with in-situ prefabrication, in respect of labour requirements and costs. The conventional on-the-spot production is set as 100%.

The need for preparatory work resulted in higher labour requirements and costs in prefabrication compared with on-the-spot production, but these requirements are usually divided among a number of identical parts, depending on the size of the series. Except for lintels, even the fixed requirements are lower in prefabrication. The more complicated the part, the higher the initial formwork investment in prefabrication, but saving in labour is higher as well. Table 1 also lists the economic limits of prefabrication. It can be seen that, for most elements under study, the limit is a single piece. The largest series is required for prefabricated stairway slabs, produced in two parts. For this element the limit is five units, but this number is present in nearly every storied building. These results indicate that in-situ prefabrication of single parts offers possibilities of improvement even for smaller buildings, the degree of economy increasing with the size of the series.

TABLE 1. Summary of Results

	Labour-requirement					Costs				
	variable			fixed		variable			fixed	
	Conventional production on the spot	Prefabrication (in situ)	%	Conventional production on the spot	Prefabrication (in situ)	Conventional production on the spot	Prefabrication (in situ)	%	Conventional production on the spot	Prefabrication (in situ)
	man-hrs.	man-hrs.		man-hrs.	man-hrs.	IL.	IL.		IL.	IL.
1. Basement-Window	3.63		100.0	0.70	4.20	23.40		100.0	3.15	
		1.00	27.6				13.70	58.7		21.08
2. Light shaft	5.26		100.0	2.10		42.55		100.0	9.45	
Three section		3.45	65.6		11.30		27.24	64.0		56.30
Single section		1.71	32.5		5.15		22.09	54.2		26.25
3. Entrance, Two Cantilever beams	2.43		100.0	0.70		16.05		100.0	3.15	
Two cantilever beams		1.60	65.8		1.71		11.29	70.3		8.66
Single slab		0.46	19.0		1.71		7.28	45.8		8.66
4. Lintel for revolving shutter	4.20		100.0	1.10		65.80		100.0	4.95	
l = 3.00 m		1.62	38.6		5.24		21.30	32.4		26.63
5. Normal Lintel	3.89		100.0	0.87		38.03		100.0	3.90	
275 × 30 × 30 cm		0.86	22.2		0.70		15.71	55.2		3.30
6. Balcony slab without balustrade	5.36		100.0	1.00		67.43		100.0	4.50	
		2.13	39.7		4.00		49.13	72.9		19.50
7. Balcony slab with balustrade	13.88		100.0	2.54		188.40		100.0	11.48	
		5.03	36.3		13.10		132.08	70.2		64.65
8. Landing	3.95		100.0	0.61		49.13		100.0	2.78	
		1.68	42.6		3.30		37.13	75.6		16.20
9. Seven Stair flight-slab	5.57		100.0	1.15		51.45		100.0	5.18	
		2.50	44.8		15.60		36.34	70.6		77.25
		1.88	33.7		14.55		33.38	64.9		71.93

It can be seen that the variable labour and cost requirements for all elements studied are lower for prefabricated parts than for the same parts produced on the spot.

The variable labour requirement for prefabrication was found to range from 19 to 66% compared with on-the-spot production. The variable costs for prefabrication were found to range from 33 to 76% compared with those for on-the-spot production but these figures cannot be generalised, being dependent on local prices and labour rates.

Conclusion. Most dwelling houses in the future are likely to be constructed by conventional methods. Hence efforts to improve these methods should continue. The increasing use of cranes permits in-situ prefabrication of elements whose on-the-spot production is time-consuming, and their incorporation in an otherwise conventional system. The present study was confined to prefabrication of common structural elements. Economy through prefabrication was found to range from 34% to 81% in respect of labour requirements and from 24 to 67% in respect of costs.

Most important is the conclusion that the economical in-situ prefabrication does not necessitate large series. In spite of higher additional preparatory-work requirements, even a single piece is mostly economical when a crane is used in any case. In consequence, it can be seen that judicious combination of in-situ prefabrication of complicated elements and improved on-the-spot production of simple parts may offer important advantages in the realisation of housing projects of any size. This can be achieved with existing equipment, without risk or additional investment. Even though only a small part of the building is prefabricated, prefabrication within these limits is especially advantageous. A prefabrication platform should therefore be provided on every site of conventional construction, where a crane is used in any case.

The possibilities of partial prefabrication should be considered at the stage of structural planning and in the tender, instead of being left to chance. The next step should consist in a study of the economic aspects of prefabrication of sanitary elements, light cladding and partition panels for conventionally-built houses.

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C. Rachenov and Miss A. Tanova

House building in Bulgaria using large size prefabricated panels

By C. Rachenov and Miss A. Tanova (Bulgaria)

Large scale house building is in progress in the People's Republic of Bulgaria. To meet workers' demand, building forecasts up till 1980 cover the annual construction of some 30,000 dwellings. Such a building programme, a very considerable one, could not be carried into effect without industrialised house building. In view of this, the country's housing policy is directed to progressive but definite industrialisation, and to setting up a building industry.

House building in Bulgaria presents some particular features:

– 1) About 80% of dwellings are built with people's own means and are their own property. This makes it necessary also that buildings erected on industrial lines contain dwelling units of different sizes and make-up, to meet owners' various needs and requirements.

– 2) The major part of the country is situated in 7 and 8 degree earthquake areas. To make buildings secure in such areas, special measures are resorted to; such measures also call for a number of restrictions in building design and house planning.

Building with large size panels without skeleton

Most residential buildings, erected on industrial lines, in Bulgaria, are made of large size panels with no skeleton. The first experimental four-storey residential building was erected in Sofia during 1958. In the course of the last five years there has been a considerable development in the construction of dwellings by means of large size panels; this was not confined to Sofia but extended to quite a number of other large towns in the country. At the present time some 10,000 dwellings using large size panels are in the course of building.

In keeping with the modern building industry set up in 1963 in Bulgaria, and following experience gathered and on the basis of foreign building, a standardised State nomenclature was prepared for ferro-concrete components for residential buildings constructed with large size panels. Using the component staken up in this nomenclature, 6, 5 and 4-storey buildings were erected, specifically suited to definite requirements. The buildings consist of two, three, four or more sections, some facing N–S, others E–W.

Each section contains two or three dwelling units per floor, each with one, two, three or four rooms, kitchen and appurtenances. Ways have been devised for providing variety in the external appearance of buildings by means of colour and different façade design. Buildings are equipped with all the essential interior installations, in keeping with modern housing requirements and local resources.

All such buildings have no skeleton; they have transversal and longitudinal supporting walls. They are designed with uniform interaxial distances – longitudinally 360 cm (including staircase well) and transversally 510 cm. The structural height of floors is 290 cm, whereas the height of ceilings is 272 cm. The floor panels have "per piece measurements". Their four sides are shouldered on the partition walls and median supporting walls and on the longitudinal façade beams. The latter transmit their load to the median supporting walls. The wall panels along the longitudinal façades also have "per piece" measurements. They are not supporting and are suspended on the façade beams. This system affords the possibility of a freer treatment of façade wall openings and, if necessary, of a change in the material used and in construction of prefabricated façade panels, without affecting the basic supporting design of the buildings.

The buildings are designed for vertical and horizontal loads (wind or 8 degree earthquake forces). They are examined as levelling elements, vertical and horizontal. Floor constructions are designed as diaphragms rigid in their plane, whereas the walls are designed as very high cross-section brackets. Suspended longitudinal façade walls are not designed to play a part in resisting horizontal loads. The distribution of the total horizontal load per floor, between separate vertical plates, longitudinally and cross-wise, is obtained by equalising their movement at each floor.

Jointing of the various prefabricated elements into a spatially resistant construction is effected by welding the round steel joints and making concrete grooves. After welding the same joints of the main structure, concrete is cast on the spot, whereas the others are covered with cement mortar. Means for protecting the joints against corrosion are not always applied in Bulgaria.

Prefabricated components do not weigh more than 4,800 kg. They are prefabricated in specialised factories or on technological lines. Façade panels are cast in reversible moulds, those of partition walls and of floors or of the roof in vertical coffers (groups); the others, on the ground are cast in dies or metal formwork.

Panels are carried upright on transport vehicles fitted with vertical sections. Assembly is carried out by means of a slewing tower crane with a net moment of 80–100 t/m.

The various prefabricated components are designed as follows:

The façade panels are 20 cm thick. For longitudinal façades of buildings light concrete is used (R "50"* perlite concrete or ceramsite-perlite R "75" concrete), protected on the external side by a 2–3 cm mortar layer. Crossfaçade panels may, according to availability of building materials optionally be made in two ways:

– a) Three layers (sandwich panel): the supporting inner layer in reinforced concrete 10 cm thick, an 8 cm isothermic layer in R "15" perlite concrete and a cement mortar protective coat 2 cm thick.

– b) A single layer of R "75" ceramsite-perlite concrete.

All façade panels are reinforced with welded netting. Their windows and doors are wooden and fixed in the shuttering framework before concrete casting. The panels are prepared with an even and smooth internal surface, ready for puttying. Their external surface is ready to be brushed over or decorated (treated with a relief roller, sprinkled with broken gravel or otherwise).

The supporting interior wall panels may be built with concrete or R "150" or "200" ceramsite concrete. They are 14 cm thick and reinforced with welded netting.

The interior non-supporting partition panel walls are built with R "200" concrete, reinforced by means of welded netting. They are 3, 4 and 10 cm thick. As an alternative, some of these walls may also be made with panels of foam concrete autoclaved to the required height, and 6 cm thick. Assembling is done by hand, following the wall panels and the floor panels. However, the alternative methods are provisional, until plates and light materials, suitable for such walls, are produced in Bulgaria.

Floor panels and roof panels are made of R "200" concrete, reinforced with welded netting.

Stairs have separate landings and steps with a plane lower surface, made of R "200" concrete, reinforced with welded netting and ossature. Stairs are made with mosaic on the steps. Their lower and lateral surface, as well as the lower surface of landings, are prepared for cementing. On the site, at landings, mosaic slabs are placed on cement mortar and monolithic mosaic strips are laid near the walls and steps.

The main cornice and roof porticos are also made of R "150" reinforced concrete.

No provision is made for interior plastering, except the staircase. Walls and ceilings are simply filled and distempered.

Room floors are boarded; kitchen floors are covered with linoleum. The floors of passages, the bath-room and lavatory are covered with mosaic slabs or monolithic mosaic.

The possibilities of diversity in planning and façade design are relatively limited in the case of buildings made of large size panels without skeleton, with small interaxial distances (up to 360 cm). Although such possibilities are not yet exhausted, research and important experimental treatment are going on, in Bulgaria, on buildings made of large size panels without skeleton, with a long interaxial distance – from 600 to 720 cm. Research carried out shows that an excellent solution for a dwelling, as a specific unit, lies within the limits of a construction frame, freed from supporting walls and other interior points of

* Compressive strength on 28th day.

support. Such are precisely the possibilities offered by the structural design with supporting partition walls and long interaxial distances. Once the rooms have been dimensioned and well proportioned, the dwelling may be altered, by means of flexible planning; in this way, the dwelling has a lasting quality and will not become obsolete in advance of material wear and tear of the building (Fig. 1).

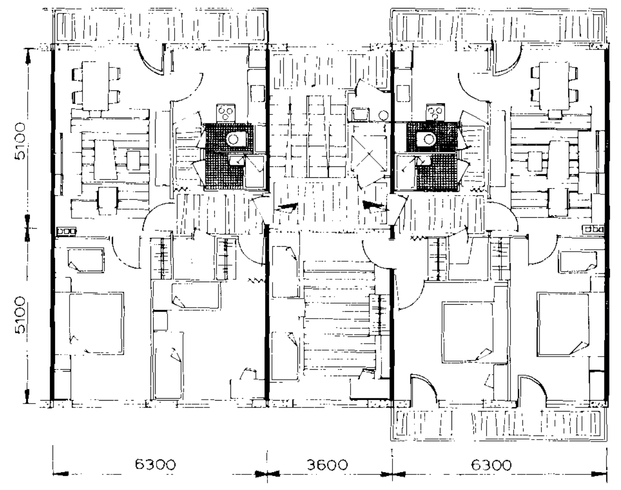


Fig. 1. Plan of dwellings built with large prefabricated panels and using a design based on long longitudinal interaxial distances.

The main point here lies in the choice of interaxial distances, length- and cross-wise, that demarcate the structural frame. In Bulgaria this problem is not yet decided. Long interaxial distances are also suitable for many buildings used for cultural purposes and many daily requirements, comprised in grouped residential buildings. This is particularly convenient for standardisation of coefficients and of construction designs and planning for buildings answering different purposes.

Buildings with long longitudinal interaxial distances have supporting partition walls made of ferro-concrete. For façade walls and non-supporting dividing walls a number of concrete and other light materials may be used, with good heat and sound insulation, as well as various partitions, closets, etc. Depending on the length of the longitudinal interaxial distance the floor panels are ribbed, with slabs below or above, or with prestressed hollows. Wind and earthquake forces, longitudinally, in the direction of the building, are damped by the ferro-concrete frames, usually placed near the staircase.

At the present time, the problem of industrialisation of construction of some public buildings is also receiving attention. Their features bear resemblance to those of residential buildings. In this respect the first experiment of some importance was the building of three hotels with large-size panels in the "Sun Coast" holiday resort on the Black Sea. (Fig. 2). The buildings are 4- or 6-storied with supporting partition walls. All prefabricated components are made of ferro-concrete. This experimental construction has given very good results. It is proposed to build on the Black Sea coast, in the next few years, a large number of hotels, using large-size panels.

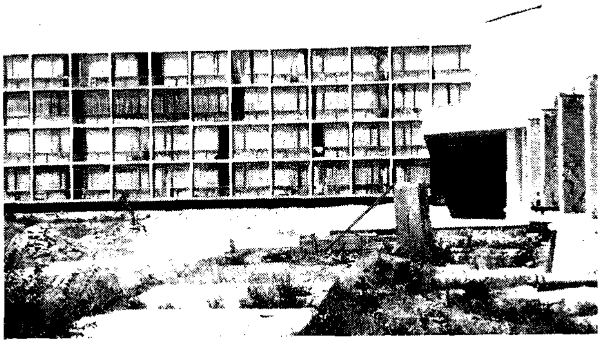


Fig. 2. Hotel built of large size panels.

Building with skeleton-panels

Present experience in Bulgaria, in regard to house building industrialisation, is that buildings made with largei-size skeleton panels only meet part of modern utilisation requirements, from the architectural and town-planning points of view. Industrial production of building materials necessitates, onuce other hand, the application also of such systems of construction, making possible the erection, with the same structural elements, of buildings of a various number of storeys, different outline, distribution and external features, and even with a different purpose. Such requirements are best met with the use of prefabricated skeleton-panels without beams. In view thereof it is planned to design and build, concurrently with buildings made of large-size panels without skeleton, residential buildings by means of skeleton-panels, four-, six- and eight-storey high, whereas now designs are being made for erecting ten to twelve-storey high buildings.

The main supporting structure of such buildings, the skeleton, consists of columns and floor panels with elliptical cavities. After assembling, the floor structure is prestressed cross-wise and length-wise by means of steel tendons. This offers the possibility of jointing between columns and floor panels being effected without steel parts or welding, even in the case of buildings in the earthquake areas of the country. The columns have a square cross-section and are continuous, depending on the height of the building, through 4, 6 or 2 floors. The column slabs (base) are prefabricated pit-shaped elements. The floor panels are of two kinds: basic, shouldered on the columns, and median, shouldered on the basic panels. Their nominal measurements are 240/480 cm and 360/480 cm; these, combined, may cover all the longitudinal interaxial distances from 480 to 720 cm every 60 cm. The structural height of floors is 290 cm, that of ceilings 265 cm. Staircases and enclosure walls in the basement are also made of prefabricated ferro-concrete components. All other walls, external and internal, and the roof slab, are made of foam reinforced concrete prefabricated panels of a corresponding thickness of 20, 6 and 10 cm. They are assembled after the skeleton and wedged between the floor structures. The partition walls between flats are double, consisting of two 6 cm prefabricated panels, with between them a sound insulation made of packed glasswool.

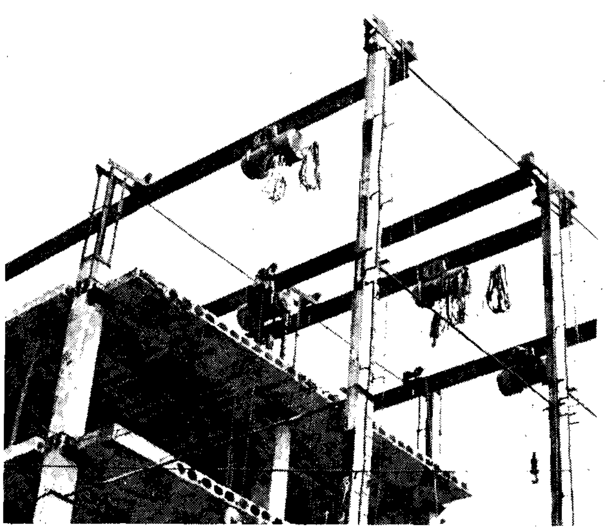


Fig. 3. Electric tackle system.

Erection of buildings up to six storeys can be effected without a slewing tower crane, by means of a Bulgarian devised electric tackle system. Three-ton lifting power electric tackles are used as hoisting and erecting appliances. They run along steel girders, placed longitudinally in relation to the building, and fixed to the tops of the columns (Fig. 3).

In the skeleton-panel system without beams, as "load" and "framing" functions are separate, the maximum use is made of the physico-mechanical properties of building materials.

Trends and future developments

According to present experience in the development of the large-size panel building system in Bulgaria and to results obtained in other countries, four main trends are shaping in respect of future research and project design;

– improvements in planning and designing residential buildings, making use of large-size panels, with a short longitudinal interaxial distance. More diversity in buildings. Major results may, in this matter, be registered when the present transversal interaxial 510 cm distance is applied in a longitudinal direction in relation to buildings. An increase in the number of storeys of residential buildings made with large-size panels without skeleton (7 to 9 storeys), more particularly of those erected in the earthquake areas of the country. Improved prefabricated components and jointing thereof;

– improvements in and even more rational use of the possibilities offered by the beamless skeleton construction system, and especially for buildings over eight storeys high;

– design and lay-out, on an ever increasing scale, of buildings made of large-size panels, without skeleton, with a long longitudinal interaxial distance (600 to 720 cm). Erection of dwellings, allowing of easy alterations in the course of their occupation;

– standardisation of planning and construction in respect of residential buildings and a number of public buildings, mainly those included in grouped residential buildings.

Development of large-panel construction in European countries

By B. D. Plessein and N. P. Rozanov (U.S.S.R.)

The large-panel construction which, in the USSR, was begun in 1948 is today considered to be the most effective approach to the industrialisation of housing. Its volume and rate are growing steadily in all European countries. In the USSR where in 1956 16 thousand dwellings were built in large-panel blocks of flats, in 1961 this number rose to 120 thousand and in 1963—to 280 thousand dwellings, not taking into account completely prefabricated houses with large block walls. In France 90 thousand flats a year are now being built in competely prefabricated buildings, with large block and panel walls. In Czechoslovakia 35 000 flats were built in large-panel buildings in 1961.

Large-panel housing is successfully carried out in Sweden, Denmark, Bulgaria, Rumania, Hungary, German Democratic Republic, German Federal Republic and other countries of Europe. It begins to develop in Great Britain where up, till recently, preference was given to traditional structures of brick and in-situ concrete. Experience shows, the cost of large-panel construction is 10–12 per cent lower than that of traditional brick construction, and building time-tables are 1.5—2 times shorter. In different countries labour-expenditure on large-panel construction including the outlay of labour in manufacturing details at factories is 5—7 man-hours per cubic metre, 35—55% of which, depending on the degree of prefabrication, fall on the factory. These labour outlays are considerably lower than those in traditional building.

Technical potentialities of large-panel construction are very great. In France, Sweden and other European countries, many large-panel blocks of flats up to 16 and even 22 storeys high have been built.

Large-panel buildings are notable for considerable variety in lay-outs of dwellings and are not inferior to traditional brick buildings in architectural aspects corresponding to a greater degree to the modern ideas of architecture.

Schools, children's institutions and buildings for cultural and every-day services are also being built of large panels.

Structures of large-panel buildings

International collaboration and wide exchange of information promote the unity in approach to a number of aspects in the developments of large-panel construction. A frameless system with load-bearing cross and longitudinal walls and solid room-size floor panels supported round the perimeter is wide spread in most countries. The most part of large-panel buildings in the Soviet Union, France, Czechoslovakia, Sweden and other countries are built according to this scheme. The main advantages of this system which determine its wide application lie in its structural reliability, economy, simplicity and high degree of prefabrication. In the USSR, Czechoslovakia and some other countries structural systems with three load-bearing longitudinal walls or with load-bearing cross walls spaced at 6—6.40 m with floors of cavity panels 1.20—3 m wide are also used. Partition walls are made of large-size rolled gypsum-concrete panels or of other similar materials. Such structural systems make it possible to provide more variable lay-outs of dwellings and to partially utilize in large-panel construction the production basis created earlier for brick construction. However the use of floor slabs with joints in the ceiling and erection of partition walls of different materials require additional finishing of the buildings on the site. The frame-panel system is used mainly in construction of administrative and commercial buildings. At present in the USSR, in Moscow, it is planned to use it for the construction of residential buildings 16—25 storeys high.

Exterior wall panels are used, both of a sandwich type with expanded polystyrene thermal insulation, mineral, or glass-wool boards, and of a solid type made of light-weight concretes or of cellular concrete. Solid panels are more convenient for manufacturing but in their thermo-technical characteristics they are inferior to sandwich panels and in many cases they require additional protection.

Room-size panels are predominantly used for the erection of exterior walls. However there is a trend to enlarge them to 2-room-size and even 3-room-size. The fabrication of room-size exterior wall panels of cellular concrete with thermal treatment in autoclaves of 3.6 m in diameter has been organised in the USSR.

Exterior wall panels leave the factory complete with window frames already pointed and glassed, with face surfaces fully finished with ceramic tiles, crushed stone or coloured textured layers. Load-bearing panels for interior walls are usually room-sized, solid, 130—150 mm thick.

The joints of panels are the most vulnerable spots in large-panel structures. The questions of the most efficient jointing and the methods of insulation of joints were discussed at the meetings of CIB Commission W19 in Paris in 1961, and in Stockhom, in 1963.

The exchange of information and experience made it possible to work out, and put into practice, horizontal profiled joints with storm-water barriers and vertical filled-in joints with decompression channels insulated with elastic gaskets and sealing mastics.

There is a tendency to use, in large-panel construction, volumetric elements with a high degree of prefabrication. Sanitary blocks fully finished and equipped at the factory are widely used in the USSR, Sweden and other countries.

Volumetric elements are also used for built-in balconies, staircases and other complicated components requiring the expenditure of much labour.

Experimental construction of residential buildings from volumetric blocks is carried out in the USSR. The degree of prefabrication of substructures in large-panel buildings usually is lower than that of superstructures. In many countries, substructures are built of in-situ reinforced concrete. In the Soviet Union and France precast elements are widely used for substructures. As experience shows, as a result of the use of precast elements, time-tables for the erection and substructures are 2—3 times shorter and outlays of labour are 30—40 per cent smaller.

Industrial basis of large-panel construction and methods of production and building

During the first period the manufacturing of large panels was carried out both at yards and at industrial enterprises. At present large panels are fabricated predominantly at specialised house-building plants. Today in the Soviet Union there are over 200 specialised plants producing sets of prefabricated concrete for large-panel buildings. About 100 of such plants are in the process of construction. The large number of house-building plants made it possible to organise the serial production of equipment for these enterprises and to build them according to standard designs. In France more than 20 large-panel house-building factories and the great number of casting yards are now in operation. The considerable number of factories and yards have also been built in other countries.

Building details are produced either fully at house-building enterprises which facilitates the complex supply of products, or on the basis of co-operation of different specialised factories. In a number of cases it might be expedient to combine both ways by means of supplying house-building enterprises with mass standard production from specialised factories.

In many cases the erection of large-panel building and other building works is done by building organisations which receive elements from house-building factories. In the view of some specialists such a system ensures high demand on the part of organisations erecting buildings. It promotes the improvement of quality of the fabricated products.

However, the majority of house-building enterprises in the Soviet Union, France and other countries carry out both the prefabrication of building details and the assembly of buildings. These enterprises are called house-building combines. Specialised organisations are sometimes invited to do some kinds of jobs (earth works, roofing, finishing, canalisation) on the basis of subcontracting. The experience shows that this method allows to integrate the production of building details with the process of erection, and to achieve considerable success in further perfection of structures of large-panel buildings and production techniques. Moreover in such a case, when the prefabrication of details and assembly of buildings can be considered as continuous, better economic results are obtained. To ensure the profitability of house-building plants, it is necessary to unify their output. The unification of products is carried out on the basis of standardisation of structures and lay-outs.

In some cases the standardisation of lay-out schemes is limited to an isolated project. However, standardisation on a national level is most profitable. In the Soviet Union, Czechoslovakia and some other European countries, large panel housing is carried out according to standard designs. Standard designs are worked out to state orders in the form of series, including designs for blocks of different height and length, with different facades and lay-outs and with flats for different families. Such series are worked out taking into account different natural and climatic conditions and architectural and aesthetic requirements.

Standard drawings are prepared for separate structures and details. In the Soviet Union the standardisation of prefabricated parts for large-panel construction is being developed. The state standard determines the main technical demands of designing, manufacturing components and erecting large-panel buildings. When standard designs are worked out in series the requirements of standardisation can well be combined with the requirements of urban development provided, of course, that the quality of the project will be high enough.

The techniques of industrial production of large panels are being constantly improved.

The widely spread stand method of manufacturing panels in open yards, is being replaced with production-line and conveyor methods at the plants with automation of several operations. Mechanised casette installations ensuring high quality of surfaces are being increasingly used. In the USSR a new method of mass production of large panels at vibro-rolling installations, (system of engineer Kozlov), is being increasingly used. This method ensures the continuity of production process and high productivity.

In most cases the assembly of large panel blocks is carried out by means of the "from wheel to place" method, without organising intermediate storage of building elements on sites; it ensures saving precast units from damage and speeding up the erection as well.

Much attention is being paid to the precision of fixing panels in the process of assembly. In the USSR, Denmark, Sweden and other countries the methods of the precise ("compulsory") assembly of large panels with the use of special conductors, fixing bolts and inserts have been worked out. These methods promote the higher quality of large-panel construction.

Ways of further perfection of large-panel construction

Fast development of large-panel construction requires the coordination of efforts of specialists of all countries in order to solve a number of important questions determining the further perfection of large-panel construction and increase its technical and economic efficiency. Some of these questions were discussed at the CIB Commission W19 meetings in Paris and Stockholm.

The following recommendations are suggested for discussion at the Congress;

1. The main trend in the further increase of the efficiency of large-panel construction should be to raise the degree of prefabrication of elements by means of their complete finishing and equipment at the factories, the enlargement of products and use of volumetric elements. To make this possible, it is necessary to solve the problems of transportation and assembly of enlarged elements with a high degree of prefabrication. Further research be undertaken on structural, technological and economic aspects.

2. The higher degree of precision in manufacturing and assembling large panels should promote the higher quality of construction and its economic efficiency. Therefore the questions of establishing suitable tolerances and the methods of control in the process of manufacturing moulds, the prefabrication of elements and erection attracted the attention of CIB Commission W19. It would be expedient to study the question of the unification of tolerances for the fabrication and erection of large-panel buildings, and the manufacture of technological equipment on the international level.

3. The wider use of new synthetic materials for finishing panels, thermo-insulation and especially for the sealing of joints between exterior wall panels would promote greater efficiency and better quality of large-panel construction. Research on new building materials should be concentrated on their durability and the most rational ways of their use.

4. The structural systems of large-panel residential buildings designed for mass construction can be considered settled. Research should be carried out on rational structural systems for large panel high blocks, blocks of flats to be built under complicated climatic and geological conditions, and completely prefabricated social buildings.

These studies should include the analysis of the durability and deformation of structures under uneven precipitation, seismic and temperature influences. Further perfection of the joints of panels is needed in order to ensure their durability and reliability, in particular, in the case of panels of light-weight or cellular concrete, where the question of the necessity of profiled jointing has not yet been settled.

5. The casette technique and some other methods of manufacturing panels have been worked out. Research should be undertaken on the development of the vibro-rolling technique and other new methods, which promote the greater mechanisation and automation of production processes.

It is also necessary to make technical and economic comparisons of different methods of organising the prefabrication of elements and erection of buildings.

6. The problem of high architectural quality of large-panel construction when prefabricated standard elements are used, is one of the most acute importance. From the technological point of view it is necessary to settle the question of profitable fabrication at house-building plants of a developed series of large-panel buildings including blocks of flats of different height and length and fully prefabricated buildings for social services.

From the architectural and town-planning point of view it is necessary to work out the ways of adding variety to prefabricated houses with the limited nomenclature of products and the ways of building complexes in which prefabricated houses should not produce the impression of monotony, thus lowering its architectural and aesthetic level.

Problems of an architectural and town planning nature can be successfully solved only in co-operation with the International Union of Architects.

Up to the present time the questions of large-panel construction have been examined mainly by CIB Commission W19. The contribution of other Commissions in solving this important problem is needed. It would be expedient to charge Commission W19 with working out and submitting to the Executive Committee of CIB a programme of international co-operation and exchange of information in the field of large-panels construction. The programme should provide for the participation of other CIB Commissions, which can contribute in solving this problem.

European brick production

Its development and role in the industrialisation of building

By R. Siestrunck (France)

The brick-manufacturing industries in fourteen Western European countries have formed a federation, the T.B.E., (Fédération Européenne des Fabricants de Tuiles et de Briques) whose primary function is the coordination of research in technical and economical developments in the manufacture and utilisation of heavy clay products.

The heavy clay industry's products have always been dimensioned or "modulated", to suit the equipment of the work-site: extension and mechanisation of this equipment will allow a significant increase in the dimensions of the elements that can be used. Consequently, the brick industry has concerned itself with developing a well-organised preassembly of its products in order to provide work-sites with wall panels of a size to suit their equipment.

This report covers the current state of development of preassembly techniques, which foster extended utilisation of heavy clay products in the industrialisation of building construction.

Mechanisation and automation in the European brick industry

Production potential: European T.B.E.-members are steadily increasing their participation in building construction:

Year	Production* in thousand cubic meters	Capacity in housing units	Labour force
1950	32,970	1,320,000	225,400
1954	46,828	1,873,000	
1958	48,265	1,930,000	
1962	56,008	2,240,000	224,100

* excl. Spain and Portugal.

This increase is basically a result of the modernisation of existing installations. Nowadays, from the completely mechanised extraction of clays to drying and firing by up-to-date high-efficiency techniques, each stage in the process has undergone far-reaching changes geared to an ever-increasing automation, improving output efficiency and control, and eliminating handling. Labour-force figures listed in the last column of the table above give a striking picture of the increase in productivity.

This increase is also a result of the building of new works that incorporate the latest innovations in manufacturing techniques, made necessary by an increased demand that exceeds the capacity of existing factories.

To attain these results, the brick industry, which, in most countries is widely dispersed, has grouped together the potentials of its various factories, thereby strengthening its research and testing facilities. Technical and scientific investigation centres have been set up. Their activity is aimed at the obtaining of more complete knowledge of the characteristics both of raw materials and manufactured products, as well as improving manufacture and utilisation. The close liaison of these centres within the T.B.E. fosters effective planning of research and speeds up the application of its results to the obtaining of higher quality products and increased manufacturing efficiency.

Taking account of the number of activities engaged in, the production capacity of the T.B.E. heavy clay industries is likely to show an annual increase of from 2 to 3 million cubic meters of bricks, representing 80,000 to 120,000 new medium-size housing units.

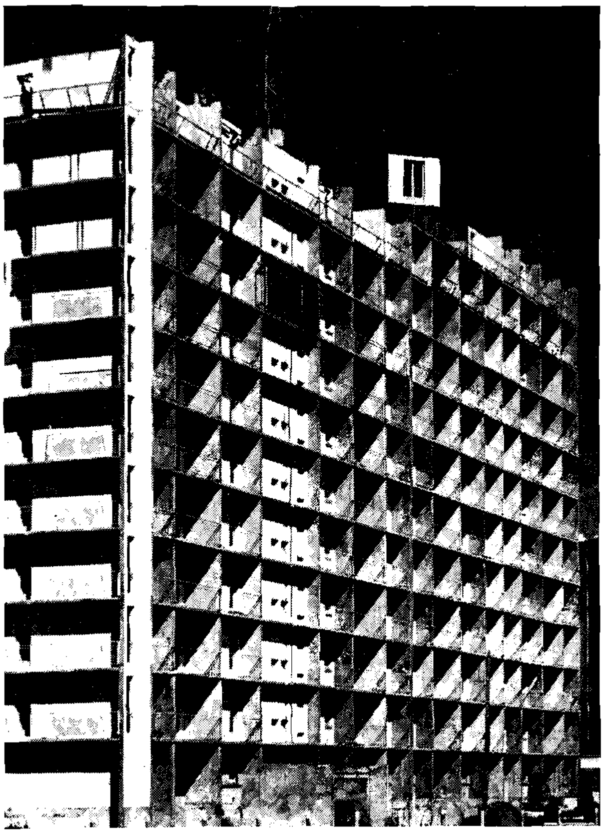


Fig. 1. FIORIO Process (France). Final assembly of a prefabricated wall panel.

Development of the structural element: pre-assembly in the factory: organisation, mechanisation, inspection. The brick is a geometrical body designed for incorporation into an assembly to which it brings its own particular features, including mechanical strength, insulation and durability. Traditionally, assembly is done right at the work-site. However, nothing prevents it from being done in various stages elsewhere. In addition, although present brick manufacturing techniques do not permit an increase in the volume and weight of a unit that can be transported and put in place by hand, the search for improved productivity entails an increase in the dimensions of the structural unit: thus, it becomes necessary to introduce a preassembly process at a stage somewhere in between manufacturing and final construction.

Preassembly is the making of a large element, and is carried out at a point that is seperate both from the brick-plant and the work-site, although it is in most cases organically related to the one or the other. The process of manufacture, right from the raw

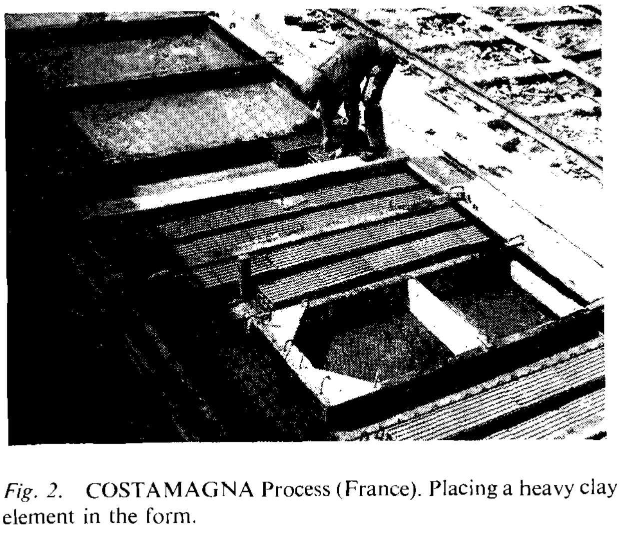


Fig. 2. COSTAMAGNA Process (France). Placing a heavy clay element in the form.

materials, is performed with a view to maximum simplification of final assembly operations at the work-site. This development requires basically:

- a concrete-producing unit,
- equipment specifically designed for producing the element (a mould or vertical-lifting device),
- handling equipment,
- storage-area and related equipment.

The fact that panel-manufacturing operations are repetitive makes it possible, despite variations in panel shape or design, to organise an effectual series of assembly-stations and provide crew labour on an efficient basis. The transporting of supplies and finished products to and from assembly-stations is completely mechanised and the only manual operation is the actual making of the panels.

Survey of the various techniques: prefabrication and final assembly.

In Western Europe, there are two fundamentally different techniques, based on differences in wall-structure design, but both of them favour horizontal preassembly: the use of one or two layers of hollow clay blocks which make up the total thickness of the wall, or the use of perforated or solid products which make up the total wall thickness in two leaves, separated by an air-layer or by a layer of a suitable insulating material.

In each of these techniques, suitable solid or hollow products must be preassembled on a flat concrete or steel surface, within a space corresponding to the overall space enclosed by the panel: the products are positioned manually by means of a screen, the bond being created by a simple pouring-in of mortar. A great diversity of interior and exterior facings can be provided, and these can be produced concurrently with the actual wall panel structure.

The product preassembly-station can be stationary (with products supplied by means of suitable equipment), or mobile with the mould-unit running on tracks from one point to the next, the necessary materials being kept on hand at each point. Local climatic conditions determine whether or not preassembly should be followed by a process to accelerate setting. When the setting is finished, the panel is taken from the mould, trimmed, and removed to the storage area for inspection. Transport for construction is carried on by means of variable-capacity special devices adapted to the elements being made, their exact type depending on the distance between prefabrication centre and building site.

On the work-site, actual wall-construction involves only three basic operations: conveying the panel to where it is to be used, mechanically, and generally in a single step, a lifting-device removing the panel from the work-site temporary storage-area and presenting it vertically at the setting place; adjustment, generally done by telescoping screws, making it possible to position the panel and hold it steady until the joints have set; making the joints, horizontally by hammering or vibratory compaction, or vertically by pouring, after the interposition of waterproof joints.

Production centres: stationary plants and mobile units. Production centres for prefabricated heavy-clay panels operate either as stationary or as mobile units.

Stationary plants supply areas where a lot of building is in progress, within distances compatible with transportation costs, and their existence is justified near building complexes consisting of multiple dwelling units (planned sectors), in which continuity is assured (current production rate is approximately two to five dwellings per day).

The stationary plant requires a complete installation housed in buildings enclosed on all four sides. The organisation of industrial planning, and execution of the programme, must be strict and maximum mechanisation is aimed at. Equipment for assembling the various elements and, when necessary, fast-setting equipment are generally specific features of the procedure.

Stationary plants require considerable investment, and the latter's amortisation, either short-dated or long-dated, is thus contingent on large-scale operations, whence the necessity for a market in which large-scale repetition ensures normal amortisation. The prefabrication plant is sometimes a subsidiary of the brick-making company, but may also be set up by independent companies.

Mobile installations supply a work-site or a series of work-sites corresponding to a limited number of housing units. They are geared to the "diffused", construction sector, which does not come under an overall building plan but depends on private promoters. The unit is basically mobile, that is it can be dismantled and set up again in another location. However, it retains its industrial features: its organisation and means of production are as carefully planned and developed as those of a stationary plant. Its production rate seldom exceeds three houses per day.

Its investment costs are largely dependent on this rate: in the preceding survey, the planning, equipping, and organisation of the unit are defined in relation to the series proposed, taking into consideration a production rate that will permit a reasonable amortisation. The mobile prefabrication unit for heavy-clay is generally the property of a contractor, who is psychologically and commercially interested in prefabricating, himself, the panels used for his own building sites.

Survey of results obtained

Although statistical data are not complete, available facts reveal that, at the present time, in T.B.E.-member countries, the heavy clay prefabrication process has been utilized for the building of over 50,000 housing units. This experience justifies the following observations:

Labour: Like all processes of industrialisation of building construction, heavy-clay product preassembly systems have aimed to require less labour than in classical constructions. The saving thus realized ranges from 10 to 30%, depending on the degrees of organisation attained by the process. However, it should be noted that traditional work-sites are organising themselves on a sound working-basis, and that the difference may become less marked in the future; furthermore, whereas the stationary plant or the mobile unit only requires unskilled labour, provided that it is competently directed, the final building assembly phase requires highly skilled workers.

The relative simplicity of both stationary and mobile plants for the prefabrication of heavy-clay elements obviates the necessity for having a highly qualified maintenance staff, required for heavy prefabrication with other materials.

Technique: Preassembly in the form of large-sized panels has made it possible to industrialise construction using heavy-clay products. Under an organised, planned, and mechanised form, bricks are integrated into the main wall structure, retaining their own traditional features.

Panel-elements are the result of scientific research; they are laboratory-tested, inspected both during and after manufacture, and offer a guarantee of constant quality. The technical improvement achieved meets the requirements of present-day developments.

Economy: Experience at actual work-sites has repeatedly shown that the systematically organised preassembly of hollow and solid bricks makes it possible to construct competitively-priced buildings of superior quality. With a large number of

Fig. 3. BMB Process (Netherlands). Preparation of the brick facing.

European brick-manufacturers, the current tendency is toward this utilization of their product. The increasingly powerful means at the disposal of this industry make it particularly well-fitted for contributing to the expansion of industrial construction methods.

Integrating the heavy-clay manufacturer into the construction group

The brick manufacturer who has been won over to prefabrication finds that his role becomes transformed and more important: together with his research staff, he assists the whole enterprise, and participates directly or indirectly in the development and operation of the preassembly installation unit. This new role often results in his collaboration with the architect at the design stage.

The brick manufacturer's interest is oriented to the industrialised use of his products, and such an expansion leads him to active collaboration on construction within the main group, starting with the preliminary survey and going through to the final assembly.

Conclusion: The European heavy-clay industry, whose current output takes care of the needs, both quantitative and qualitative, of a large proportion of housing construction, is now deeply committed to the industrialisation of building construction. It can offer several processes for the prefabrication of both single- and double-walled panels. These systems have been exhaustively tested and are found to meet, with the proper degree of flexibility, the various criteria of industrialisation.

Because of its flexibility, it is possible to adapt brick-panel prefabrication to any modular architecture. The brick-manufacturing industry can therefore readily integrate into an international system of dimensional coordination. Through these existing processes, heavy-clay products have shown that they can measure up to the criteria of the "closed" type of industrialisation. Their flexibility of application satisfies the requirements of dimensional coordination, and it will require only the solving of financial and organisational problems to provide heavy-clay products with access to the "open", or "catalogue", type of industrialisation.

Mechanized lines for the production of precast reinforced concrete

By A. A. Susnikov (U.S.S.R.)

Precast reinforced concrete articles are used very extensively in industrial construction and house building.

In the erection of any buildings, whether designed for industrial enterprices, public or residential purposes, there are employed linear framework structural members such as pillars, beams, girders, and flat enclosing structural members, viz. ceiling and wall panels.

Unification and reduction of the number of types and sizes of members to a minimum is the first condition in organizing the industrial production of large-size precast reinforced concrete structural members. Only this will allow mechanisation of the manufacturing process and, therefore, make the enterprise profitable.

In the precast reinforced concrete industry, as in other branches, there can be three kinds of production, namely, single, small-batch and mass production. The last two kinds are possible only after standardization of the structural members.

A second condition must be observed in the manufacture of precastr einforced concrete structural members, viz. complete interchangeability within each type and size of article produced by an enterprise. This is attained by strict observance of the allowances in the linear overall dimensions and flatness, as well as in the dimensions related to the installation of the embedded parts by means of which the building is assembled.

The production of interchangeable parts within the limits of the given allowances requires the employment of accurately made moulds, mechanisms for performing the separate operations involved in the manufacture of the structural members, as well as control apparatus and instruments that will guarantee the production of high-quality articles in small-batches and especially in mass production.

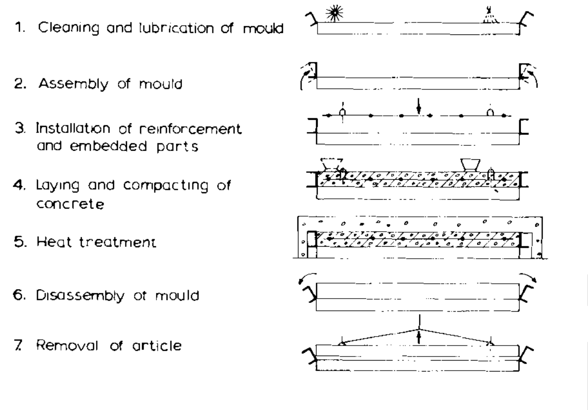
From the economical viewpoint the industrial manufacture of precast reinforced concrete should comply with a third condition, namely, a building being erected of precast reinforced concrete should be cheaper than a traditional building of wood, brick, steel or in-situ reinforced concrete.

The cost of the structural members manufactured at an industrial enterprise consists of the cost of the materials and semi-finished articles, which is a constant value for a given factory, and the cost of manufacture at the factory, which depends upon the quantity of articles produced per unit of time and the method of manufacture employed at the factory.

The main technological ratings influencing the cost of manufacture include production indices per unit of output (square or cubic metre of articles) produced by the factory, the output per square metre of production area, the weight of the equipment and the expenditure of labour, which characterize the degree of mechanization.

The process of manufacturing precast reinforced concrete structural members at an industrial enterprise consists of a number of technological operations, an exemplary list of which is given in Table 1.

Table 1



In single production the main method of manufacturing structural members is the stand, in which all the technological operations are performed at one workplace (a stationary mould secured in place) by a team of workers. Manual labour is prevalent in this method. Each worker in the team must be skilled in performing a number of technological operations. The men should have considerable experience in order to manufacture each article of desired quality in the shortest possible time.

Small-batch production is characterized by the employment of a mechanized equipment line, along which the mould is made to move by means of transportation equipment between a number of specialized workplaces, each of which is designed to perform a single operation.

In these instances, it is possible to mechanize the operations of moving the moulds, laying and compacting of the concrete, embedding the reinforcement, and transportation of the articles to the setting chambers. This reduces the number of operations performed manually and the number of men required. The employment of movable moulds allows to carry out heat treatment of the articles in several rows by stacking them, which, in turn, reduces the production area.

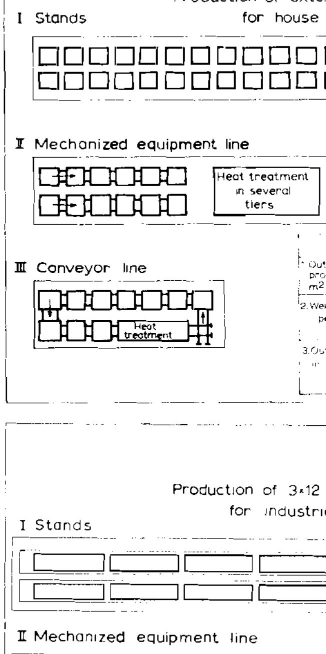
Mass production allows the employment of the most perfect conveyor line, along which the moulds move at a predetermined rate, and the operations of assembly and disassembly, cleaning and lubrication of the moulds, and the heat treatment, are performed automatically.

The employment of precast reinforced concrete in the Soviet Union has increased from 2.3 million cubic metres in 1953 to 45 million in 1963. The wide range of types and quantities of articles required make it necessary to employ all three kinds of production. The increasing attention being paid to the standardization of precast reinforced concrete structural members will allow to do away with single production methods and considerably to increase the employment of conveyor lines.

Comparisons of the principal technical and economical ratings

Table 2

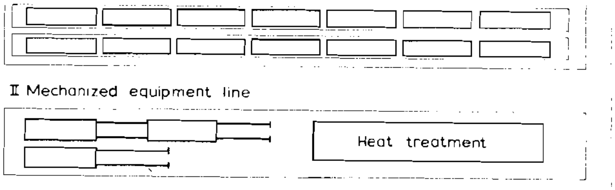
Production of external wall panels for house building

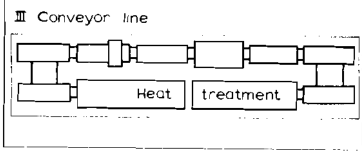


Ratings	I	II	III
1. Output per m² of production area in m² of articles per year	504	762	1500
2. Weight of equipment per m² of article in kg	0.7	0.9	1.0
3. Output per worker in m² of articles per year	1530	2720	3000

Table 3

Production of 3×12 meters ceiling panels for industrial buildings





Ratings	I	II	III
1 Output per m² of production area in m³ of precast reinforced concrete	2.24	12.0	16.0
2 Weight of equipment per m3 of precast reinforced concrete in kg	48.7	24.1	21.6
3 Output per worker in m³ of precast reinforced concrete	281	812	2000

for two examples of employing a mechanized or automatic production line are given in Tables 2 and 3.

Mechanized equipment lines for the production of flat precast reinforced concrete structural members up to 3 × 6 metres in size for residential and industrial buildings are being employed with considerable success at many enterprises. A mechanized equipment line for articles of 3 × 12 metres is being tested at present. Conveyor lines for articles of 3 × 6 metres for house building and of 3 × 12 metres for industrial buildings are in the stage of manufacture.

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J. Szukszta

Use of linear programming to define location and production capacity of regional factories producing large panels

By J. Szukszta (Poland)

The planned development of large-panel construction in Poland needs intensive extension in the hinterland, above all the extension of large-panel production plants (LPP).

For a predetermined large-panel construction plan in a given region it is necessary to find such an alternative of the extension of the existing production plants and building new plants, as assures the minimum supply costs of prefabricates for building sites in the period of the plan.

The precise formulation of the problem

By accurate formulation, the problem has the following elements:

1. The demand for large-panels from individual building sites in the region for the successive years of the plan.
2. Existing production plants with known production capacities, eventual possibilities of their extension and modernisation.
3. Areas where new production plants can be located.
4. A series of production plant projects with different production capacities, having predetermined indices of investment outlays and exploitation costs.
5. Determined road network in an area.
6. Sources of raw materials.
7. The unitary costs of the road and rail transport for main raw materials and prefabricates.

Unknown: sizes, location places, actuating terms of the production plants and the connections of the production plants with the customers.

The optimalisation criterion of the location problem is the supply costs of the prefabricates for the building sites.

The general suppositions

To solve a problem formulated in this way, it is necessary to use a series of suppositions, which allow us to simplify the calculation.

1. The problem of supplying the prefabricates is being solved for a region: it is a self-sufficient area in the production and acceptance sphere.
2. Because the demand can be given for a shorter term than the amortisation term of the investment outlay, we assume that the demand in the later term is no smaller than in the given term in a case where we do not have more precise data on this subject.
3. In the elaboration, the possibility of discontinuing the outlay is overlooked.
4. The problem of restriction of the investment outlay quantity and the problem of a convincing structure of this outlay is overlooked (e.g. limited investment possibilities in heavy transportation equipment etc.)

The parameters of the problem - The calculation methods - Detailed suppositions

Given:

(At 3 above) The information includes the definition of the maximum size of the production plant from the point of view of the site etc. and the estimation of the construction costs dependent on the location.

(At 4 above) A set of projects of a production plant includes the most effective solutions for a given production plant size and determines the general investment outlays, the construction cycle and exploitation costs of a production plant.

It is accepted, that production plants with intermediate production capacities can be constructed. The production plant indices at that time will assume intermediate values.

On account of the size of the annual demand of the region (9000 rooms/year), only production plants with full assortment are accepted for further considerations. It is allowable in some years not to utilize the production capacity of the production plant up to 15%. It is agreed that this does not cause any change in the accepted indices. It is also agreed, that the whole large-panel construction of an area is done by one system—"PBU".

It allows for:

1. acceptance, that every production plant can supply every construction.
2. definition of the consumption indices of the raw materials and prefabricates for one room.

The elementary cost of the prefabricates used in construction, consists of the following elements.

	Investment outlays of a production plant	Exploitation costs (without transportation costs)	Transportation costs
Symbol	a_i = investment	a_i = exploitation	a_i = raw material a_{ik} = prefabricates
Independent of the location of the production plant	Outlays on the base departments. Other outlays-average advantageous conditions	Basic exploitation costs	
Dependent on location of the production plant.	Over standard costs for outside communications. Site works. Co-operation effects; the necessity to construct or the possibility to discontinue to construct some departments: Housing	Additional exploitation costs of some departments	Raw materials (the source of raw materials production plant). Prefabricates (production plant: construction).

On the basis of a series of available materials, the elementary, independent from the location, investment outlays and exploitation costs of the production plants of different classes, were estimated.

(At 7 above). The transportation costs were calculated on the basis of transport tariffs. The transportation cost of prefabricates was calculated in the basis of special analysis in the supposition of applying "the assembling from the wheels" by using a set: tractor Tatra 141 and 25 tons trailer.

The solution of the problem in simplified conditions

The simplification of the problem formulated above can proceed in two directions:

1. The solution of the problem for one time-stage.
2. The acceptance of an additional supposition, that an area, or any sub area, is served by one production plant. Problems simplified this way, will form the stages of the end solution. To get the solution, first of all we must explain which is the orientation LPP from the point of view of the transportation costs. This orientation depends on:

1. The amount of the raw materials and prefabricates for the end product unit (e.g. for one room = 7.20 m^3 prefabricates).
2. The elementary transportation costs of the raw materials and prefabricates.

The elementary transportation costs of raw materials and prefabricates are:

Road transport

Material	Amount for 1 room tons	Transportation cost per 1 ton (in zloty)	Transportation cost for 1 room (column 2 × column 3) (in zloty)
1	2	3	4
Prefabricates	15.74		28.30 L + 379.0
gravel	6.41	8.00 + 1.42 L	9.10 L + 51.4
sand	3.205	8.00 + 1.42 L	4.55 L + 25.7
cement	2.005	6.40 + 1.15 L	2.305 L + 12.8
steel	0.223	8.00 + 1.15 L	0.256 L + 1.775
		Together without prefabricates	16.20 L + 91.7

The assembly shows, that from the point of view of the transportation costs LPP are strongly orientated to the building sites. We must decide what is the difference between marginal transportation costs of the prefabricates (Δ prefabricated = 28.30 L/km room) and the raw materials (Δ r.m. = 16.20 L/km room). These costs characterise the savings we get by shortening the raw materials and prefabricates transportation by a distance of 1 km.

The establishing of the location of one production plant which supplies "n" given receiving points. The first approximation we get by application of the so called mechanical method.

Given: Receiving points and the quantities of their demands for prefabricates.

Accepting the suppositions, that (1) for the first approximation the raw materials do not have any important influence and (2) we have to deal with a transportation area (transportation is possible on any line of an area) and not with a real road network, we can find the place of the production plant location by using an elementary device where loads simulate marginal transport costs.

The second approximation is the calculus analysis of the attraction forces of the production plant, in the direction of the sources of the raw materials and the receiving points of the prefabricates. We move the point we got in the first stage to the nearest road and examine the gravitation forces to the raw material sources and to the building sites. Quantities of these forces are the products of the marginal transportation costs by the quantity of the transported material. We examine the possibility to move the production plant by 1 km in different possible directions. The direction, for which the algebraic sum of the forces shows to be positive, is the direction in which it is advantageous to move. We move the production plant to the nearest road-crossing and conduct further the analysis of the possibilities of moving the production plant in all of the possible directions. If all of these possibilities give a negative result, it means that we have found the proper location of the production plant. Otherwise, we repeat the operation.

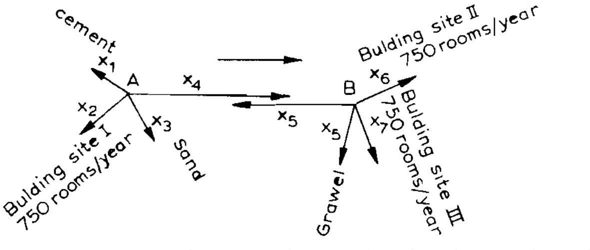

Fig. 1. Analysis of forces of attraction for the location of a factory manufacturing 2250 rooms per year.
$X_4 = X_6 + X_7 + X_8$, $X_5 = X_1 + X_2 + X_3$. If $X_4 = X_1 + X_2 + X_3$ we proceed to the analysis of point B. (Example of values for forces: $X_3 = 455:2250$, $X_7 = 38.30:750$ etc.)

The application of the linear programming to the LPP locations

Conducting a preliminary selection of the location places, we take into account:

1. the receiving points of the prefabricates.
2. the location places of the production plant for certain groups of the receiving points (according to indications of the mechanical devices, and analysis of the location forces).
3. other points in which the location is especially advantageous (railway sidings, roads, etc.).

For the assembly of the points we conduct a calculation, formulating this problem as a transportation problem of the linear programming.

The matrix of the prefabricates transportation costs, from production plant (i) to the building sites (k) consists of expressions a_{ik}:($a_{ik} = a_i$ investment $+ a_i$ exploitation $+ a_i$ raw material $+ a_{ik}$ prefabricates.)

Index (i) includes the indication of the location place and the size of LPP alike. Production plants, which in the solution process are subordinated to a fictitious customer, are irrational. This way, when the demand is constant, we can solve the problem of location for a time period. The method assumes the stability of the elementary production cost of a given production plant and is usable, especially in cases where there is no necessity to apply a production plant of intermediate size.

On account of the specific conditions of the problem in the Katowice region it was more effective to apply the parametric programming, which takes into consideration the instability of the elementary production costs together with the growth of the production plants size. It is accepted, that these costs are linear variables in individual classes of production plants.

Consideration of the change of the demand in time

In the case of a necessity to readjust the locations (LPP) to a variable in time demand, the first stage will be the solution of the problem for all, assumed as independent time periods. The sums of the supply costs of the individual independent solutions constitute a starting basis for the next stage.

Comparing the independent solutions, we must coordinate them together, to insure the production continuity of the production plants. We consider production plants, which repeat themselves for successive periods, as established production plants. That production which always goes to the fictitious customer, we cancel from the consideration. For production plants, the production of which in some years goes to the fictitious customer, and in other years to a real customer, we test the different construction alternatives and the eventual liquidation. We accept the alternative, which assures us the minimum supply costs as the final solution.

The location method was tested for the analysis of the LPP locations in the Katowice region, where a great number of receiving points, and differences in the time program of construction, did not allow for a direct solution of the question, as to which production plants have to be located, where and in what terms.

Conclusions. The proposed method ties together and systematises the general dependencies of location factors, which allows for a precise solution of the best alternative of the production plant locations in an area. In case we accept another decision, it is possible to compare directly its effects by this method.

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W. Triebel

Obtaining good results with the use of prefabricated components with regard to cost, time, and quality of building work

By W. Triebel (West Germany)

Building by means of prefabricated components may help to develop techniques for building rationalisation, if it tends to erect constructions of normal value and lasting quality with less labour than otherwise required. In other words, prefabricated-component building must show results in respect of less labour, shorter building time or lower building cost.

Building labour

When the first buildings were put up in Hamburg in 1959, one square metre of dwelling area required 18 hours' work. But less time was taken on assembly proper. However labour for preparation, heavy masonry and building finish should be taken into account.

With gradual training and the results of research work, labour required has been reduced from year to year. Nowadays, well planned and organised building, using large prefabricated components, is carried out on the site at the rate of 8 to 10 hours per square metre of dwelling area.

These figures, according to typical and comparable examples, are accounted for as follows:

Preparation: 1.8 to 2.5 hrs/sq.m of dwelling area
Erection: 1.3 to 2.0 hrs/sq.m of dwelling area
Finishing: 4.7 to 5.5 hrs/sq.m of dwelling area

(To this should be added time required for prefabrication at the factory. This may be reckoned to be 5 to 8 hrs/sq.m of dwelling area, depending on the method and scope of prefabrication). Assembling prefabricated components amounts to 15 to 20% only of total working time on the building site.

As a comparison, buildings constructed by other methods need labour at the rate of 20 to 22 hrs/sq.m. It would require 30 hrs/sq.m, or even more, to erect buildings by less rational methods.

As regards erection, on rational lines and in large numbers, of single-household dwellings with prefabricated components, the rate of labour required is in the region of that for multi-storied buildings constructed by means of prefabricated components. Taking a major building scheme in Bremen, this rate ranged from 7.5 to 11 hrs/sq.m of dwelling area.

"Part prefabrication", viz. using many prefabricated components for interior building in combination with locally-produced heavy wall work (e.g. masonry, reinforced concrete floor and wooden roof), has achieved a 30% reduction in labour for finishing work. Labour required for the entire building work was thereby cut down by approximately 15%.

Building time allowed

When comparing time required for prefabricated building with that by other building methods, allowance should also be made for the additional time spent on factory prefabrication. However, in the case of current production and current assembly, time required is the same, and total labour time is not substantially increased.

With a well-run production plant and continuous prefabrication of components, in Western Germany, the smallest groups of buildings, of 30 to 40 dwellings, using prefabricated concrete components, have been erected in a matter of 22 weeks. Time required was inclusive of all work on all building jobs, from the beginning of the initial spade-work to finishing dwellings ready for occupation. In the case of a typical building project, this is how such building time is accounted for:

Preparatory and foundation work (ground levelling, site installation, earthwork etc.)	11 weeks
Erection of all prefabricated elements	6 weeks
Other finishing jobs	9 weeks

However, total time was 22 weeks only, because, due to good organisation of building job sequence, these divisions overlapped. To carry out good and properly organised construction of the same sort and size by the other traditional methods, time required is reckoned to be at least 35–40 weeks for similar buildings and under favourable conditions.

Building time required is shorter in the case of separate household houses, using prefabricated components. In a successful case, a one-storied household dwelling, without basement or roof, was completed in ten days after due preparation.

Taking the abovementioned example of part-prefabrication (buildings with masoned walls and prefabricated minor finish components), it has always been possible to cut down building time by 20 to 30% in comparison with ordinary, and rational building, thanks to the systematic use of such minor finish component details.

Building cost

Building with prefabricated minor finish components may produce a reduction in costs, provided the most appropriate processes are used. Selection and concentrated application of always the most economical prefabricated components may, according to an investigation (Institut für Bauforschung), reduce by about 10% the cost of building a typical three-storied house. Prefabricated elements come in for approximately 30% of the total value of the building.

But, on the whole, the cost of buildings erected by means of large prefabricated components has so far, as a rule, not been less than that of otherwise similar buildings erected by other methods. It should be borne in mind that, alongside the sort and method of building, there is planning and preparation that are material in regard to cost and economy.

For this reason it is required that town planning and plans for private buildings take first into account the suitable production of prefabricated components, their transport and assembly. But the overriding consideration in town planning, and planning for buildings and dwellings, is human needs and demands. To be worthy, techniques must not be detrimental to the fulfilment of recognised human needs, physical, psychological and economic.

The following is the analysis of the cost of some multistoried typical buildings made with heavy prefabricated elements:

Prefabrication 55%, transport 2%, preparation 10%; assembly 7%, finishing 26%.

However, some prerequisites to cheaper building with prefabricated components intervene in building value and human needs. These include:

- simplicity and clearness in design;
- standardisation of measurements and of elements despite the different sorts of buildings;
- planning to be completed prior to starting production;
- under-ground construction precedes that above ground level;
- proper timing of all production and building stages in relation to each other;
- large building schemes making uninterrupted use of repeatedly similar components, etc.

Such suitable planning, preparation and construction have resulted in a 10% saving in the cost of building with prefabricated components, as compared with other such buildings where there had been no adequate planning and preparation.

However, due to the above suitable conditions, the cost of competitive buildings, constructed by traditional methods, has also gone down. The great number of typical and exemplary buildings in the Federal Republic are there to prove the merits of such measures.

Thus, under suitable conditions, there have been cases of constructions, rationally planned, prepared and carried out according to current methods, proving to be cheaper than those carried out with prefabricated components. On the other hand, in suitable conditions for prefabricated component building (e.g. groups of sky-scrapers located close to each other), this method of building has been carried out 10% cheaper than other methods.

On the whole, building with prefabricated components, provided the system is well prepared and applied, has already achieved a substantial reduction in building labour and time of completion. But, at the present time, whether or not building with prefabricated components is going to be cheaper than other processes depends on the kind of design, on the programme and preparation. These very measures, the proof of the rules they follow, and their general application will be of particular importance in the future.

W. Triebel

Prefabricated component building methods and their limitations in West Germany

By W. Triebel (West Germany)

Prefabrication and erection of large components brings a new feature into the building industry, the transfer of building work from site to factory. The location and nature of production are changed. But the end product – a dwelling, an office, a factory – should eventually answer the same purpose and be of the same good quality as buildings erected so far on traditional lines.

In this way building with prefabricated components may be carried out on a large scale. It is not confined to the application of particular building materials. As a matter of fact, nearly all the current products are made use of for prefabricating components: wood, woody products, concrete, light concrete, bricks, perforated bricks, chalky sandstone, plastics, steel, light metals, and so on. But the selection of a building material means determining at the same time certain qualitative features of the building in which such materials are used.

The size range of prefabricated components covers small handy elements (steps, clustered tubes, railing, etc.), elements as high as a floor and as large as a wall, as well as elements big enough to form a whole section all of a piece, and still larger elements.

Now the choice of the necessary transport and erecting equipment depends on the size and weight, of the separate component units. The smaller the elements, the larger the number of fabricating and erecting operations. But the better adapted these elements are to different shapes of buildings, the smaller the range of elements to be used for these various buildings. Elements may be prefabricated in particular factories, in fixed shops or in mobile shops which can be moved from one place to another and set up on the building site.

Now, the fabrication process and location govern the size of capital investment for setting up the plant, the necessary amount of depreciation and the limits of local possibilities. Whole buildings are made of site-fabricated components. But use is also made of prefabricated components that are fitted together with site-made components.

But, whatever the extent of prefabrication, what really matters is to prefabricate the building components, of which the production would otherwise be elaborate and costly. Such are mainly many internal component parts.

These various possibilities which building materials offer, the size and methods of fabrication, have resulted, in above-ground and dwelling construction in the Federal Republic of Germany, in four practical fields of building application with prefabricated components:

- building single-household houses and others one- or two-storied, making use of wooden or woody product prefabricated components, made even in small shops or minor plants;
- building houses of all sizes, mostly large size, with large components made of mineral materials (concrete, light concrete, brick etc.) in fixed factories;
- building houses as above, but with large site-fabricated components;
- parts made of prefabricated components, otherwise of complex manufacture, of all sizes of houses are fitted together with site-fabricated parts of simple manufacture.

Each of the four fields of application has its advantages and its limitations.

The first field of building application of prefabricated components, that is, using wooden and other organic building materials, is confined, in most European countries, to one- or two-storied, mostly detached, houses. Such are, for instance, school buildings with no upper floor, auxiliary buildings for public use and single-household houses.

The second field of building application, namely, using large prefabricated components made from mineral materials, produced in a fixed plant, has bounds set to it by the financial outlay for building and equipping such plants. As a rule, factories, in which building components are prefabricated, should have a supply capacity of 500 to 1,000 dwellings p.a. These are only erected where, within a radius of some 30 miles, a continuous demand over a number of years may be anticipated. The capacity of existing firms using other "traditional" building processes should be taken into consideration. This application finds an outlet mostly in large towns and industrial centres.

The third field of application, i.e. using large prefabricated components, made from mineral products on the site in a mobile shop, is not dependent on a question of space. However, building projects of some size are needed to pay for the fixed expense items of the site-fabricating plant. A few years ago, about 300 dwellings were considered as the lower limit. The development of fabricating plants has reduced fixed expense items. Now such plants are considered a paying proposition for a little over 100 dwellings.

The fourth field of building application covers the use of prefabricated components mostly for the many small parts, of complex and costly manufacture, for the building finish work. Such parts can be assembled on walls, floors and the roof that are masoned, cast or adjusted on the spot, following rational methods. As a matter of fact, as a rule with this building process, a smaller part of the house is prefabricated than in the case of total prefabrication of large components. Nevertheless, prefabrication in this restricted field is particularly effective.

All these small elements are adaptable to various kinds of buildings. They can be carried and assembled by simple means. So such prefabricated elements are applied, above all, to minor constructional details. That is where they should particularly be used.

It cannot be said that one or another of the above four methods is the most economical. Each has its field of application, according to the sort, the scope and local dispersion of building demand, and in which it finds the most favourable conditions and may be put to the most rational use.

A coordinated mechanical-structural component system for schools in California

By Robertson Ward Jr. (U.S.A.)

S.C.S.D. is a joint project of the School Planning Laboratory and the Department of Architecture of the University of California at Berkeley under a grant to Stanford University from Educational Facilities Laboratories, Inc., a non-profit corporation established by the Ford Foundation. This paper deals with the initiation and organization of the S.C.S.D. project, the competitive participation in the project by major producers in the U.S. building industry, the bidding and development of the four compatible component systems, technical details of these systems and the implications of this unique project. The author is the designer, together with The Engineers Collaborative, of the Structural and Lighting-Ceiling Systems in the S.C.S.D. project being produced by Inland Steel Products Company.

Initiation and organization

Proceeding on the premise that the normal pattern of building one shool at a time does not provide sufficient opportunity or incentive for architects and industry to explore new approaches to building schools, S.C.S.D. convinced thirteen school districts to join together and form The First California Commission on School Construction Systems, who, by pooling their projected building needs, would be able to offer twenty two schools as a guaranteed market for component systems to be developed by manufacturers according to requirements to be set up by S.C.S.D.

The S.C.S.D. project team was headed by project architect, Ezra Ehrenkrantz, whose experience with the postwar British consortia programs was a prime impetus to the S.C.S.D. program. This 6 man team was assisted by an advisory committee of prominent architects and educators and consultants in acoustics, color, mechanical, electrical and structural engineering.

Performance specifications for industry

The S.C.S.D. team, working with the school districts, their architects and engineers, the advisory committee, consultants, governments and regulatory agencies and the EFL, outlined objectives and developed detailed criteria as a basis for preparation of the extensive performance specifications. In addition to the identification of users needs, a continuous feedback of comments on material, technical and system feasibilities was carried on with all segments of the building industry. Industry participation during this stage enabled the final performance specifications to reflect the realistic capabilities of industry without inhibiting areas of new technological possibilities. The "Blue Book", a definitive manual of project organization, timing, procedure and detailed performance specifications was issued in final form to industry in August 1963. Four component systems were asked for, constituting the basic environmental and structural "umbrella": Structure, Heating, Ventilating and Air Conditioning, Lighting-Ceiling and Interior Partitions. Manufacturers were first asked to submit their basic scheme for an "evaluation submittal" in Sept. '63 to assure basic conformance with specifications and compatibility with other systems. Final bid submissions were asked for on Dec. '63 with lump sum installed prices of all components. Systems were judged not on the lowest actual bid but on the lowest "composite" bid indicating the extent of integration and compatibility with the other component systems. A measure of the importance of compatibility was shown in the bidding where an identical mechanical system was nearly twice as high on one structure over a second structure due entirely to compatibility.

Structural system

The structural system awarded the S.C.S.D. component contract consists of a steel deck system, supporting primary beams, and columns. The system allows column spacing of 10′ (3 m) to 30′ (9 m) and 30′ (9 m) to 75′ (22.5 m) in 3′ (.9 m) depth. Deeper spans of 5′ (1.5 m) available up to 110′ (33 m) and floor spans (3′ depth) to 45′ (13.5 m). The system utilizes the steel roof deck as the top compression chord of the truss system action with a vertical Warren truss square tubular web system and formed bottom chords. The floor system utilizes the metal deck in composite structural action with the concrete floor slab, both acting as top chord of the web and bottom chord system. The metal deck thicknesses vary from .036″ (.915 mm) to .066″ (1.675 mm) for the roof system and .030″ (.762 mm) in the floor system.

The primary beams are designed as conventional Warren trusses with welded connections. Roof cantilevers of 5′ and 10′ may be achieved with cantilever primary beams connected to columns or with cantilever deck units connected to primary beams.

The columns are cruciform metal tubes of varying wall thickness with constant outer dimensions for all loading conditions. Where necessary to achieve a desired fire rating the columns will be filled with concrete and have an intumescent coating on the outside.

For ease of handling and shipping, the webs and bottom chords of the deck unit fold into a compact package. Erection involves lifting the deck unit from its package, allowing the webs to unfold to their normal vertical position. The unit is then hoisted into position and attached to primary beams or columns.

The structural system was designed to integrate compatibly with the mechanical and partition systems provided by the other manufacturers, and the lighting-ceiling system developed by the same manufacturer. The structure permits the use of roof mounted mechanical equipment with space available for air distribution between the top deck and the ceiling. The structure provides lateral support points at five foot centers in both directions for anchoring of interior partitions. As all schools in this project are in the California seismic zone, standard lateral load bracing components were designed so that shear walls can be located at any 5′ module line and in either direction.

Lighting ceiling system

S.C.S.D. criteria for the Lighting-Ceiling system required that the system perform multiple functions by providing the source of illumination, the finished ceiling or soffit, the ceiling sound absorption, the sound attenuation between rooms, the fire protection for the steel structure, the support for demountable partitions, and the supply and return air devices. Photometric criteria required that an illumination level of 70 foot candles be maintained in the academic spaces. At the same time brightness levels of no more than 350 foot lamberts in the direct glare zone and 500 foot lamberts in the reflected glare zone could not be exceeded. Three different types of lighting systems were required to satisfy these specifications: a "direct" system, a "semi-indirect" system and a "luminous ceiling" system.

The lighting-ceiling system in the successful component design satisfied these basic requirements by providing a system of formed steel light-coffers and flat ceiling panels supported by a 5′ × 5′ (1.5 m) grid system 4″ (10 cm) in width. The grid system is attached directly to the structure and allows the accurate factory tolerances of the structure to determine the ceiling location. Flat panels in 20″ (.5 m) widths allow the module to be divided into thirds. A single standard light fixture is utilized consisting of two 40W 4 ft. fluorescent tubes with triangular housing containing the ballast. Four positions for this fixture are possible in the coffer. A choice of 4 plastic light diffusers are provided: a low-brightness upward reflector for the semi-indirect, a low-brightness lens for the direct, a large area vinyl diffuser for the luminous ceiling, and a prismatic lens for the surface mounted units.

By varying the combinations of these basic components, a great variety of lighting systems are available. One, two, or three fixtures can be installed in any coffer. The coffers can be oriented in either direction of the structure and can alternate with flat panels. The components can be changed readily to other configurations and access to the space above the ceiling is provided in every module.

The cruciform shape of the standard structural column allows it to penetrate the ceiling system only at the supporting grid;

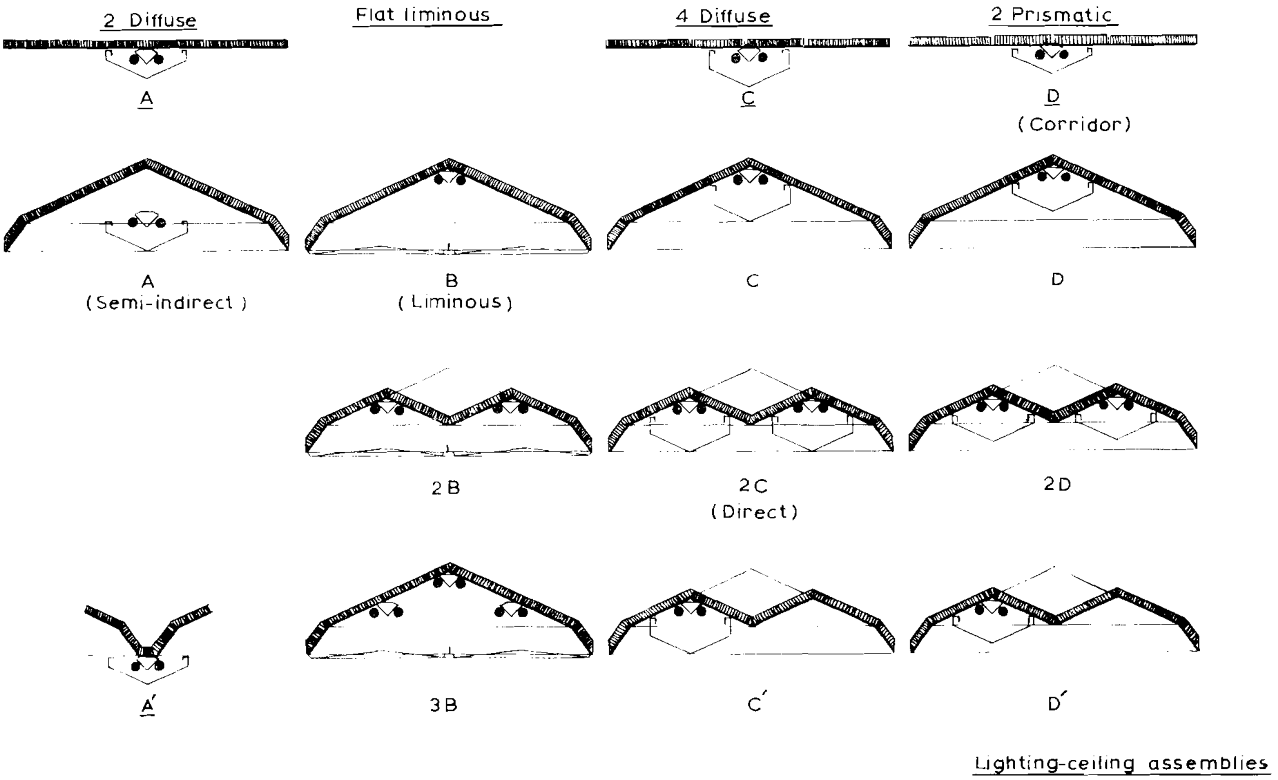

Fig. 1. Lighting–ceiling assemblies

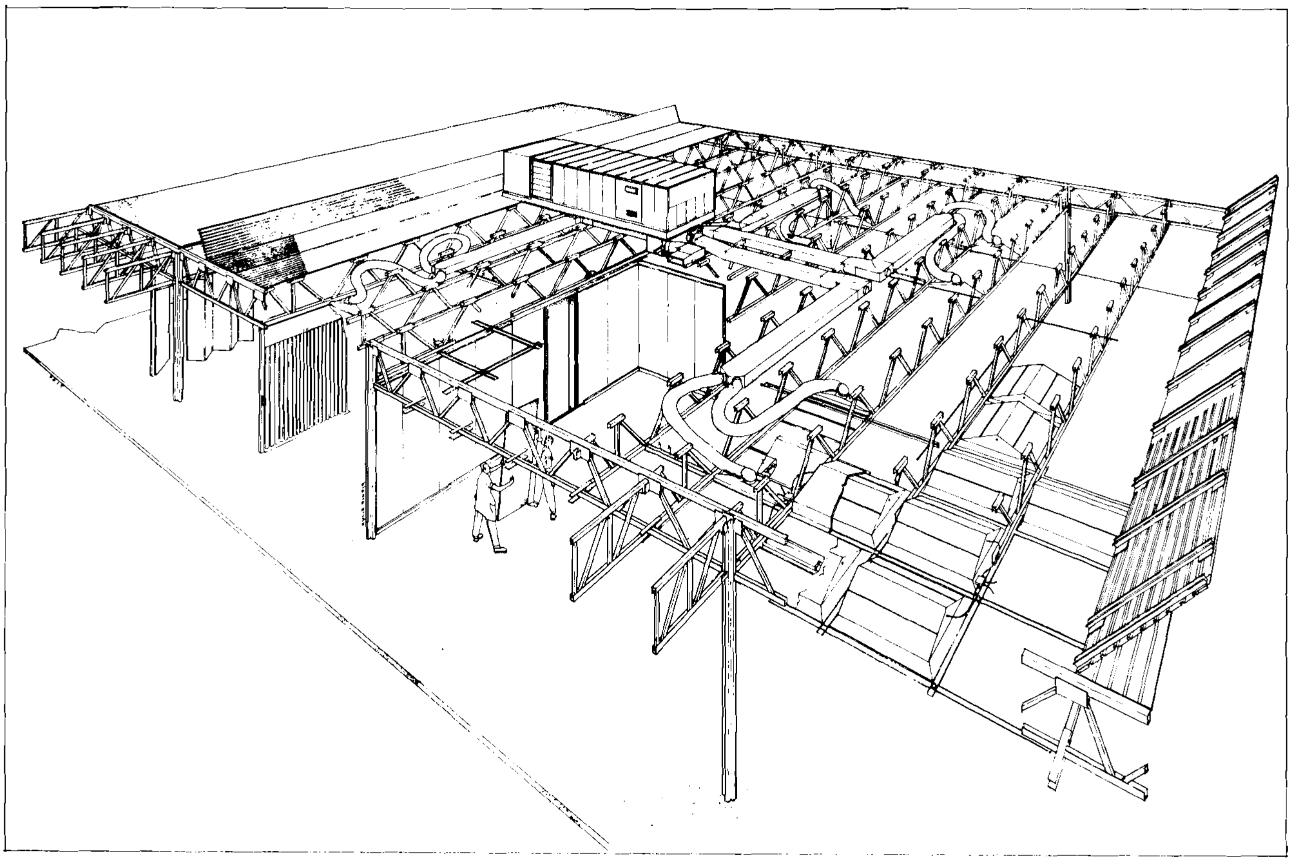

Fig. 2. Assembly of structural system and heating, ventilation and air-conditioning system.

thus, the flexibility of the ceiling arrangement is never impaired by the structural column location. Interchangeable with the 4″ ceiling grid members are air supply diffusers, air returns and protecting fire-dampers. A mineral fiber blanket covers all the ceiling elements to provide the required 1 hour fire protection to the structure. Perforated ceiling panels utilize the mineral fiber blanket for increased acoustic absorption.

Heating-ventilating-air conditioning system

S.C.S.D. criteria demanded a system of high flexibility to match the anticipated educational demands. A larger module of 3600 sq. ft. (334 sq. m) was established as a unit of air conditioning servicing. This in turn was divided into eight zones of 450 sq. ft. (41.8 sq. m) for individual control of temperature. As these zones could change with partition layout, the distribution system was required to be equally flexible. Mechanical cooling was required in 56 per cent of the average school area. Types of spaces where mechanical cooling was required include general academic areas, administrative spaces, sciences, music and multi-purpose areas. Cooling would not be required in physical education, food service, storage and mechanical equipment areas.

The component system to be used in the S.C.S.D. project utilizes a roof-mounted self-contained unit for complete air conditioning, filtering and heating. Each unit serves one 3600 sq. ft. (334 sq. m) service module. The unit can recirculate 100% of the air or supply 100% outside fresh air or any intermediate mixtures. Capacities for controlling eight separate zones are provided in the unit; air to each supply zone is then distributed through a fixed duct system to pairs of flexible ducts, each pair serving 450 sq. ft. (41.8 sq. m) of floor space. Flexible ducts allow attachment to ceiling air diffusers at a wide choice of positions within the modules and can be moved from one position to another without disconnecting any element of the system. Air is returned to the central unit by the same linear ceiling elements opening directly into the structural cavity.

A significant aspect of the S.C.S.D. procedure was a requirement for a five-year full maintenance contract as part of the competitive bidding specifications. A measure of the effectiveness of this requirement was the willingness of the successful component contractor to extend this maintenance contract to a period of 20 years.

Interior partition systems

S.C.S.D. criteria for the interior partition systems required not only flexibility on the 5′ (1.5 m) module but on any 4″ (10 cm) planning module as well. These requirements demanded a major portion of the partitions to be demountable and included additional operable partitions both of the panel and the "accordion" type. An interesting result of the bidding was the substitution by the successful contractor of demountable walls for that portion of the interior walls which were allowed to be normal "fixed" walls. This was partially due to the S.C.S.D. requirements for the partition surfaces, i.e., that they be supplied with integral chalkboard and tackboard surfaces and that each face of the wall be separately changeable. The demountable wall system to be used will have an independent metal "stud" core on 40″ (1 m) centers with separate panel faces, each a sandwich of gypsum board between steel sheet surfaces.

Development mock-ups and testing programs

Component contractors in the S.C.S.D. program were required to include in the bidding amount the cost of an extensive development program including the construction of two phases of component mock-ups. The development period after award of the contracts in January 1964 extended through Fall 1964. The first phase of mock-ups and testing required the erection and testing of rough working mock-ups in any form necessary to solve problems arising during the development work.

The purpose of the phase 1 mock-up as explained in the S.C.S.D. specifications was to assist in the solving of critical problems in relationship of structural and equipment, to solve detail problems before system is too far advanced in development, to provide an opportunity for testing and detail re-design with material, which can be damaged, where finish and future use is unimportant, and to provide opportunity for S.C.S.D. to assess efficacy of system integration.

Phase two of the development period included the erection and testing of a final full scale mock-up building of approximately 4,200 sq. ft. (390 sq. m) designed by S.C.S.D. and constructed at Stanford University at Palo Alto, California. The purpose of the phase 2 mock-up was to check the component system in detail at a prototype level in a well-designed and well-furnished building, to test components in relation to one another, to test the lighting, acoustics and mechanical environment, to present a visual check on the results of the system for participating school districts, manufacturers, district architects, and any other interested parties; to exhibit the system and to provide an example to general contractors prior to their bidding on individual schools.

Testing in the mock-up included environmental testing of lighting, acoustics and air distribution in characteristic spaces. Performance standards for lighting levels and brightness control, air velocity and patterns, temperature control and response of systems and ventilation were tested. At the same time testing of individual components under laboratory conditions fulfilled other test requirements of the S.C.S.D. specifications.

Lessons and implications of S.C.S.D.

At the time of the writing of this article, the S.C.S.D. phase two mock-up program was not yet completed and thus must await a further report for its final technical evaluation. Naturally the full program cannot be judged until its completion in 1966–67. However, even at this stage the S.C.S.D. program can be credited with significant accomplishments:

1. The first to be emphasized by S.C.S.D. itself, and certainly one of basic consequence is the fact that these higher standards of educational requirements were met through component systems at the cost levels at least equal to lower standards of construction, the fact that costs actually were less than the cost of these conventional elements by 18.4% is additionally satisfying but was de-emphasized as a goal of the program.
2. Active client participation has been shown to produce a clear identification of needs in the form of performance specifications, a process highly dependent on the group cooperation of all concerned in the problem area, the users, the architects and engineers, the educational and professional advisors, the governmental and regulating agencies, and the union, contracting and industry associations.
3. The role of a coordinating agency such as S.C.S.D. as a catalyst in this industry-user reaction was essential.
4. The provision of a fixed market of sufficient size by combining the purchasing power of smaller units can stimulate industry to enter new fields and participate in at least a degree of intra-industry joint development towards more integrated construction systems.
5. Component systems developed by industry can offer the architect a design "keyboard" of elements at predictable installed unit prices and provide a future basis for competitive bidding of equivalent systems based on common performance specifications.

Some questions remain to be answered as to the final significance of the particular S.C.S.D. approach. Although S.C.S.D. owes its original inception to the stimulus of the British consortia approach, it differs in significant respects from that pattern. The role of S.C.S.D. as coordinating, programming team (rather than design team) demanded a wider participation by various sectors of the industry in the design process. Much development effort was stimulated in U.S. industry by this project, it is true. There is some feeling that, although progress has certainly been made, as high if not higher levels of coordination might have been achieved had S.C.S.D. participated as the design team directly.

At present, several new projects in various areas of the U.S. are taking form, as a direct consequence of the S.C.S.D. project and in a pattern similar or identical to the S.C.S.D. performance specifications. Some of these are of magnitudes equal to or greater than the S.C.S.D., others are being undertaken by architects who have school projects in the S.C.S.D. program but who are anxious to use the systems on other outside projects, others are individual schools around the country, still others are groupings of the unsuccessful bidders on S.C.S.D. forming compatible bidding teams for systems-bid projects. The S.C.S.D. approach is but one permutation of a generic range of procedural reforming of the industry-product-consumer relationship; it has produced valuable lessons; it is germinating many more.

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Group G
Materials Development

Final report from the group rapporteur Dr. A. Allan Bates, National Bureau of Standards, U.S.A.

Most of the discussions in Group G on Materials Development related to specific questions which are best treated as subjects for debate between individual experts rather than for report to a large assembly such as this.

Certain points of general importance were made, however, and these I shall summarize briefly:

Several speakers emphasized that the most extensive progress toward industrialisation of building has been made with *traditional* materials such as reinforced concrete, brick and clay tiles, steel, wood, etc. We have learned, through much research, to use these older materials in new and more effective ways. Meanwhile, truly *new* materials have played a much smaller, though important, role. This has been especially true when we consider the versatile synthetic plastics with their wide applications as protective coatings, as adhesives and as insulation. The *production* of materials, both new and traditional, is already highly industrialised. It is in their use, both singly and *in combination*, that more progress toward industrialisation can and will be made.

In some countries, such as Japan, the continued availability of low-cost, highly skilled labor—skilled, that is, in use of traditional materials—makes industrialisation of building less urgent. Also, the danger of earthquakes places limitations on some forms and methods of building. Nevertheless, progress is being made with improved materials such as lightweight concretes, laminated wood, lightgage steel, plastics, gypsum board, etc.

Newly developed electro-mechanical methods for rapidly testing the elastic modulus of every piece of lumber make possible a much more exact engineering use of wood in construction. Certain species of wood formerly regarded as unsuitable for high-grade applications can now be effectively used since each piece can be cheaply tested.

Permanent, jointless waterproof membranes have been recently developed by applying successive layers, of decreasing elasticity, composed of polyester and epoxy resins. These materials are acid-proof and alkali-proof, as well as impermeable to water. They remain unaffected by temperatures from −20 °C to 150 °C.

The necessity for accelerated production of manufactured building components is leading to development and use of cements capable of very rapid, controlled hardening.These cements are of high specific surface and can produce concretes which will set and usefully harden in as little as two hours' time.

Much of the progress toward industrialisation of building has been related to high-rise dwellings. In many countries most people prefer individual dwellings or low-rise apartments of not over two or three floors. There is need for much more development of industrialised methods for producing such units, within the discipline of dimensional standardisation, yet capable of individual variation in appearance and plan.

Several authorities concerned with building regulations expressed hope that more research work will be done on certain special aspects of materials such as durability and quality control. Also, methods of jointing are as yet unsatisfactory and must be further perfected. Assurance was given that materials producers and engineers are also concerned with these problems and will support continued research work on them.

Dimensional stability of materials, when exposed to variations and cycles of temperature and moisture, is particularly important when large continuous panels are employed as the major elements in buildings. By using numerous materials together in composite members, to which each material contributes its special properties, great progress is made toward stability. This indicates that research on materials should be carried out with close attention to the complex problems of compatibility between individual materials when used in intimate combination.

Professor V. I. Ovsiyankin of the U.S.S.R. offers the following comments relative to materials development and the ensuing effects on industrialisation of building:

Main directions on the development of building materials are defined by the contemporary industrial design as well as by the industrialisation of building and its economy.

Development of each given type of material should correspond to the tempo of development and introduction of new types of construction elements and components.

For example, it is recommended to use as wall materials the following things: ferro-concrete panels, light and expanded concrete panels, ceramic panels and panels with asbestos cement and aluminum finish (sandwich panels), and large concrete hollow blocks.

Methods of industrial building are being developed and perfected step by step with the process of perfection of physical and technical properties of the traditional materials.

Industrial mass production of construction elements for housing has recently attracted to its orbit such traditional materials, which had been tested in the course of centuries as bricks and ceramics, and positively influences further development of these materials, as well as the quality of brick-panel buildings.

There exists two main directions on the development of construction systems of large panelled houses—frame structure scheme and panel structure scheme. However, their elements will change in corresponding with newly developed insulational and other properties of materials.

Usage of concrete assumes durability, stability of a multi-storied building, while polymerics materials combined with light metal in finishing will make the building look lighter.

The development of new building materials and production and continuous perfection of production methods of pre-fab elements open best possibilities to cut down the cost of building and increase functional qualities of large-panelled houses.

Further development of large panel methods goes in the direction of an ever increasing degree of enlarging the elements (panels) and of their readiness at the factory.

Panels for walls, partitions, and floor slabs, staircases are brought to the highest possible degree of readiness at plant, bath units completed at factory with all installations, electrotechnical panels and 2–3 room size exterior wall units, heavy wall panels with fixed heating installations are in an ever necessary use.

Considerable development of large-panel building and expected expansion in the near future will require a corresponding increase of all experimental, scientific research and design in order to further it. Technological advance in architecture and building is combined with new production and development of new effective building materials and constructions.

Therefore the problem of new material durability is coming to the foreground and becomes ever more pressing. Continuous research and durability tests of new constructional finishes and insulational materials will permit us to define rational limits and to use different construction schemes for fully prefabricated buildings and reasonable scope of new materials production.

In prefabricated industrial construction a very wide use is made of different plastic materials. One could state, that following tendencies are gaining impetus, in the usage of plastics, and they are connected with the following scientific research and experimental work.

1. Development of thermoplastic and thermosetting resin to bonding concrete and mortars, and to use concrete epidermis.
2. Development of new and waterproof roofing materials, easy to place and standing up well to normal wear, large profile foam components to be produced by special equipment.
3. Development of special types of equipment to produce large components.
4. Development of assembly processes for large plastic components and their constructural combination with ferro-concrete and ceramic elements.
5. Developmentsof processesto increase durability(wear, tear, obsolescence) and fire resistance.

Buildings with metal frame and aluminum sheet roofing are as competitive on industrial buildings as the ones with ferro-concrete structures. The former are especially economic when they have spans of more than 21 meters.

As a final point to be made after having studied all the reports and discussions of this Third International CIB Congress, this rapporteur would like to emphasize the observation that building materials development is moving in similar directions in all the nations; it is therefore evident that research and progress in building materials are international on a world scale and that the more closely co-operation is exercised among the nations the greater will be the benefit to all.

Use of hydraulic lime in building construction

By N. S. Bawa (Ghana)

In many African countries, lack of good quality limestone deposits and/or high quality fuel does not allow local manufacture of Portland cement, thus impeding appreciably the desirable rate of building construction. Where good quality deposits do exist, they are sometimes not sufficient for economical running of even a small cement manufacturing unit.

On the other hand, inferior quality limestones are usually available, which, due to apprehensions in the minds of engineers concerning the use of lime in building construction, remain unexploited. For example, in Ghana, small deposits of siliceous and magnesian limestone are found scattered throughout the country which could be exploited for the manufacture of hydraulic lime from siliceous limestones or limepozzolana mixes from non-siliceous magnesian limestones. Up till now all the lime used in the country is imported from abroad.

Portland cement is sometimes used indiscriminately without regard to its shortcomings and unsuitability for many conditions of use. Hydraulic lime is in many cases an alternative to cement of equal status and should not be considered a secondary substitute to be used only if cement is not available. Rather, standard quality hydraulic lime is superior to Portland cement in workability and elasticity, all of which go to make it a better material for certain uses such as in mortars and plasters. In marine masonry structures, where Portland cement mortars are liable to attack by sulphates in the sea water, hydraulic lime or lime-pozzolana mortars could be the answer to withstand corrosive action of sea water.

TABLE I
Minor limestone deposits in Ghana
(Magnesia content less than 5 percent)

Serial No.	Location	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Cementation Index
1	Anyaboni	10.89	—	1.02*	3.23	45.15	0.64
2	Kintampo	25.30	1.49	1.81	0.69	39.58	1.86
3	Abeasi (i)	6.66	1.31	1.01	1.26	49.28	0.41
4	Abeasi (ii)	18.77	3.73	1.27	2.02	39.63	1.36
5	Daboya	28.24	—	5.28*	1.16	34.68	2.32
6	Bongo-da	3.33	—	1.43*	1.51	51.42	0.20
7	Bongo-da	5.16	—	3.09*	4.17	46.01	0.34
8	Salaga (i)	29.53	4.18	1.06	0.98	33.67	2.51
9	Salaga (ii)	19.74	5.42	1.82	2.11	36.97	1.57

TABLE II
Minor magnesian limestone deposits in Ghana

Serial No.	Location	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Cementation Index
1	Longoro	14.79	2.29	3.41	9.89	33.11	0.98
2	Kolenso (gonja)	27.90	0.90	1.25	14.17	22.22	1.90
3	Daboya	24.70	—	1.55*	13.17	25.19	1.62
4	Kago	9.87	—	4.76*	5.29	40.71	0.67
5	Walewale	22.27	—	3.40*	11.59	27.51	1.51
6	Du	4.90	—	1.53*	16.56	33.26	0.27
7	Kakuruge	5.40	—	3.00*	10.14	39.57	0.34
8	Kpandu	10.80	5.04	1.01	12.42	32.57	0.73

Note: * includes Al_2O_3

Limestone deposits in Ghana

There are two main workable limestone deposits in Ghana (1), as follows:

(i) Nauli Deposits

The deposits are quite pure with low magnesia and silica and thus could be used for all purposes where pure limestone or lime is required. In fact these deposits are the only ones suitable in quality and quantity for the manufacture of Portland cement.

(ii) Buipe-Baka Limestones

These deposits are unsuitable for the manufacture of Portland cement due to high magnesia content but could be used for the manufacture of hydraulic and non-hydraulic lime for building construction.

In addition to the above two main deposits many minor deposits are found throughout Ghana. These deposits are not useful for the manufacture of Portland cement due to poor quality or low quantity, but could be exploited for the establishment of a lime industry on a small scale at different centres in the country. Quality of limestone of various minor deposits is given in Tables I and II.

Hydraulic lime

Hydraulic lime is made from limestone containing sufficient argillaceous matter to impart to the lime the property of setting and hardening under water. Silica and alumina and/or iron oxide are in chemical combination with some of the calcium oxide content of the lime. Limestone with potential hydraulic property may be classified by the cementation index calculated by the following formula:

$$\text{Cementation Index} = \frac{(2.8\ SiO_2\%) + (1.1.\ Al_2O_3\%) + (0.7\ Fe_2O_3\%)}{CaO\% + 1.4\ MgO\%}$$

An index of 0.30 to 0.60 suggests a feebly hydraulic lime whereas an index of 0.60 or more suggests an eminently hydraulic lime. A fat or white lime may be made hydraulic by the addition of good quality pozzolana. If magnesia content is more than 5 percent the lime is classified as magnesian lime and great care should be exercised in slaking the lime as dead burnt magnesia results in unsoundness.

Quarrying and calcination

In Ghana, wood is the only fuel available locally. Wood fire, fortunately, gives a long soft flame which is very well suited for burning limestone. Use of wood as fuel for calcination of magnesian limestone has another very important advantage in that maximum temperature obtained is not very high as is the case with coal or oil fired furnaces. Very high temperatures, such as those above 1000 °C are not desirable for the calcination of magnesian limestones due to conversion of magnesium oxide into dead-burnt magnesia which imparts unsoundness to the lime. Similarly in the case of siliceous limestones, temperatures higher than 1000 °C will result in a portion of the product sintering into lumps which are difficult to slake unless ground to a very fine state.

The limestone may be calcined in country type batch kilns. Quarrying of limestone may be done with pick and shovels or drilling and blasting may be necessary depending on the nature of the rock. Provision of drills operated by compressed air would be very helpful. In the first instance production would be on a small scale, but as demand for lime increased and more experience is gained, larger production will require mechanical aids for quarrying and crushing, continuous kilns for burning and standardized testing of the product.

Slaking of hydraulic lime

Quick-lime can either be slaked in a pit with great excess of water which results in lime putty (wet slaking) or with a relatively smaller quantity of water which gives dry hydrated lime in a powder form (dry slaking). In dry slaking, some portion of the quicklime remains unslaked and must be air-separated. The unslaked portion is further slaked with more water or ground finely and then mixed with the main portion of the hydrated lime. Hydraulic lime should be slaked by dry process to ensure that the final product is marketed in dry condition to avoid loss of strength due to setting with excess moisture.

Marketing

Hydraulic lime is usually marketed as hydrated lime in the form of fine powder packed in waterproof bags. It sets like ordinary Portland cement on coming in contact with moisture and thus the same precautions in storing and use are required as for cement. Unlike Portland cement, which is manufactured to set standards by controlling the mixing of raw materials, the quality of hydraulic lime very much depends on the composition of the parent limestone. It is, thus, very difficult to market a product of uniform composition and quality. In building construction, almost any type of lime could be used provided it contained a certain minimum amount of calcium and magnesium oxides. However, it must meet certain requirements of fineness, soundness, setting time and compressive and flexural strength (2). Soundness test, using Le Chatelier moulds for determining expansion of lime when subjected to saturated steam, shows whether the slaking of quicklime is adequate and complete. The strength tests are usually based on testing of lime-sand mortar of 1:3 (by weight) mix proportion. Compressive strengths of 250 lbs. per square inch after 14 days curing and 400 lbs. per square inch after 28 days curing, are considered sufficient for hydraulic lime to be fit for use in mortar or plastering.

Use of hydraulic lime mortars

Hydraulic lime mortars have excellent working properties and they adhere well to the masonry units. They have good water retentivity and do not easily loose water to the bricks or blocks of high suction. Also they have sufficient strength which they develop much more quickly then do lime mortars. Their use does not lead to excessive shrinkage as shown by cement mortars.

Thus, hydraulic lime mortars combine the advantage of lime mortars and cement mortars and could be very well used instead of the usual cement-sand or cement-lime-sand mortars for bricks and block masonry. In addition, hydraulic lime mortar should be preferred to ordinary cement mortar for the following:

(i) Hydraulic lime mortars, when set, are less rigid than cement mortars and are thus admirably suited for construction of chimneys. In chimneys, if the brick work is too rigid, it may crack due to stresses caused by differences in temperatures between the inner and outer faces.

(ii) Sea water contains a lot of sulphates which produce harmful expansion and loss of strength in Portland cement mortars. In such situations hydraulic lime or lime-pozzolana mortars should be preferred to cement mortars for the construction of sea walls, groynes etc. Similarly for masonry construction in sulphate bearing soils, hydraulic lime mortars could replace ordinary cement mortars.

Usual proportions for hydraulic lime mortars are as follows:
Hydraulic Lime: Sand
1:3 (by volume)
(a) Normal block or brick work above damp-proof course.
(b) Internal walls and partitions
(c) Porous limestone and sandstone masonry.
1:2 (by volume)
(a) For block or brickwork where extra strength is required such as to resist frost conditions.
(b) Tall chimneys.
(c) Rendering for external walls.

Lime-sand blocks

Use of ordinary white or fat lime in the stabilization of soils for road construction or soil-lime blocks for building construction is well established (3). Lime combines chemically with certain constituents such as silicates and aluminates in the soil to form stable compounds resistant to water. Also dimensional stability of the soil is improved by modifying the character of the clay fraction of soil by base exchange. Lime replaces the sodium or potassium ions in swelling types of clays to give more flocculent calcium clays which have less affinity for water.

Fat lime is a good stabilizing agent for clayey soils but is ineffective in the case of sands or soils deficient in clayey fraction. In such cases hydraulic lime may be used instead of non-hydraulic lime.

In the areas south of Sahara, from Senegal to Congo, the material normally used for the construction of walls is a block made from a mixture of Portland cement and sand and known as "Sandcrete" block. The compressive strength of these blocks usually varies from 150 lbs. to 500 lbs. per square inch in the case of non-vibrated blocks of 1:6 cement: sand mix. Information obtained by the Institute from Nigeria suggests that blocks with strength as low as 160 lbs. per square inch have been used for blockwork on a major project (4). Experiments conducted at this Institute with a hydraulic magnesian lime to study the possibility

TABLE III

Unconfined compressive strength and durability of different soils stabilized with hydraulic magnesian lime.

Material	Mix Proportion (by weight)	Wet Compressive strength (9 days) lbs./sq. inch	Loss after 12 cycles of Durability Test (grams.)
Lime: Sand	1:3	800	0.0
Lime: Lateritic Soil	1:10	152	2.45
Cement: Lateritic Soil	1:20	252	15.8
Lime: Clay: Sand	1:2.5:2.5	277	5.9
Cement: Clay: Sand	1:5:5	141	120.4

Note: (1) For compressive strength, 3-inch cube specimens were cured for 7 days at a room temperature and then 2 days at 40 °C.
(2) Durability test used was a simple erosion test called WABRI Test (5). A loss of 42 gms. showed poor quality of the product.

of using it for the manufacture of soil-lime and sand-lime blocks, gave very encouraging results as shown in Table III.

Lime-pozzolana mixtures

Sometimes non-hydraulic lime and a pozzolana are marketed as lime-pozzolana mixtures ready for use. These mixtures have all the properties of hydraulic lime and can be used for all purposes where hydraulic lime mix is required such as mortars, wall renderings and lime-sand block production. Pumice, trass, pulverised ash and calcined clays are some of the common pozzolana. Low grade kaolin and poor quality bauxite when calcined and finely ground also yield good pozzolanas.

Calcium limes are known to give good results when mixed with pozzolana but not much data is available on the reactivity of magnesian limes with pozzolanas. More work is in progress in this Institute to find out the suitability of non-hydraulic magnesian or dolomitic limes, abundantly available in this country, for lime pozzolana mixes.

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Contribution of the hollow clay block industry to the development of the industrialisation of building

By J. L. Charrière (France)

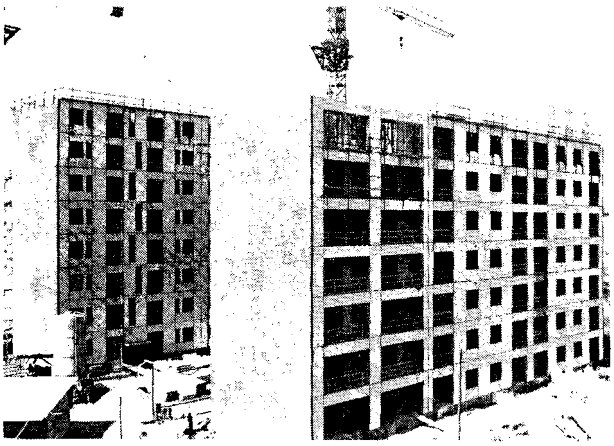

Fig. 1. Ten storey building in construction. Load bearing prefabricated panels made with hollow clay blocks. (Costamagna System—Contractor Co. Impre—Turin, Italy).

In the majority of European countries a rapid increase has taken place in the production of hollow clay blocks. For example, in Italy, production has doubled between the years 1950 and 1963, and in France during the same period it has almost quadrupled. With an annual output of more than 10.000.000 m^3 of these products in Italy, France, Belgium and Switzerland together, the contribution to building made by this material is of very considerable importance.

The methods, which at the present time have been developed for utilizing hollow clay blocks in prefabricated large structural units, are contributing directly to the advancement of the industrialisation of building. In fact, if these methods had not come into use a whole section of the building materials industry would by degrees have been excluded from technical development and this would have involved the depreciation of considerable capital investments and the non-utilisation of a very abundant quarried material, namely clay, which is part of the natural resources and not easily replaced in many countries.

Experience gained in the use of hollow clay blocks for prefabrication of large wall and floor units

The methods of prefabrication of large units for external walls, internal walls and floors, on the basis of hollow clay blocks, have to-day, in France and in the neighbouring countries, important testimonials in the form of completed dwellings, the total number of which is 50,000. As a result of these extensive applications, detailed technological experience has been gained by those who have become specialists in this new form of use of traditional material. By prefabrication the hollow clay block has become raw material, equally with sand or cement, and is integrated in the process of manufacture of a finished structural unit of large dimensions, the weight of which may vary from 1 to 5 tons. It is, therefore, the brickworks, which, in general, are well distributed geographically, which constitute a source of raw material near the places of conversion.

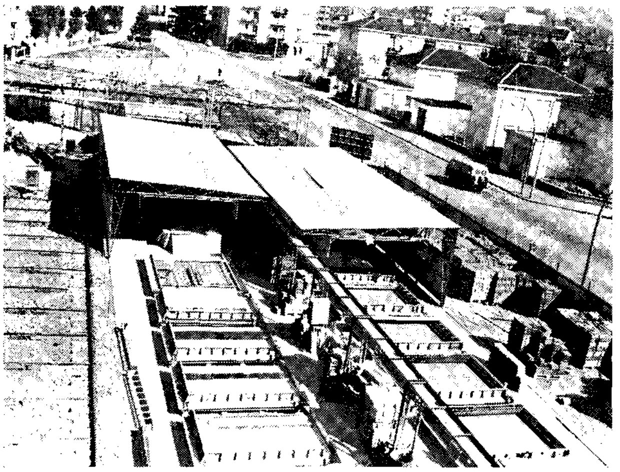

Fig. 2. General view of a mobile prefabrication plant with a production capacity of 2 dwellings per day (Co. Impre—Turin).

The promotors of processes for prefabrication on the basis of hollow clay blocks have, as a general rule, aimed at reducing the capital investments required for prefabrication, whether it is a question of factories or mobile workshops. In this way they have contributed to decentralizing the movement for industrialisation of building. If, indeed, it is now more or less generally accepted that industrialisation is indispensable, if the needs of housing are to be met, the fact remains that, at the present stage of development, the methods of industrialisation are concentrated in large urban centres, where there is a very great and continuous market. These large centres, however, are only a fraction of the market, of which one-half at least is distributed over a vast territory, where it is scattered and intermittent.

It is necessary, therefore, to find suitable means of popularizing the techniques of industrialisation, so that they may reach all channels of the enterprise, and do not remain only at the disposal of those with the best equipment, and, in general, established in the zones of high urban and industrial population density. The idea of economy in capital investment seems to be the key to such popularization. It is known that the average or small enterprise rarely has at disposal pecuniary reserves of considerable size and that their resources, if not precarious, are necessarily limited, so that the idea of industrial capital investment seems still to be beyond their ordinary scope. Judging by their attainments, the "processes on the basis of hollow clay blocks" have been found to be well adapted for these criteria, in that they put within the reach of "local" enterprises the means of technical development.

Practice of prefabrication on the basis of hollow clay blocks

As regards the technique of prefabrication: the properties of clay blocks are well known and do not need to be reviewed here. It may simply be stated that these properties are used to best advantage in prefabrication:

- physical durability with reduced risk of cracks.
- relatively light weight, but guaranteeing good thermal inertia.
- perfect bond with concrete or masonry mortar.
- high compressive strength.
- property of water absorption with rapid return to normal state of dryness.
- porous structure favourable to gaseous exchanges.

On the architectural plane:

- the fact that a systematic study is made of the economy of capital investment has enabled the "processes" on the basis of hollow clay blocks to be applied for relatively short architectural series (of about 150 dwellings), it being possible, nevertheless, to meet the cost of the specific means of production, namely, the moulds. In this way, the architectural variety of applications is practically unlimited.

As regards technique of construction:

- use of contract equipment already in existence or in regular, not exceptional use.
- manufacturing stages and preparation not complicated.
- reduced employment of highly skilled staff owing to simplicity of plant required for prefabrication.

As regards the economic viewpoint:

- use of a structural material available everywhere in the territory.

- considerable reduction in the number of working hours per dwelling. In spite of the apparent simplicity of the plant for prefabrication, it has been established that the number of working hours per dwelling is competitive with that resulting with much more mechanized processes.

This may be partly explained by the fact that a highly skilled staff for maintenance (mechanics, electricians, and others) can be dispensed with.

Developing methods

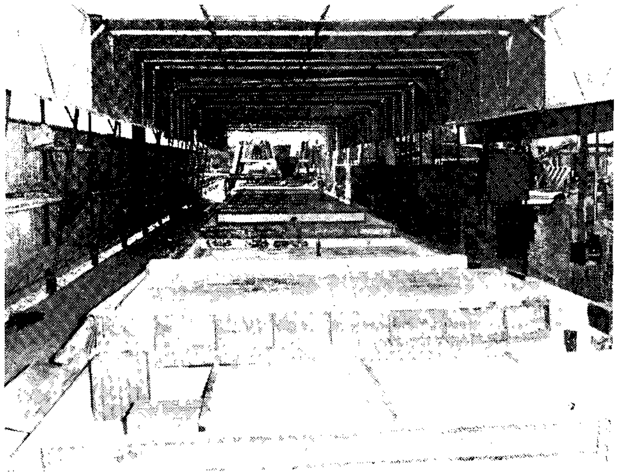

Fig. 3. View of a series of moulds for the prefabrication of large panels of hollow clay blocks (Costamagna System). The moulds are protected by rolling sheds under which the coverings for the steam-heating of the moulds are suspended.

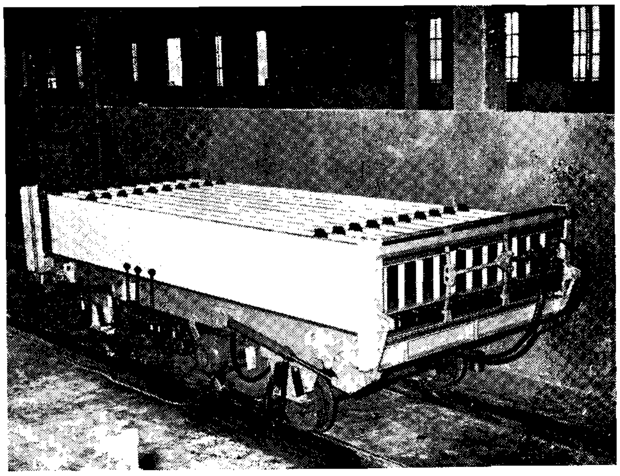

Fig. 4. Machine provided with an hydraulic device for the production in large series of one storey-high standard panels for inner walls made of hollow clay blocks and gypsum plaster (Costamagna System).

Factories or mobile workshops? In our opinion the idea of an established factory is not to be regarded as the opposite of a mobile factory. The two conceptions correspond to different needs:

- the established factory has a concentrated and continuous market.
- the mobile factory has a widespread and sporadic market.

Does the future lie in the development of mobile factories or in that of the established factories? In fact, as was stressed above, the technological evolution will depend on the evolution of the market. As long as the market remains unsettled and scattered the mobile factory will retain an indisputable economic interest.

It is at this point in our considerations that the ideas of "open" prefabrication and "closed" prefabrication occur. It seems that, in its present state, the building market, in "liberal" economies, does not permit the avoidance of restrictions, of "closed" prefabrication. These restrictions, moreover, are themselves the result of the "closing" both of the designing of dwellings (by architects) and of the ways of financing and drawing up contracts (government and legal staff). Attempts have been made, notably in France, to consider the planning and the execution of work together, and to guarantee payments extended over several years; in this way, continuity can be promoted, even in the widely spread section. These efforts, however, cannot bear fruit till a certain time has elapsed, during which "closed" prefabrication will remain predominant.

As regards "open" prefabrication, it can easily be established that this has had its first applications in firmly directed economies, in which the *PLAN* defines the needs and determines the short and medium term funds required to meet these needs. The restrictions referred to above do not exist in these economies, so that it is possible for a state department to define in an actual catalogue the types of units to be made and applied. It is certain that for the "processes on the basis of hollow clay blocks", "open" prefabrication, according to a catalogue, could constitute a considerable basis for development, in that the manufacture of long series of standard units could take place, which, especially, would greatly promote the development of mechanized methods of manufacture. However, there are numerous obstacles to be overcome before this stage is reached:

- architectural limitations.
- financing of stock of units.
- reticence on the part of enterprises as regards reduction of their activity to the assemblage of factory-made units.
- new responsibilities of the manufacturer encroaching on those of the contractor, which are already codified.

At an intermediate, transitional stage the standardization of certain functional components can be contemplated, such as ventilation shafts, ducts, landings, flights of stairs, acroteria, lintels, etc.; the specific components of footings of load-bearing walls would, however, be made in connection with each operation according to the drawings and particular wishes of the architect. At the level of the raw material "hollow block", the ways of development will certainly be constituted by obtaining products of constant, controlled quality with finer diaphragms. The length of cross section of blocks must increase (i.e., be doubled or trebled), if account is taken of the improvements made in the methods of extrusion, drying and firing.

Conclusions. We have shown that prefabrication with large units on a basis of hollow clay blocks, far from being a transitory phenomenon is, on the contrary, a solution with applications becoming daily more extended, which must be included in the inventory of methods for developing the industrialisation of building. The development of ideas and of new techniques in every case needs human support, that is to say, the support of men animated by motives encouraging them to undertake such development. The manufacturers of hollow clay blocks now have the urgent duty to include their building materials in the transformation of methods of construction. By so doing, they constitute a "motive" group making important intellectual and material contributions to the idea of industrialisation. In this way the part taken by the manufacturers undergoes a change, since they now tend to become active outside the factory limits in the actual work of construction, as technical collaborators of enterprise in the use of their products in the new form.

As regards the manufacture of hollow clay blocks for prefabrication, it would seem advisable to turn attention to obtaining larger units with finer diaphragms and of constant quality—objectives made possible by the rapid improvements attained in the domain of the treatment of clay from the quarry to the kiln. The development of prefabrication will assuredly be influenced by the possibility or impossibility of inserting "open" systems (catalogue series). An important saving of labour requirements for constructing a dwelling, due to the mechanization of methods of production, seems possible only if the promoters of building admit and favour the use of standard units.

It may be added that the considerable outlets which the industry can find for the use of hollow clay blocks in prefabricated units of buildings, are not necessarily tied to "processes" termed "total prefabrication", but there are also partial utilizations of clay products, where they are applied as a logical necessity in combination with other materials having different functions.

The development of wooden concrete form plates regarding a production running in Austria

By A. Gratzl (Austria)

The aim of this report is to point out the physical and technological background of the production of a good concrete form sheet according to the requirements of the building site and to follow the way of its development. It is not intended to penetrate into closer details of building construction.

Reasons for the development of concrete form sheets

Procurement of concrete form timber and establishment of the form used to constitute an important part of the costs in erecting a building in concrete. The timber on average was not used more than twice. Cutting the timber produced many shortings which were never used again. Also there was a great temptation to waste the timber damaged during dismantling. The modern concrete form sheet is worthy of consideration. Because of its price the worker will understand tighter handling instructions. In return on well managed buildings sites it can be used up to thirty times, but with careful treatment it can be expected to be used for fifty times or more. This is the basis of its economy. The timber normally is spruce, less often pine or larch.

The development of these concrete form sheets has taken place only during the last five or six years. It was promoted by ever increasing claims on the sheet's physical properties. In contrast to many other applications the solid timber in this case has not been displaced by metals, plastics or similar materials. Indeed, even treated woods like plywood, fibre boards and particle boards do not compare favourably. First of all, solid wood has the highest modulus of elasticity E, derived from the direction of the grain. More exactly, it supplies in the cheapest way the highest value of elasticity E. J., which is responsible for the smallest deflection f under the load of hydraulic pressure of the liquid concrete.

The following formula makes this clear

$$f = \frac{P}{E.J} \cdot \frac{l^3}{k}$$

P being the pressure power, l the length of the plate as a girder and k a factor, dependant on the way the plate is supported. With timber the E-modulus of bending in direction of the grain is about 25 times higher than in a direction perpendicular to the grain; with ply-wood, deflection results are about 50% higher than for solid timber, presupposing its layers to be all of the same thickness and the constituent fibres alternately vertical and horizontal. The stiffening effect of the glue therefore is taken into consideration. The same effect is to be found with fibre- and particle-boards, where all fibre directions are present in layers parallel to the surface. In special cases steel sheets are in use, but it is not easy to give a high moment of inertia J to the plate in a cheap way. Therefore behind the steel sheet a full area timber form is necessary to support it. Large area concrete forms are in use to produce finished concrete. They are of up to 4 meters width and are manufactured of 4 mm plywood, solid wood not being able to be glued together at so small a thickness. Finished concrete which ought not to be adapted afterwards, needs a jointless form of greater area.

Course of development

Since the beginning, the main quantity of manufactured plates had a measurement of 50 × 150 cm. Today a 90% majority of all plates is produced and used with these dimensions. The customary thickness is 22 mm, since manufacturing the plates from boards of one inch thickness by planing and grinding easily gives this size. This measurement also will be the basis of standardising concrete form sheets in Germany which is now under preparation. There are also lengths between 75 and 225 cm, scaled down from 25 to 25 cm. In special cases also thicknesses of 28 mm occur. The smaller edges of the plate are always protected by irons pressed from sheet steel since the timber endgrain is more easily damaged than the side grain and may even be split. Especially at the corners, parts of the timber may be split off and so corners are covered in a special way, (edge and corner protection). The iron is fastened in the middle, the timber being freely movable to cope with swelling and shrinkage so that a lateral shifting of the iron never occurs.

In such a plate armament which has proved succesful, the cover of the corner is held fast in its place only by the iron. Originally the small boards of different width of which the plate consisted were not joined together and the liquid concrete was able to flow through the joints. A poor mixture occurred, the remaining concrete being full of blisters and pores. Connections by tongue and groove and further by dovetail joints were the next stages. Liquid concrete, penetrating into the joints pushed the slabs apart and in some cases destroyed the plate. Joints with wood- and wiretacks behaved in a similar way. The glueing of the dovetail was inferior and therefore ineffective, as it was not possible to prepare it in a weatherproof way. The automatically working glueing machine became dirty and could not be cleaned. The solution was finally found in using the so-called dull joint according to the author's proposal. At that time nobody had believed in its reliable strength considering that no mechanical aid was to be applied. However, sufficient strength can be transmitted in each joint by a glued area of 320 cm^2. It was now possible to use waterproof glues of the highest quality (heatproof or weatherproof). Today the whole industry which produces those plates has accepted this method.

It is of the highest economic importance that for the fabrication of concrete form plates shortings can be used to a great extent, being about half the price of normal board-ware.

Swelling and shrinking

These properties form a general disadvantage of timber in its technical application. Also in concrete form work a lot of trouble arises from them. To lessen this, three types of plates have been developed,

a) slab plates,
b) ledge plates,
c) stick plates.

A slab, about 10 cm or less in width, manufactured at a certain moisture content m will remain in the shape of a true rectangle in crosscut as long as its moisture content is not changed. Otherwise the rectangle will turn to a parallelogram. In addition to that the slab shows a tendency to arch. A contrapolar disposition of the annual rings in neighbouring slabs makes it possible to avoid extensively the arching of the whole plate.

Swelling and shrinking in radical direction r being only one half of the amount of the tangential direction t, standing growing rings are used as much as possible. Nevertheless in application the plate changes its width for about 3 mm, its length correspondingly changing for ¼ mm, if water passage is not effectively checked.

Not all slabs can have standing growing rings. This called forth the development of the ledge plate which combines several merits. The slabs are converted into ledges of square crosscut and the ledges with flat lying rings are turned through 90°, so that all have standing annual rings. By doing this, the use of side ware, the boards of which have rings in a vertical plane becomes possible Being clear of knots, it is widely used. There is a certain surplus on the market, since cabinet-makers, who once estimated it very highly, now prefer chipboards to a wide extent. Special advantages arise by glueing the ledges together (see later). Extensive troubles occur, when solid timber plates are exposed to sun irradiation for a long time. This case takes place very often with ceiling and bridge form work, particularly when the iron armament is built up above the plates. This normally needs a longer time. The water inside the timber avoids the higher temperature and gathers on the opposite side of the plate. By investigation I found out m = 2% on the sunside and m = 22% on the other side. The abovementioned values occur, when the plate is coated. In the case of an uncoated plate the difference in m on both sides is less, as water evaporates. In the other case an extreme arching arises so that a deflection of 4 cm in the midst of the plate has been measured. In such cases it is a good idea to use a 3-layer-plate, as the two glue-lines, separating the layers, considerably diminishes moisture diffusion and the sheet remains practically even. This method is preferable to similar working multiple plywood sheet, as there are only three layers, the two decks lying lengthwise and the core, with its small E-modulus although lying crosswise is unimportant with regard to the moment of inertia. The 3-layer-plate therefore is quite rigid. The stick plate has been found to give a sheet of highly-stable shape. The warping of a sheet originates through the action of its constituent parts. The variation in shape of each of the constituent parts acts one on the other and thus effects the whole sheet. The moment of inertia of the crosscut counteracts this to a high degree. Because the elements are loosely affiliated they cannot transmit the bending force. The core here consists of strips ("stick") from waste veneers 3 to 4 mm thick. They are stuck together with glue at points about 15 cm apart.

The plate gets its rigidity from two deck veneers of about the same thickness as the strips. These strips are fully glued to the decks. Tropical timbers (abachi, ozigo, gaboon a.s.o.) are often used in these plates, since in the veneer and plywood industry the waste of these timbers is available and they are largely free of knots.

Adhesion

Because of the alkaline properties of cement, normal waterproof glues, such as urea formaldehyde glue, used a great deal in other cases, are not suitable for the construction of concrete form sheets. Only waterproof and heatproof species, such as phenolic resin glues or phenol-resorcinol resin glues, which satisfy the AW 100 test, are suitable in all cases. With 3-layer-sheets, where the glue lines lie deeper and are therefore better protected, urea formaldehyde glues, reinforced by melamine or resorcinol (and satisfying the A 100 test) may suffice. Phenolic glue can only set if the moisture content of the timber to be glued is small (about m = 10 to13%). For this reason the more expensive phenol-resorcinol glue is preferable. Phenol-resorcinol glue allows a moisture content of up to 25% so that m can here equal 14–17%. Furthermore this type of glue is a cold-setting glue so that, when heat is applied, very short setting intervals occur (7 min. or less). Also, this type of glue is 'gap-filling', that is to say it can be used on sawn joints, while phenolic glue needs planed joints. Generally speaking, when glue is applied to rough-sawn surfaces, air is trapped between the loose fibre-ends. The pressure needed to force the timber surfaces together enlarges the area of the trapped air-bubbles thus diminishing the adhesive power. The same disadvantages apply to the pointed joint, resulting both from the drying up of the wood through the heat of the glueing machine, and by the feed roller pressing down the arched slabs during edging. When glueing together two slabs to form a pointed joint pressure can be only applied to the lower part of the joint. No pressure is applied to the upper part, which is the larger, during the setting process, with the result that there is no adhesive strength in this part. When bending stresses occur in the sheet, therefore, these joints do not have sufficient strength to withstand them and open in use. A difficult manufacturing problem is involved in avoiding this eventuality.

By the use of narrow ledges such as those mentioned above, the pressure during glueing is sufficient to turn them a little, with the result that the whole joint is sufficiently pressed. To obtain an even glueing pressure implies the use of blunt, rather than pointed joints.

The coating

Originally, a rather high water permeability of timber was necessary to get a good quality of concrete surface. Water deposits form easily during setting with the result that hollow blisters perforate the surface after dismantling. Recently we have learned to avoid this inconvenience by diminishing the water-cement-fraction. It is now possible to seal up the timber surface, desirable for a variety of reasons.

The difference in the course of moisture content across a coated and an uncoated plate is given by the amount of water passing through during an hour. This water diffusion can never be fully stopped by coating. A large difference in moisture content on both surfaces causes extreme warping in the sheet. Fortunately at this moment normally the concrete is already so stiff that arching does not occur. Nevertheless the stress in the sheet exists as can be seen by the high curvature after dismantling which is in an opposite direction to that expected, resulting from the effect of a slow movement. Not only does the coating give a good "fabricated" appearance but also its smoothness prevents high adhesion of concrete on the sheet surface. As the tensile strength of concrete is not very high, such sticking may be the reason for its partly tearing out the surface. This damages both the sheet and also the concrete. The small differences in moisture content inside the coated plate during application is the reason for any warping being extremely small. Working time in using ordinary form timber being 1.2 hours per square meter, this figure diminishes to 0.7 for uncoated and to 0.5 for coated concrete form sheets. This results from easier dismantling and by reducing cleaning work. Nevertheless many believe they cannot work without planking oil which is a necessity in uncoated sheets. Tests revealed that at least half of the oils supplied by commerce have no separating effect and that with the rest this effect is rather small. But these oils represent a higher danger for the concrete surface. They drift away into the concrete and so separate the cement particles by coating them. Their connection is damaged, if not made impossible. The result is that a 'tuffy' layer is formed on the surface of the concrete, having little resistance. Pastes which have a higher consistency and therefore do not drift away are admissible. It is further necessary to point out that on both endgrain sides of the sheet and under the iron a good coating has to be applied since moisture seeps most easily through the endgrain.

The information described in this paper is the result of cooperation between the Austrian Timber Research Institute and the firm of "Nordland" to develop concrete form sheets of high value to the building industry.

The role of concrete in industrialised building developments

By A. W. Hill (U.K.)

Materials research and development

Modern methods of concrete construction for industrialised building apply the results of extensive research carried out by government agencies, materials producers and by contractors. The quality of materials for concrete is steadily improving and methods of control of concrete quality have been established, and are being applied, to ensure uniformity and durability of the final product. The expansion of the ready-mixed concrete industry is a substantial contribution also. The accepted principles of accelerated curing of concrete are being systematically applied to allow rapid release of moulds, and the improvements in placing and compacting concrete contribute to greater dimensional accuracy and surface uniformity of concrete members. Increased productivity arises on site and in the factory from greater mechanization.

The ease of providing connection and continuity between structural members when in-situ construction is used provides a challenge when alternative methods using precast concrete are employed, but considerable ingenuity has been displayed in the variety of solutions available to meet structural and weather resisting requirements. In most cases monolithic joints can be made succesfully and easily with in-situ concrete or mortar so that the strength across the joint is maintained. Fairly large tolerances can be accommodated and reinforcement connected by welding or other means. The provision of shear keys in these joints is seldom necessary.

Many of the joints in cladding panels do not provide load transfer problems but must be weatherproof. Tests at the Building Research Station[1] have indicated general principles which apply to both vertical and horizontal weatherproof joints. Modifications to suit widths of vertical joints from ¼ in. to 1 in. using a cruciform weather strip of flexible p.v.c. have been tested by the Cement and Concrete Association[2].

Concrete excels over all other structural materials in its ability to provide a wide variety of texture, colour and profile, and this is being utilized effectively in the large scale production of cladding units on an increasing scale. Methods of factory production for these finishes are being refined, and considerable progress has been made with formwork design and improvements in mould oils to eliminate most of the surface blemishes with vertically cast units. This has enabled internally finished concrete units to be provided which do not need subsequent plaster. An important contribution in this field is the battery method for site casting of internal walls and floor panels, suitable for contracts of 100 to 200 dwellings, which has been developed at the Building Research Station[3].

There has also been a considerable increase in general research on building operations and economics at the Building Research Institutes, which will be more appropriately discussed by other groups at the Conference, but which all have an important effect on the application of concrete construction for modern conditions.

Large concrete panel construction

Large concrete panels for wall and floor construction are a feature of many of the more successful systems of building. They use materials which are cheap and readily available, and when designed for load bearing requirements provide, at no extra cost, high standards of sound and thermal insulation, and of fire resistance – functional requirements essential in modern construction. Units may be provided with services and finishes prior to erection.

Although first reported in use in Liverpool for tenement flats by J. A. Brodie in 1905, it is only in the last decade that circumstances favouring large-panel construction have become fully apparent especially in France, the Scandinavian countries and in Eastern Europe. Economic and environmental factors, coupled with the provision of large programmes of work have justified the large initial capital expenditure on factory production.

In Britain these conditions have not operated in the past and developments with large-panel construction have competed with traditional methods and a spasmodic demand. Nevertheless, success has been achieved in both low- rise housing and multi-storey flat construction, and there have been extensive developments in other fields for structural precast concrete which have encouraged a high standard of quality and finish.

Concrete load-bearing panels are particularly suitable for housing since the spans are normally small. They are used for single storey buildings, for two-and three-storey houses, and for multi-storey flats where they are adaptable for stairwell access, corridor, balcony and scissors access, as well as for tower blocks.

Panels of dense concrete incorporating additional insulation where necessary are used for external walls, party walls and partitions. They may all be loadbearing with floor slabs supported to span in two directions, or the external walls may be non-load bearing and the resulting egg-box frame has floors spanning in one direction only. Another variation provides standardized load bearing storey-height panels around the periphery, finished both internally and externally, which support the floor units and provides considerable flexibility in the internal planning. Staircase and lift shaft units and special service units are available for flat construction. Erection is by crane and units tend to be room size to reduce the number of joints.

One of the advantages of the egg-box form of construction is the facility afforded for variation in architectural treatment of the facade. This may be of increasing importance with further standardization of dimensions. A large variety of light façade units are available to compete with dense and lightweight concrete in panels of one or two-storey height. The advantages of reduced weight may be offset by the loss of structural stiffening, however, in some cases.

Whilst most of the large panel systems use full room-size panels to reduce joints, there are exceptions, e.g. the Danish Jespersen system[4], which is being modified in Great Britain on the 12M basis, with comparatively small panels having a maximum weight of 2½ ton. The variations in width are 4 ft, 6 ft and 8 ft for wall panels, with a hollow floor unit 4 ft wide to give greater flexibility. The jointing relies on the extremely high standard of accuracy of the units (tolerances 1/16 in.). Cladding may be in a variety of materials, but flow-line production methods for concrete cladding are being considered.

The schemes prepared by the Research and Development Group of the Ministry of Housing and Local Government cover a wide variety of dwelling type and size, but the standard units can be erected with mobile equipment on small or hilly sites. When the 12M system has been fully developed and proved it will be made freely available as an open system.

Concrete box units

Because of handling and transporting problems the majority of the systems based on concrete structural units utilize large panels, but box units are also used in which the floor and wall units are combined and an even greater proportion of the building work (up to 90–95%) can be carried out in the factory. The earliest examples were developed in Russia and Eastern Europe, but other countries are interested in attempts to include all fittings, finishes and decoration away from the site. Two such systems have recently been developed in Great Britain. The WILMAC system[4] provides a complete housing unit made up of seven boxes which can be erected in one day, suitable for both low-rise and multi-storey construction. Foundations are provided in the traditional manner. The seven units consist of precast reinforced concrete cavity walls for external and party walls, and solid 3″ thick slabs for the internal walls. Roof and floor slabs are of hollow concrete and the staircase is also in concrete with applied soft finishes. Factory jointing is mainly with epoxy resin adhesive. External finishes are of patterned and coloured concrete. The box form of construction is specially suitable for subsidence and earthquake areas.

The TRUSCON[4] box unit system has been adopted for flats and maisonettes of up to 20 storeys. Each block is 6′–8′ deep and between 16 and 20 ft. wide for transport. The ten sections of a housing unit can be accommodated on five lorries. The frame is of ribbed concrete panels and all services are fitted in the factory. Lift walls and staircases are in structural concrete and cantilevered access balconies are available. Elevational treatment may be varied, but the gable walls are of exposed aggregate panels.

Site developments with formwork

Industrialised techniques have not been limited to factory production. Notable contributions in speeding construction have occurred on the site, by increasing the amount of work done at ground or the lower levels and by the use of sliding forms and of repetitive formwork techniques in multi-storey construction. These aspects are briefly reviewed below: —

(a) Lift slab[4] Floor slabs of reinforced or prestressed concrete are cast around the columns at ground level and subsequently jacked up into position. The ground floor slab forms the soffit shutter for the first floor slab using a separating medium, and other slabs are cast on top in succession. Lifting collars cast into the slab around each column provide a means of fixing after lifting. Specially designed jacks placed on top of each of the columns are synchronized to lift one or a group of slabs as required either to the final position or to a temporary position to await the extension of the columns. Slabs are usually of plate construction but may be hollow to reduce weight. Columns may be of steel or reinforced concrete. The system has also been used in conjunction with sliding forms. Greater efficiency arises by confining the wet work to ground floor level, open planning results and the non-structural external walls permit variety in treatment.

(b) Jackblock[4] This is a recent development to improve site working and extend factory conditions to the whole of the site operations, by constructing the top floor of the building first at ground level and then jacking it up. At this stage cladding, partitions and other finishes are fixed. Successive floors are constructed at ground level and the building is jacked up until it reaches the final height.

A 17-storey block of flats at Coventry was constructed around a structural hollow core housing services, lifts and staircases, and the reinforced and prestressed concrete floors cantilevered from this. The lifting jacks are provided under the core.

With planned erection and finishing no men work above the fifth floor. After the third floor level is reached the building is encased in polythene sheeting to provide factory conditions for the remainder of the finishing operations. External scaffolding is only required up to third floor level.

With building operations at the lower levels there is a saving of time and money. Once the foundations and roof slab have been completed there is weather protection for the workmen and even in the very cold winter of 1962/63 work continued throughout under the protection of the polythene sheeting and blower heaters. Finishing work is carried out concurrently with the structural frame. The form of construction is suitable for earthquake or subsidence areas since any tilt can be corrected by reinsertion of the jacks.

(c) Sliding forms The use of sliding forms to construct the central core of multi-storey buildings is becoming increasingly common. The work can proceed at a rapid rate and on completion a site is available for the crane to erect the surrounding framework and cladding. Progress is of the order of 6 in. per hour so that a 17 storey construction is completed in 3 weeks, and staircase access provided for workmen thus eliminating the need for scaffolding.

(d) Heated formwork systems For construction where there is considerable repetition of form, as in multi-storey flats, the site can be industrialised using heated formwork in conjunction with mechanical handling. In the SECTRA system[4] steel formwork is lifted into place by tower crane and the concrete poured in rectangular tunnel sections of room widths and heights. Reinforcement is prefabricated into mats containing service cables and incorporated by crane. Special details are necessary to accommodate lift well and staircases and the ends of the forms can be closed either by steel sections or by precast concrete cladding units. The concrete is heated after placing to accelerate hardening and the floor slab is finished smooth with power floats to receive the final covering without screeding. The hot water heating system built into the formwork maintains a temperature of 45 °C for 13 hours. Two days after casting the heating system is disconnected, the shuttering struck by inward collapse, and the section re-erected in new positions after cleaning and oiling. In this way the structure of one floor is completed in two days.

Components

In addition to the development of industrialised housing systems which are complete in themselves, there is a need for the production of standardized components which can be used interchangeably between systems and in rationalized semi-traditional construction, such as modular storey-height floor and wall units, partitions, staircases, etc. This has been possible in other fields, e.g. in the development of standard prestressed concrete bridge beams, and in development work for schools, and is being encouraged by the dimensional co-ordination and standardization by Government Departments.

A range of interchangeable components freely available would be of considerable value to the industry. The architect would have flexibility in planning but would be saved considerable time in detailing. Competition would be ensured. The prospect of continuing orders would justify a high standard of initial tooling up and production planning, and good supply arrangements, so that work on site was not held up. For success a more rigid standardization of dimensions is necessary since the number of variations must be reduced as far as possible, followed by design development activities aimed at adequate variation within the standardisation imposed.

In this field concrete, both dense and lightweight, will have an important part to play. Developments in lightweight concrete already include units for walls, upper floors, roofs and partitions of terrace houses. Panels are up to 20 ft. long and 2 ft. wide. Exterior wall units are usually 8 ins. thick, partitions, 3″ thick, may be tongued and grooved where demountable. Floors and roofs are usually 6 ins. when used in housing. Jointing and fixing details have been standardized and erection is by a small track crane. Walls may be papered direct and ceilings finished with emulsion paint. Foundations are normally traditional with a mass concrete ground floor slab.

Conclusions. During the past decade considerable developments have occurred in industrialised building techniques for both factory made precast concrete and for in-situ concrete construction. These have utilized the results of substantial research to improve the quality of construction and construction techniques, to reduce costs and increase productivity. The process is continuing.

The important part played by concrete in the industrialised building field is shown by its use in many constructional systems involving large panel slabs and box units, in a variety of components, and on-the-site developments where techniques have been improved by industrialised methods bringing the factory to the site.

The conditions likely to create increasing demands for industrialised building are favourable in the immediate future, and the economy and speed of construction obtained with concrete, together with its low maintenance, favour a considerable expansion of concrete construction in the next decade.

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New developments in the Swedish lightweight concrete industry

By A. Hillerborg (Sweden)

The present paper deals solely with steam-cured aerated lightweight concrete products, which are always used in the form of precast building components. The development in this field during the past few years has primarily tended towards simplification of building site work, which was achieved by more advanced machining and treatment of the elements in the course of the manufacturing process, as well as by bringing forth new types of elements and by evolving new methods of construction.

Stave units replacing wall blocks

By using improved manufacturing methods, it is nowadays possible to produce lightweight concrete blocks which are dimensionally accurate to such a degree that no thick mortar joints are required to compensate for differences in dimensions. Such precision wall blocks are known in Sweden as "stave units". In the first stage of development, the stave units were joined together with a glue, which was chiefly based on cement, and the joints were about 1 mm in thickness. This method is still used to a large extent, but it is increasingly superseded by all-dry construction procedures, in which the stave units are simply laid one on another, and are guided so as to be fixed in a direction at right angles to the plane of the wall either by nylon discs which are inserted in slots milled in the staves (Ytong) or by tongue-and-groove joints which are formed by the stave units themselves (Siporex). In these cases, the stave units are milled so as to ensure adequate precision.

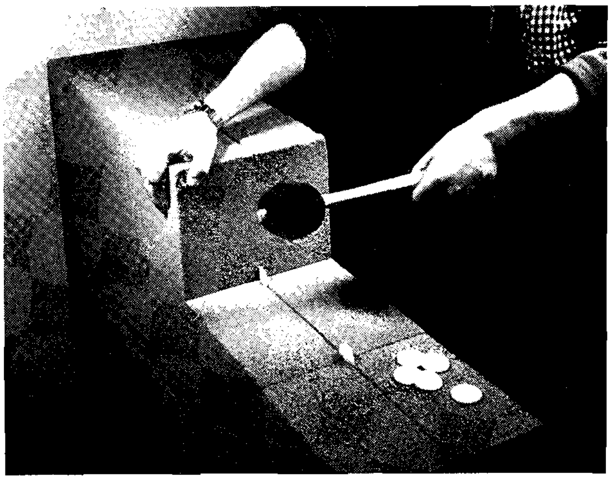

Fig. 1. Precast lightweight concrete stave unit of high dimensional accuracy, with milled slots and nylon discs for all-dry assembly.

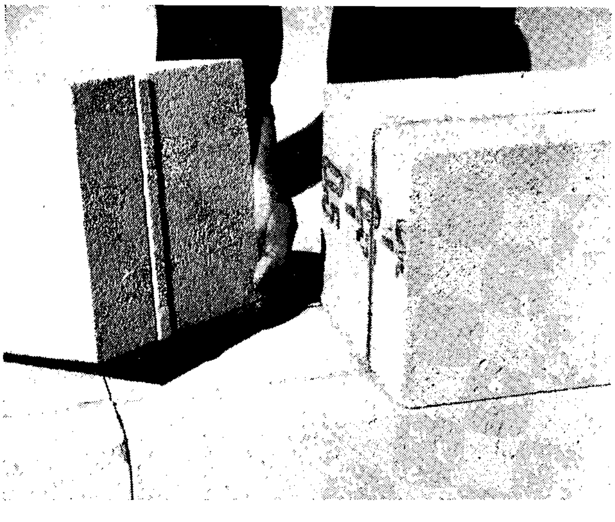

Fig. 2. Precast lightweight concrete stave unit of high dimensional accuracy, with tongue-and-groove edges for all-dry assembly.

Stave units as compared with wall blocks offer the following advantages; simpler methods of construction, smoother wall surfaces, which permit simpler surface treatment, better thermal insulation, and—in the case of all-dry assembly—reduced influence of the temperature during site work.

Sandwich panels

Even though precast lightweight concrete construction in most cases provides satisfactory thermal insulation, it may sometimes be advisable from an economic point of view to improve heat insulation still further, e.g. in such countries as Sweden, where the winters are very cold, and where it is nowadays considered to be desirable to have relatively high inside temperatures. For this purpose, use is made of sandwich panels, which consist of two layers of lightweight concrete, 7 cm in thickness each, with an interposed, glued core of rigid foamed plastic, 6 or 8.5 cm in thickness. As a rule, these sandwich panels are storey-high and 50 cm in width.

Large wall panels

Although lightweight concrete wall panels have so far usually been 50 cm in standard width, it is now possible to manufacture much larger wall units. In many practical cases, for instance, use has been made of wall panels which were 1.5 m in height and 5 to 6 m in length. They are assembled in such a way that they cover the surface extending from the tops of the windows in a storey to the sills of the windows in the storey situated directly above. Such wall panels, handled with appropriate cranes, render possible very rapid assembly of external walls.

Surface treatment

The modern precast lightweight concrete building components are characterised by such a high dimensional accuracy that they make it possible to use surface finishes which are thinner than conventional plaster. Various materials for thin surface finishes of this type are now available on the market. Among them, it is particularly the exterior surface finishes using acrylic plastics as bonding agents, applied in layers of 1 to 2 mm in thickness, that have exhibited good properties, and are extensively employed.

Elements provided with "Preobas" exterior surface finish, which is applied during the manufacturing process, are also supplied on a fairly large scale. This surface finish is constituted by coloured mineral grains, about 1 to 1.5 mm in size, which are embedded in a layer of transparent acrylic plastic.

Furthermore, panels covered with fabric-base plastic or jute burlap are used for partitions. Up to now, these panels have mostly been employed in office buildings where it is desired to have movable partitions, which can be made to change place in a simple way when required.

Milling

As has already been mentioned in the above, precast lightweight concrete products have to meet more and more severe requirements in respect of dimensional accuracy. This is achieved partly by improved cutting methods, and partly by milling the products after steam curing, if required. Milling ensures very high dimensional accuracy, and makes it possible, moreover, to manufacture various special shapes, e.g. elements with tongue-and-groove edges.

Standard dimensions

The standard basic module in Sweden is 1 dm, but a "large module" of 3 dm will be standardised for horizontal dimensions of building frames. For this reason, the Swedish lightweight concrete industry will adopt 6 dm as a standard width of precast elements, instead of the present value, 5 dm, as soon as this will be technically and economically feasible.

The line of precast lightweight concrete products has been substantially reduced during the past few years, and further reductions are regarded as desirable, because they will simplify manufacture, facilitate stock keeping, and enable more rapid delivery. Estimates of the products which may be excluded from production are in part based on the information about actual deliveries, which is analysed by means of data processing equipment.

Conclusions. Some characteristic trends of development in the field of precast lightweight concrete products have been outlined in the above. The Swedish lightweight concrete manufacturers have well-equipped laboratories at their disposal, and the work carried on in these laboratories as well as in other quarters is conducive to steady development with the object of adapting lightweight concrete products to continually varying market requirements.

An experiment in collective research into new methods of prefabrication

Regional study groups on precast concrete

By R. Lauret (France)

The need to find new forms of prefabrication

The development of heavy prefabrication methods and other modern industrialisation methods in the building industry, has so far been limited to the construction of large real estate blocks, the only types with a sufficient repetition rate to result in economic costs. In no country has this type of construction using such industrial methods exceeded 30 to 40% and, faced with criticism of these large blocks which are too often soulless, it is likely that this percentage will not be maintained.

The rest of the building industry, 60 to 70%, consists of small and medium building sites in which variety and wide dispersion make it impossible, in practice, to make use of presently known procedures, "tailor-made" procedures in which the components are designed for the particular project (closed systems).

So far, outside a few medium and light prefabrication systems which have not caught on to any great extent, this important market has remained closed to industrialisation in building methods.

It has been recognised that this industrialisation could only be applied if mass produced functional components were available and suitable for assembly together as desired by the planners; it is therefore necessary to find open systems complying with dimensional standards, independent from individual designs and such that the planners can produce all types of constructions.

Who can devote research to these new forms of prefabrication?

It is, indeed, a question of research into a new class of materials of better quality than conventional ones since they will be more highly developed for more skilfully designed purposes and will be easier and more economical to erect. This research can be carried out on the initiative of various professions:

1) To begin with the planners architects or consultants. Interesting attempts have been made in various countries; particular mention may be made of the Kirchner and Rose (of Düsseldorf) procedures and especially, the remarkable work of the Malmström Bureau (of Copenhagen) which has resulted in the Jespersen-Modulbeton system.

2) Such work may also be undertaken by contractors who, in this case, carry out vertical integration of construction work and are not long in becoming partially industrialists at the same time as builders.

3) Lastly this initiative may be taken by the manufacturers of materials who, although they do not build themselves, are nevertheless obliged to promote and maintain a regular sale of their products.

These three channels have the common denominator of being private businesses capable of achieving efficiency, but devoted to finding quick profitability and little concerned with working for their colleagues or competitors. Accordingly, there is a tendency to develop the particular system whose exclusivity will bring in profits; so much so that, starting with the aim of an open system, the result will inevitably be a closed system with its own limitations.

The search for an open system must:

- be collective within each profession
- cover many professions.

It must be collective within each profession because it is the only way of preventing the greed and desires or fears which might otherwise result. It is also the only way of making available to the system being sought after, the vast field it needs for large scale production runs, the only method of making it viable.

This search must also cover many professions, since a building is a complex whole, in which are concerned to varying degrees, the property developer who orders, the architect who plans, the design office which calculates and specifies, the component manufacturer, the prime contractor who selects, transports and erects and shoulders the responsibility, the manufacturer of building equipment, the subcontractors who equip the building, not to mention the technical inspector and also the official or professional research bodies and the Government Construction Authorities. In this connection, the Prague Seminar of 1964 on the change of structure of the building industry showed how much this complex variety of functions had grown with progress in construction methods.

The construction of a building and the design of new types of construction components can no longer be the province of a restricted group of individuals.

This is why some members of the Prefabrication Committee of the European Cement Association proposed, at the 4th International Congress on Precast Concrete (Paris, April 1963) the establishment of study groups by the manufacturers of Precast Concrete – already in possession of industrial equipment for such production – for the purpose of:

- devoting research to the development of one or more open prefabrication systems, using modular and functional components,
- representing collective action of the profession as a whole (or at least of its fighting wing),
- being freely open to other professions or bodies connected with construction.

Why Regional Study Groups?

In such an undertaking, what counts above all is the individual with his professional and personal contacts; if the problem were to be tackled by centralised functional organisations in a country as big as France it would be so overloaded as to be rendered impotent. In this respect, countries of smaller size or with smaller populations are in a better position, since personal contacts are easier to establish. It is for this reason that the choice was made to start work on a regional basis. There is a further reason: rivalry between various regional groups working on the same problem will undoubtedly result in different solutions to the problems, depending on the particular skills present in each group. It is at national level that a synthesis will be made of these different results.

A programme of work

This programme is based on the following principles:

- consideration, not of the components themselves as materials, but the whole construction including the erection on the site and the other equipments, which requires integration, within the working group, of the representatives of all those taking part in the process of construction,
- complying with recognised dimensional standards; this is a primary requirement which has only recently been made possible,
- the acceptance of only those solutions which meet the widest possible functional and human requirements,
- the provision of sufficient flexibility in use to avoid monotony, to cover the possible field of application and to enable the Architects to become reconciled to prefabrication.

To cover the widest possible field (without hoping to cover all fields) a limit of 5 storeys has been set including, in addition to individual houses and small and medium blocks of flats, present day utility blocks (trade, offices, schools, dispensaries, small workshops, etc.) not forgetting agricultural requirements whose development can already be foreseen.

With regard to the purpose of the studies, discoveries or new ideas which might result in delays are not expected. It is a question of discussing the vast field of knowledge already available and of selecting variables such as:

- the size of components (dimensions and weight),
- constructional procedure (structural methods and separate techniques, feasibility of "marrying" different procedures),
- assembly methods (attachment systems, tolerances and jointing),

– the role, composition and design of the various components for external walls, floors, internal partitions, and roofing,

– the incorporation or attachment of sub-contractors equipment.

Lastly, the following general studies are included in the programme:

– for Architects and Design Offices: (lists of components and typical examples. Design, preparation, coordination and inspection),

– for suppliers of components and equipment (manufacturing methods, subcontracting, quality control, distribution arrangements),

– for building contractors (building methods, organisation and planning, equipment for transport, handling and lifting),

– for all professions: educational arrangements (training and refresher courses) at various levels,

– commercial, financial and legal problems (responsibility and insurance),

– development: the position of the Government Construction Authorities, the finance houses, the property developers (communities, promotors and individuals) and the public (the users).

Results to be expected

Setting up such groups is difficult since it involves creating a lot of goodwill, which may be much in evidence at the start but which is liable, in part, to dissipate before the goal is reached. At the moment, a single group, that of the region of Lyon and the South East, led by a dynamic personality, has made a good start with two teams, one of architects and the other of manufacturers of prefabricated components. Quite by chance, at about the same time, the contractors' regional organisations started similar action in cooperation with the buildings and materials productivity associations (Interapro). These two bodies have started working together and valuable results may be expected.

It must not be denied, indeed, that a complete study of the programme will take a long time. The French Construction Authorities, who quite rightly want quick results, even if they must be only provisional, have organized competitions for the design of components and it is not surprising that the activities of the study groups are also being devoted to these short term studies. Long term work, however, remains the primary purpose. The experience of this first study group is being closely watched in professionnal circles and it is hoped that another group will soon be established in the South West (Bordeaux).

Others will no doubt follow; perhaps the instigators will no longer be the Precast Concrete Manufacturers, but, instead Architects, Contractors' Groups or Producer Associations. This is of little consequence, since the primary requirement is that the search for these solutions, which are essential to the complete industrialisation of the building trade, should be undertaken as soon as possible through the widest possible discussion of the subject by all those participating in the process of construction.

Electro-mechanical stress-rate of lumber

By H. B. McKean (U.S.A.)

By far the largest use for structural lumber is in light frame construction. Consequently most structural lumber is in the form of 2″ × 4″ to 2″ × 12″ used for the structural parts of houses, small industrial buildings and small farm buildings. Also these sizes are used extensively as purlins in a wide variety of large industrial and commercial buildings.

The modulus of elasticity, more than any other single structural property, determines the sizes of members that are to be used in light frame construction. This is particularly true for floor joists and ceiling joists. On the other hand, many species of wood produced in the United States are seriously underrated with respect to modulus of elasticity. Furthermore, in the past an inadequate allowance for drying has been provided, which further reduced the design value as compared with the real stiffness of lumber. Consequently it has become important to accurately determine the modulus of elasticity for any species that is cut into structural sizes.

Determination of the structural properties of visually stress-rated lumber is based on tests of small, clear specimens tested when green. This basis is a hold-over from earlier days when the principal structural members were large beams that were installed green and which, upon drying in service, split and checked to the extent that possible increases in strength from drying were offset by the development of drying defects.

In order to obtain working stresses for visually graded lumber, the average values from the small, clear green tests were reduced by certain factors in arriving at the so-called basic stress. This basic stress was then further reduced by a so-called grade ratio which was developed for each grade to account for the number and size of growth characteristics allowed in such grade.

Preliminary investigation of machine grading

Recognizing that modulus of elasticity is extremely important in determining sizes or spans for joists and rafters, and Potlatch Forests being a manufacturer of several species underrated by conventional systems, our Central Research Department conceived the idea of developing a testing procedure to measure modulus of elasticity of every piece of structural lumber. Since modulus of elasticity in bending is a function of applied force, as well as the amount of deflection, it is possible to accurately determine modulus of elasticity without breaking the piece - thus a non-destructive test that could be applied to every individual piece of structural lumber.

A machine design was conceived which provided for a given amount of deflection and a measurement of the force required to induce this deformation. Furthermore the machine provided a system that eliminated any incorrect readings that could have been caused by warp. Since dimension lumber is machined to a relatively few sizes and these sizes are accurately controlled in the planing mill, the machine was designed on the assumption that the cross section of all pieces being fed to it would be constant within any size of material.

TABLE 1. Regression and correlation of modulus of rupture on modulus of elasticity for five species.*

Species	Number of Samples	Regression Equation	Correlation Coefficient
Douglas fir (inland)	223	MOR = 0.00609E–2113	0.724
Douglas fir (coast)	225	MOR = 0.00608E–3474	0.787
Western larch	222	MOR = 0.0063E –2054	0.703
Southern pine	540	MOR = 0.00619E–1880	0.875
Western hemlock	225	MOR = 0.00621E–2779	0.742
Grand fir	300	MOR = 0.00608E–2492	0.748

* All tested as plank at 12 per cent moisture content. Results corrected to standard 1/d = 14 and form factor = 1.0.

This machine provided that lumber be introduced by sidewise motion to the machine and removed by reversing the direction. Although having perhaps limited commercial application, there are some special situations where it can be used effectively for the measurement of elasticity.

The early machine provided rapid measurement of modulus of elasticity of a great many pieces. Studies were undertaken on several grades and species of lumber to establish the range and average of modulus of elasticity being produced by our own mills. As a result of these studies it appeared that the old concept of a constant modulus of elasticity, regardless of grade, was in error. In fact, the early use of the machine strongly indicated that there is a relatively precise relationship between modulus of elasticity and modulus of rupture.

Determining mechanical properties

A preliminary test was made to explore the possible relationship between modulus of elasticity and modulus of rupture. This test was accomplished by randomly selecting 300 pieces of 2″ × 4″ to 2″ × 10″ white fir, *(Abies grandis)*. These pieces were selected from several different mills in order to include variations that might develop from drawing the timber from different locations. The 300 pieces representing not only several cross sectional dimensions, but also several grades, were subjected to a bending test with the force applied to the flat side of the piece rather than the narrow edge. The regression of modulus of rupture on modulus of elasticity showed a correlation coefficient of 0.748, a particularly high coefficient of correlation for a material as variable as wood. (See Table)

Encouraged by the highly favorable results on the white fir, similar tests were also made on Douglas fir from two different regions, western larch, western hemlock and southern pine. These tests were conducted at six different, independent laboratories scattered throughout the United States, five of them connected with universities, the sixth being operated by a State Forest Service.

These tests, like those on the white fir, were made on the flat faces rather than on the edges of the pieces. The principal reason for using the flat or plank position was that we preferred to do the machine grading in the flat direction. Testing as a plank provides a higher degree of accuracy – a given amount of force causes a much greater deflection so that the measurement of deflection is relatively more accurate measured flat than measured on edge.

Sizes for the additional species were also 2″ × 4″, 2″ × 6″ and 2″ × 10″. Grades were Select Structural, Construction and Utility. These grades were selected to provide an adequate number of samples at the high end of the strength curve as well as at the middle and low end. All samples were randomly selected under a prescribed pattern. Samples for all species were obtained at a number of different planing mills. There were 225 test specimens for each species in the second group of western species; 350 test specimens were used with the southern pine. Thus, in the original series of tests, over 1,500 commercial sized pieces of dimension lumber were tested to investigate the relationship between modulus of elasticity and modulus of rupture.

Working stresses and grade rule

Figure 1 presents the data for a representative species tested in connection with establishing the relationship of modulus of rupture to modulus of elasticity. The figure also shows the basis of arriving at stress grades or working stresses for commercial application. As previously mentioned, modulus of elasticity, designated by "E", is the most important structural property for many light frame construction uses. Furthermore it is the property being measured by the grading machine which is being ascertained most accurately. Consequently it was decided to divide the

H. B. McKean

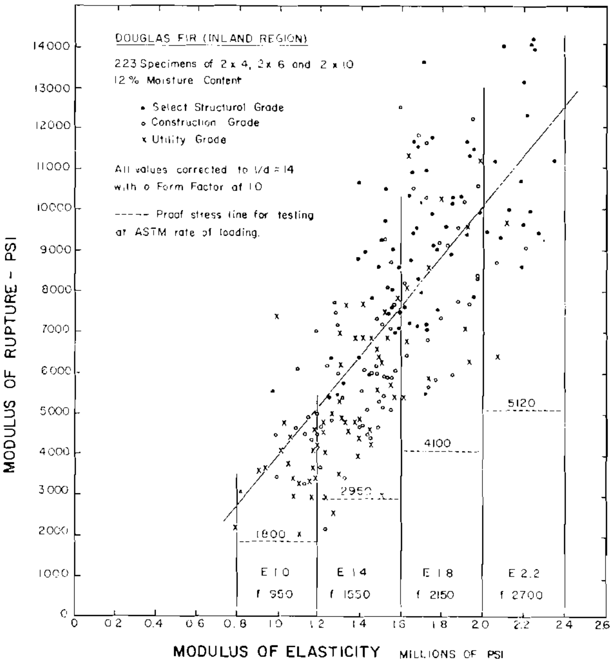

Fig. 1. Relationship of MOR to MOE for Inland Douglas Fir.

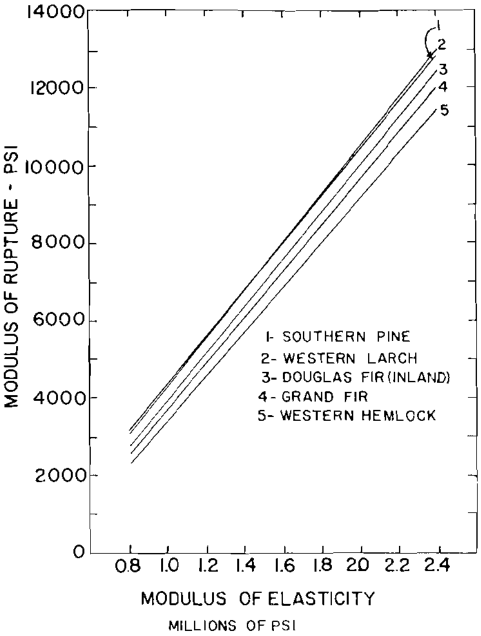

Fig. 2. Regression lines for MOR on MOE for five structural woods.

working stress classes or grades into groups based on E values. The Potlatch Forests staff felt that the range within an E class should be 400,000 p.s.i. Some investigators entering the field later felt that a smaller range of 200,000 p.s.i. would be more satisfactory, primarily because the steps in f, or fiber stress in bending, of the present visual grades would have the same increments as the f for the machine grades. Both E ranges are in commercial use. It was also established that a mixture of the two ranges could be used effectively.

In Figure 1, the ranges of the modulus of elasticity or E grades are shown by vertical lines. Traditionally, design values for modulus of elasticity have been based on the average for the group represented, thus the midpoint of each E class is used as the design value as well as the E designation for that class or grade.

A determination of the fiber stress in bending, designated by f, follows the traditional procedure. The average modulus of rupture for the group or grade is determined from the regression line. This value is reduced by factors shown in Table 2. The table shows that the average modulus of rupture of a group, multiplied by 0.24 provides the working stress for the grade. Reference to Figure 2 shows that the regression lines for the several western species are similar and close together. A study was made to determine the feasibility of combining all of the species of the western region so that the grade designations would be the same for all. It was found that by slightly decreasing f for some species and increasing others slightly, that such a grade could be produced. As a consequence the Western Pine Association published a grade with combined values. U.S. building code authorities and the Federal Housing Administration of the U.S.A. have accepted these grades.

TABLE 2. Factors Applied to Modulus of Rupture to Obtain Allowable Bending Stress.

Purpose	Present Method	Nondestructive Test Method
Variability of MOR (5 per cent exclusion limit)	3/4	3/4
Duration of load ASTM loading rate to long-time loading	9/16	9/16
Long time load to normal load	11/10	11/10
Accidental overload	6/10	6/10
Strength ratio for grade	0.5 to 0.86) (depends on grade)	...
Plank to joist correction	...	0.85
Product of all factors	0.28 × strength ratio*	0.24**

* Bending stress = 0.28 × strength ratio × average MOR for clear specimens of the species.

** Bending stress = 0.24 × average MOR for defect containing pieces of standard lumber size for each E-grade of the species, corrected to l/d ratio of 14 and form factor of 1.0.

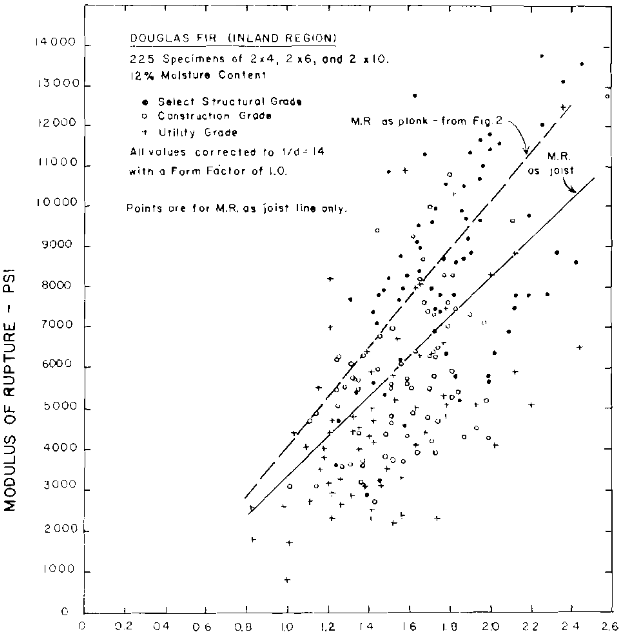

Fig. 3. Comparison of regressions of MOR as joist and as plank on MOE as plank.

It will be noticed in Table 2 that a reduction of 0.85 is made in determining the working stress in bending for lumber used on edge as a joist. The fiber stress in bending published in the grades is for use of the member as a joist. Consequently if a machine graded piece is used flat, the f values shown in the grade rule may be increased 18%. Figure 3 presents this relationship between joist (piece on edge) and plank (piece flat).

The traditional working stresses in tension parallel to the grain and compression parallel to the grain have been the same as fiber stress in bending. At about the time machine grading was being developed, however, engineers in the U.S.A. began to question whether all of these design values should be equal. Consequently Potlatch Forests made tests on full size dimension lumber in both tension and compression and as a consequence recommends that values for tension parallel to the grain and compression parallel to the grain be 80% of the fiber stress in bending as a joist. There is a fair correlation between compression parallel to the grain and modulus of elasticity.

Investigation of the relationship between horizontal shear and modulus of elasticity revealed little evidence of a correlation between them. Consequently, at least for the present, values for shear parallel to the grain in machine graded lumber are based on the values for the visual grades. Other studies have been made, such as the influence of moisture content, local strength reducing characteristics, influence of diagonal grain and other features that have an effect on the strength of wood. These details cannot be covered in this paper because of the limitations on length. The subjects are, however, covered in other papers referenced.

Development of the present grading machine

The original side loading machine proved to be accurate but appeared unlikely to provide the necessary rate of production. It was believed important for commercial acceptability to develop a machine that could operate at approximately the same speed as modern planers, which could run as fast as 1,000 linear feet per minute. It was preferred to feed the lumber endwise if a machine could be developed to accurately measure the modulus of elasticity of the lumber passing through the machine at this high rate of speed. Such a machine is being manufactured by Industrial Sciences of Portland, Oregon. It is called the CLT-1, an abbreviation for Continuous Lumber Tester. This machine combines mechanically moving lumber through the machine, mechanically bending the piece a prescribed amount and mechanically measuring the force required to bend the piece. The measured forces are read by electronic apparatus which records the readings as a piece passes through the machine and then at the proper time quickly averages all of the readings and stamps the grade on the piece just as it leaves the machine.

A diagramatic sketch of the CLT-1 machine is shown in Figure 4. The sensors 1 through 4 determine the position of the leading and trailing ends of the boards passing through the machine. The transducers 1 and 2 electrically read the loads that cause the prescribed deflections in the piece as it passes through the machine. As soon as the leading end of the piece has been engaged by the second set of feed rolls, the first transducer begins to send data to the memory system. When the leading end reaches the third set of feed rolls, the second transducer also begins to send data on bending forces to the memory system. As soon as the trailing end of the piece leaves the second set of feed rolls, the values sent to the computer by both transducers are averaged and the modulus of elasticity computed. The computer actuates a grade stamp that marks the piece as it leaves the machine, with the appropriate grade values. In addition to the averages, if either transducer shows one particularly weak reading, which we call the low point, the reading for that low value will govern the grade of the piece.

The purpose of the "S" curve, or reverse bend applied to the piece going through the machine is to provide a system that will eliminate influence of warp on the working stresses determined by the machine and stamped on the piece. The machine briefly described here is the CLT-1 machine which has resulted from Potlatch research and development. There is another machine available in the United States, operating on somewhat similar principles. In addition, there are laboratory developments of other machine grading systems for lumber in the U.S. as well as in other countries.

Commercial status of machine grading

The first CLT-1 machine was placed in pilot operation in Lewiston, Idaho, in December, 1962, by the Potlatch Forests, Incorporated, Central Research Department. In August, 1963, this machine was transferred to a planing mill of the company and has been in commercial operation since. In the meantime one other machine was put into operation in Oregon later in 1963. The estimated total sales for machine graded lumber in 1963 reached five million board feet. By mid-1964 a total of five CLT-1 machines had been installed in sawmills or planing mills in the United States. The anticipated sales from these five machines for the year 1964 is 100 million board feet. In addition, about six of the other types of grading machines have been installed at sawmills, but their volume of production is reported to be less than that of the CLT-1 machines.

Machine stress grades provide generally higher design values than are available with visual grades. The extent of the increases, however, varies with species. In white fir *(Abies grandis)* over 90% of the lumber will have higher moduli of elasticity values and higher fiber stress in bending values. With inland Douglas fir, 70% of the stock will have higher moduli of elasticity; 95% will have equal or higher fiber stress in bending.

In the first twelve months of commercial operation of the machines, by far the biggest use for the material graded by the machines has been in roof trusses or trussed rafters as used in home construction. This market has drawn the greatest quantity of the machine graded lumber because lumber prices for this use are high.

Span tables for floor joists, ceiling joists and rafters have been prepared, based on the machine grades (see Table 3). Of all of the values in the tables, only three or four were controlled by fiber stress in bending; all of the others were governed by modulus

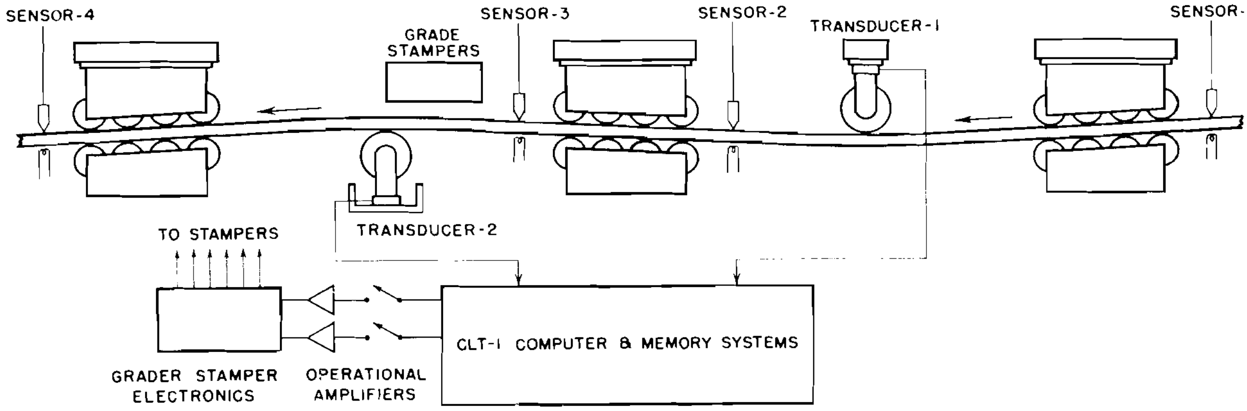

Fig. 4. Diagramatic sketch of continuous lumber tester.

of elasticity. It is apparent from the span tables that economies can be made with machine graded lumber, particularly in some species.

Several approaches have been made to gain wider acceptance of machine graded lumber for joists and rafters. A current program is to produce a special high strength grade, which will be in the E 2.2, f-2700 grade. A study of the sizes necessary to frame a typical 28 foot by 40 foot house with that grade has revealed that in all of the floor and ceiling joists the depth of the joists can be reduced two inches. The roof rafter spacing can be spread from sixteen inches to twenty-four inches. As a result of these reductions, about $ 80 to $ 90 per house can be saved in the cost of lumber and about $ 30 per house can be saved in reduced freight on lumber shipped from western U.S. to Chicago, Illinois.

Conclusion. Machine grading has made possible the use of a great many more species for structural purposes. It has resulted in improved profits for the mills and can result in decreased costs for the home builder. Although other, possibly more accurate methods may ultimately be developed, the present system of measuring E and deriving other working stresses through their relationship to E is now well established.

TABLE 3. Maximum allowable spans for electro-mechanical stress rated lumber. Applicable for Douglas fir, white fir, larch, hemlock and southern pine and other machine rated and grade marked species.

Floor joists

Nominal size Inches	Spacing Inches	40 PSF Live load*					30 PSF Live Load*				
		E 2.6	E 2.2	E 1.8	E 1.4	E 1.0	E 2.6	E 2.2	E 1.8	E 1.4	E 1.0
		ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in
2 × 6	12″	12– 0	11–3	10– 6	9– 8	8– 8	12–11	12–2	10– 4	10– 5	9– 4
	16″	10–10	10–3	9– 7	8– 9	7–10	11– 9	11–0	10– 3	9– 5	8– 6
	24″	9– 6	9–0	8– 4	7– 8	6–10	10– 3	9–8	9– 0	8– 3	7– 4
2 × 8	12″	16– 0	15–4	14– 5	13– 3	11–10	16–11	16–3	15– 5	14– 3	12– 9
	16″	14–10	14–0	13– 1	12– 0	10– 9	15– 8	15–1	14– 0	12–11	11– 6
	24″	13– 0	12–3	11– 5	10– 6	9– 5	13–11	13–3	12– 4	11– 4	10– 1
2 × 10	12″	19– 1	18–3	17– 5	16– 4	15– 0	20– 2	19–4	18– 5	17– 3	16– 0
	16″	17– 9	17–0	16– 2	15– 2	13– 8	18– 9	18–0	17– 2	16– 0	14– 8
	24″	16– 0	15–4	14– 6	13– 4	11–11	16–11	16–3	15– 6	14– 4	12– 9
2 × 12	12″	12–11	21–0	20– 1	18–11	17– 5	23– 2	22–3	21– 4	20– 0	18– 4
	16″	20– 4	19–7	18– 8	17– 7	16– 2	21– 7	20–8	19–10	18– 7	17– 1
	24″	18– 5	17–8	16–11	15–11	14– 4	19– 6	18–8	17–11	16–10	15– 6

* Plus 10 PSF dead load.

For floor joists designed on basis of F.H.A. minimum property standards requirements: total design load used for both stress and deflection.

Deflection = 1/360 span to 15 feet; 1/2″ maximum in longer joists.

Ceiling joists

Nominal Size Inches	Spacing Inches	No Attic Storage*					Limited Attic Storage**				
		E 2.6	E 2.2	E 1.8	E 1.4	E 1.0	E 2.6	E 2.2	E 1.8	E 1.4	E 1.0
		ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in
2 × 4	12″	13– 6	12–10	12– 0	11– 0	9–10	10– 9	10– 2	9– 6	8– 9	7–10
	16″	12– 3	11– 8	10–11	10– 0	9– 0	9– 9	9– 3	8– 8	7–11	7– 1
	24″	10–10	10– 2	9– 6	8– 9	7–10	8– 6	8– 1	7– 7	7– 0	6– 0
2 × 6	12″	19– 0	18– 4	17– 4	16– 3	14–11	16– 0	15– 4	14– 5	13– 3	11–10
	16″	17– 8	16–11	16– 1	15– 2	13– 7	14–10	14– 0	13– 1	12– 0	10– 9
	24″	16– 0	15– 4	14– 5	13– 3	11–10	12–11	12– 3	11– 5	10– 6	9– 1
2 × 8	12″	23–11	23– 0	21–10	20– 6	18–10	20– 2	19– 4	18– 4	17– 3	15–10
	16″	22– 4	21– 5	20– 4	19– 1	17– 7	18– 9	18– 0	17– 1	16– 1	14– 8
	24″	20– 2	19– 4	18– 4	17– 3	15–10	16–11	16– 3	15– 5	14– 4	12– 4
2 × 10	12″	28– 7	27– 5	26– 1	24– 6	22– 6	24– 1	23– 1	21–11	20– 7	18–10
	16″	26– 8	25– 6	24– 3	22–10	21– 0	22– 5	21– 5	20– 5	20– 2	17– 8
	24″	24– 1	23– 1	21–11	20– 7	18–10	20– 2	19– 5	18– 5	17– 4	15– 7

* Slope of roof is 3 in 12 or less. 15 PSF total design load.

** Slope of roof is 3 in 12 or greater. 20 PSF live load + 10 PSF dead load.

For ceiling joists designed on basis of F.H.A. minimum property standards requirements: total design load used for both stress and deflection.

Deflection = 1/240 span to 15 feet; 3/4″ maximum in longer joists.

TABLE 3 *(continued)*

Low slope roof joists

Nominal Size Inches	Spacing Inches	Not Supporting Finished Ceilings*					Supporting Finished Ceilings**				
		E 2.6	E 2.2	E 1.8	E 1.4	E 1.0	E 2.6	E 2.2	E 1.8	E 1.4	E 1.0
		ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in
2 × 6	12″	16–0	15–4	14–5	13–3	11–10	15–4	14–8	13–8	12–7	11–3
	16″	14–10	14–0	13–1	12–0	10–9	14–1	13–4	12–5	11–5	10–3
	24″	12–11	12–3	11–5	10–6	9–1	12–4	11–8	10–10	10–0	8–5
2 × 8	12″	20–2	19–4	18–4	17–3	15–10	19–4	18–7	17–8	16–7	15–3
	16″	18–9	18–0	17–1	16–1	14–8	18–0	17–4	16–5	15–5	13–11
	24″	16–11	16–3	15–5	14–4	12–4	16–9	15–11	14–10	13–8	11–5
2 × 10	12″	24–1	23–1	21–11	20–7	18–10	23–2	22–2	21–1	19–10	18–3
	16″	22–5	21–5	20–5	19–2	17–8	21–6	20–8	19–8	18–5	16–11
	24″	20–2	19–5	18–5	17–4	15–7	19–5	18–9	17–9	16–8	14–5
2 × 12	12″	27–9	26–8	25–4	23–10	21–10	26–8	25–7	24–4	22–10	21–0
	16″	25–10	24–9	23–7	22–2	20–4	24–10	23–10	22–8	21–3	19–7
	24″	23–4	22–4	21–3	20–0	18–4	22–5	21–6	20–2	19–3	17–5

* 20 PSF live load + 10 PSF dead load.
** 20 PSF live load + 15 PSF dead load.

For low slope roof joists designed on basis of F.H.A. minimum property standards requirements: total design load used for both stress and deflection.
Deflection — 1/240 span up to 15 feet; 3/4″ maximum for longer spans.

Rafters

Nominal Size Inches	Spacing Inches	Light Roofing*					Heavy Roofing**				
		E 2.6	E 2.2	E 1.8	E 1.4	E 1.0	E 2.6	E 2.2	E 1.8	E 1.4	E 1.0
		ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in	ft in
2 × 4	12″	13–1	12–5	11–7	10–8	9–7	11–10	11–2	10–5	9–7	8–5
	16″	11–11	11–3	10–6	9–8	8–6	10–9	10–2	9–6	8–9	7–4
	24″	10–5	9–10	9–2	8–5	6–11	9–5	8–11	8–4	7–8	6–0
2 × 6	12″	18–6	17–9	16–11	15–10	14–6	17–2	16–5	15–8	14–7	12–9
	16″	17–3	16–7	15–9	14–8	12–11	15–10	15–4	14–5	13–3	11–1
	24″	15–7	14–11	14–0	12–10	10–6	14–3	13–5	12–7	11–7	9–1
2 × 8	12″	23–5	22–5	21–4	20–0	18–5	21–7	20–9	19–9	18–6	17–0
	16″	21–9	20–11	19–10	18–8	17–2	20–1	19–4	18–4	17–3	15–0
	24″	19–8	18–10	17–11	16–10	14–4	18–2	17–5	16–7	15–7	12–4
2 × 10	12″	27–11	26–9	25–5	23–11	22–0	25–10	24–10	23–7	22–1	20–4
	16″	26–0	24–11	23–8	22–3	20–5	24–0	23–1	21–11	20–7	18–11
	24″	23–6	22–6	21–5	20–1	18–1	21–9	20–10	19–10	18–7	15–7

* 15 PSF live load + 7 PSF dead load.
** 15 PSF live load + 15 PSF dead load.

For rafters designed on basis of F.H.A. minimum property standards requirements: total design load used for both stress and deflection.
Deflection = 1/180 span to 15 feet; 1″ maximum in longer rafters.

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G 8

A. F. Milovanov

Industrial methods for erection of heating aggregates

By A. F. Milovanov (U.S.S.R.)

Present heating aggregates are complicated engineering constructions, which work under the simultaneous action of load and high temperature. Up to the present the majority of heating aggregates are built of fire-proof materials in steel frames or casings. The refractory brickwork requires much labour and does not allow the use of industrial methods of erection.

The application of fire-proof concrete and reinforced concrete in construction of heating aggregates in many cases gives large possibilities for industrialisation and reduction of construction cost. Moreover it helps to increase productivity by means of manufacture and mounting these constructions out of prefabricated large blocks and panels.

Compositions of fire-proof concrete, design methods and common principles of heating aggregates design have been worked out in the USSR. The high compressive strength of fire-proof concrete and the high tensile strength of reinforcement permits the working out of new original types, of more economical and simple design, in which the bearing capacity of both materials is used completely.

Fire-proof reinforced concrete constructions are made monolithic, prefabricated or a combination of both, depending on their type and the work conditions.

Monolithic fire-proof reinforced concrete is used in constructions which are difficult to divide into uniform parts (foundations of blast-furnaces, of pyrite furnaces, furnaces for boiling layer burning and in conic chimneys). It is also used in cases where low gas-penetrability and high germetic qualities are required according to the working conditions required of aggregates (electric filters, scrubbers and dust-catchers). The erection of monolithic fire-proof reinforced concrete constructions requires application of inventory moulds, welding fabrics, welding frames, crane equipment and heated housing in winter time. Concrete is compacted by means of vibration. Prefabricated fire-proof reinforced concrete constructions are much more progressive than monolithic. The erection of the heating aggregate is done by means of mounting prefabricated large elements, panels or blocks. Prefabricated reinforced concrete fire-proof constructions can be put into operation in a shorter time. Separate construction elements can be dried in advance. This permits to shorten the period of the first heating of the aggregate.

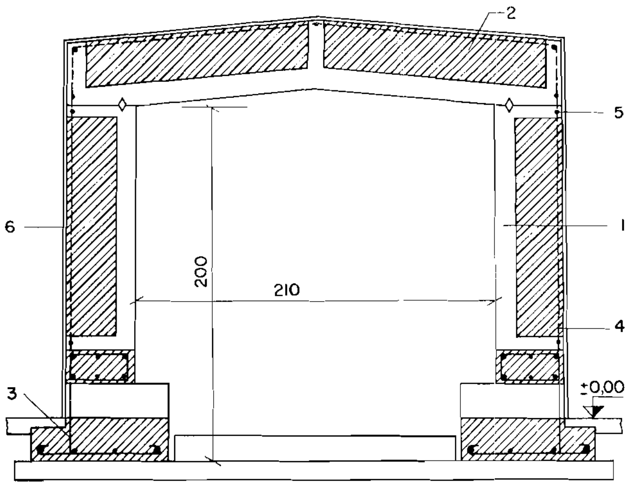

Fig. 1. Cross section of diatomite brick kiln. Temperature of burning equal to 1000 °C. Constructed of prefabricated fireproof reinforced concrete members.
1. Wall panel.
2. Vault panel
3. Foundation blocks
4. Reinforcement
5. Butt straps
6. Heat insulation

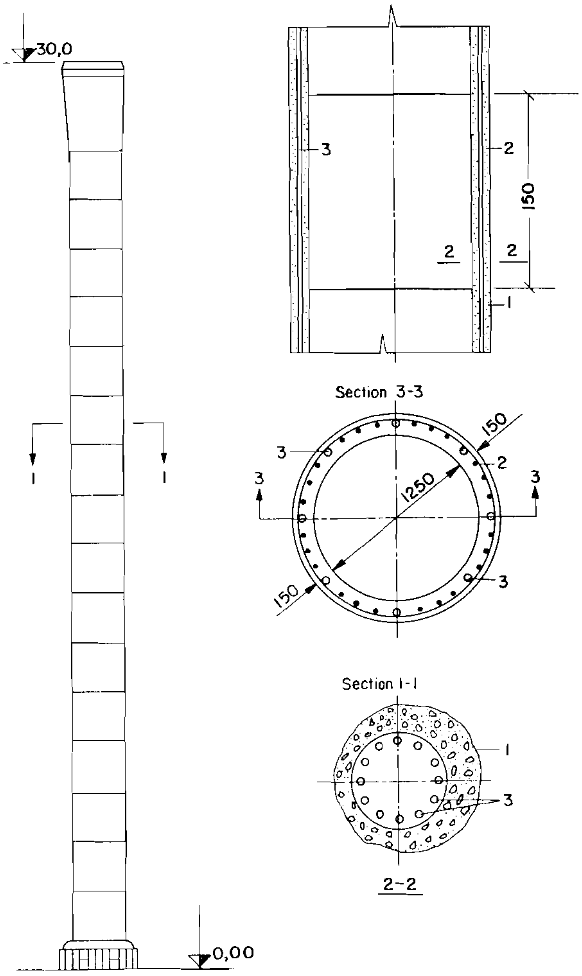

Fig. 2. The design of a chimney of 30 m in height for diversion of gas with temperature of 300 °C. Constructed of prefabricated fire-proof prestressed members.
1. Fire-proof concrete
2. Horizontal spiral unstressed reinforcement.
3. Prestressed longitudinal reinforcement made of high-strength wire of 5 mm diameter.

Prefabricated fire-proof reinforced concrete is used in furnace constructions and other heating aggregates (tunnel and thermic kilns fig. 1, smoke uptakes, cylindrical chimneys fig. 2, oil furnaces fig. 3, and air heaters fig. 4).

Prefabricated reinforced concrete fire-proof constructions are particularly profitable when we can reach a low number of type-sizes of parts of heating aggregates.

Combined constructions are a combination of prefabricated elements and monolithic concrete or reinforced concrete, which is placed at the building site. (For instance it is used in the construction of coke batteries).

The use of large prefabricated elements made of fireproof concrete and reinforced concrete makes it possible to shorten the time necessary for erection, to increase the productivity of labour and to eliminate the manual and wet operations. Thus the building site becomes purely an erection site.

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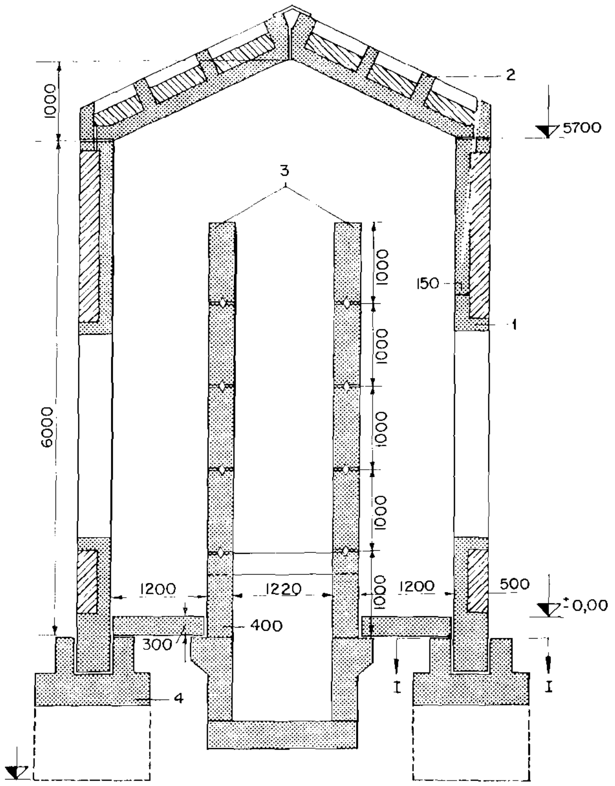

Fig. 3. Cross section of tube stove for oil distillation with a temperature of 1000 °C. Constructed of large prefabricated fire-proof reinforced concrete members.

1. Reinforced concrete wall panel
2. Reinforced concrete vault panel
3. Concrete blocks of internal waddle wall.
4. Foundation blocks.

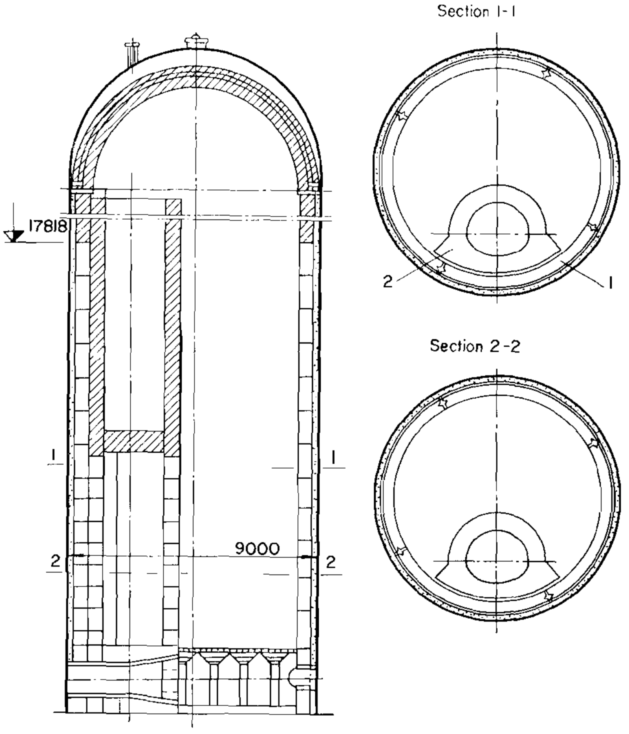

Fig. 4. Refractory lining of air preheater walls made of large fire-proof concrete blocks. Temperature up to 1200 °C.

1. Wall block
2. Block of combustion chamber.

Foam plastics for housing in the interest of international development

By S. C. Paraskevopoulos (U.S.A.)

Frame of reference

The program of research on the structural use of plastics now being conducted at the Architectural Research Laboratory of the University of Michigan, has been sponsored by the Agency for International Development (AID), United States Department of State. It is aimed at exploring the feasibility of using plastics, especially foam plastics, for the construction of dwellings in the underdeveloped areas of the world.

The housing problem cannot be divorced from any country's total problem of social and economic development. The available resources of the technologically less advanced countries should be viewed as something more than just mere expedients for an immediate output of needed dwellings. The extent to which any particular material or method of construction might be used should depend on the degree to which they also help to increase the national productivity and to raise the national standard of living.

The often advanced theory that only locally available materials should be considered for housing use to the exclusion of any imported materials must accordingly be viewed with some skepticism. If by importing certain materials (such as may be the case with chemicals needed for the production of plastics) a country can upgrade its local resources or create new ones, then it may be to the advantage of this country to import such materials.

If we think in terms of a worldwide international development rather than merely the assistance contributed by the privileged to the underprivileged nations, then the most advanced technology should be considered for introduction in every country. Even innovations in the developmental stage could be introduced in a cooperative program in which the experience of those being aided will also benefit those who are providing technical assistance.

Plastics and industrialisation

Being a synthetic product, the plastics require industrial facilities for their manufacture and processing. Industrialisation will therefore be promoted in any country where markets can be created for the various types of plastics. Many different kinds of products with very precise specifications can be readily produced to meet many different requirements and conditions without any great change-over costs in production. Quality can also be largely controlled in the laboratory where the attitude traditionally has been always to improve a product through continuous research and experimentation.

The main industrial advantage offered by the plastics lies in their wide variety of possible uses, ranging all the way from tableware and small toys to large structural components. This versatility in turn assures a greater diversification of markets. If production facilities can be created for the building market, potentially the largest, the output should be ample enough to take care of other markets, notably furniture and equipment of all sorts, all of which present equally pressing needs in the newly developing countries.

This diversification of markets makes the plastics attractive from the standpoint of capital investment in the underdeveloped countries. Even if the existing housing market is not immediately large enough to absorb an output of building materials commensurate with low unit costs and a reasonable margin of profit, the investment may be justified by producing needed consumer items for which there is already a large market demand. The production and sale of allied products will assist in amortizing a considerable part of the initial capital investment, and this will eventually make possible the production of building materials at lower unit costs.

Basic premises

The foam plastics, besides offering advantages in terms of global logistics, have such virtues as ease of fabrication at low investment cost, light weight, and excellent insulation properties. As their density decreases so also does their cost when measured in volume of material. This fact does not necessarily mean that the lowest density foams will produce the most economic structures, but it does indicate that in order to achieve maximum economy in a structure the density of the materials must be taken into careful consideration.

Economy is a factor that always has to be considered, especially in the case of the underdeveloped nations. It is misleading, however, to compare plastics on a pound or board-foot basis. Much depends on how efficiently their properties are being used, and thus the only meaningful figure is their cost in place.

A decision which formulated the course of our research was that plastics should not be viewed as substitutes for conventional building materials but for their own intrinsic value in building construction. The aim has been to explore such new or improved structural solutions as are made possible through the introduction of these new materials. With each plastic material the objective is to develop a total system (design, production, and marketing) consistent with its inherent properties and to make whatever adjustment may be needed within the system to enable it to cover the widest possible range of specific housing requirements.

Approach to structure

To determine priorities in our structural research, we have approached the problem of structure from three directions: (1) structural analysis, (2) production methods, (3) erection techniques.

Since the foam plastics have very low moduli of elasticity, flexural stiffness will depend primarily on the distribution of the material in the structure; in other words, on the structural geometry. The proper geometry will also lead to the reduction of stresses within the structure. Low stress values are essential not only because of low material strengths, but also because creep seems to depend upon the stress level of the material.

Foam plastic structures which offer the largest potential are those in which stress levels are kept low by the distribution of loads throughout the structure, and where load and stress concentrations are avoided as much as possible. Structural solutions have therefore been sought within the family of "surface structures", especially shells and folded plates, which have such characteristics.

Through further analysis involving the basic families of internal stresses, theoretical solutions can be obtained which will be fairly ideal from a purely structural standpoint. However, these solutions may be far from ideal with regard to application, especially so far as our particular project is concerned.

The possibilities and limitations imposed by efficiency in production methods are major factors also influencing the structural solution. Such factors affect the form of the structure as well as the form in which materials can be used. Finally, the erection technique must be considered, because these plastic materials present some unique possibilities which may affect considerably both the structural form and its cost in place.

Experimental structures

The structures described below have been erected primarily in order to obtain information regarding their behavior. This information will be a guide in developing a second generation of experimental structures freed from certain present shortcomings.

a. Polystyrene foam structure: This structure—a dome 45 feet in diameter—was erected in collaboration with the Dow Chemical Company through their "Spiral Generation" process. The process involves the use of a specially designed machine which bends, places and fastens boards of plastic foam together in a predetermined shape, layer upon layer, into a rising structural spiral.

In erecting this structure a trench, corresponding to the diameter of the dome, was excavated and bridged by 2 × 4-inch wood blocks which supported a base ring. A starter strip of

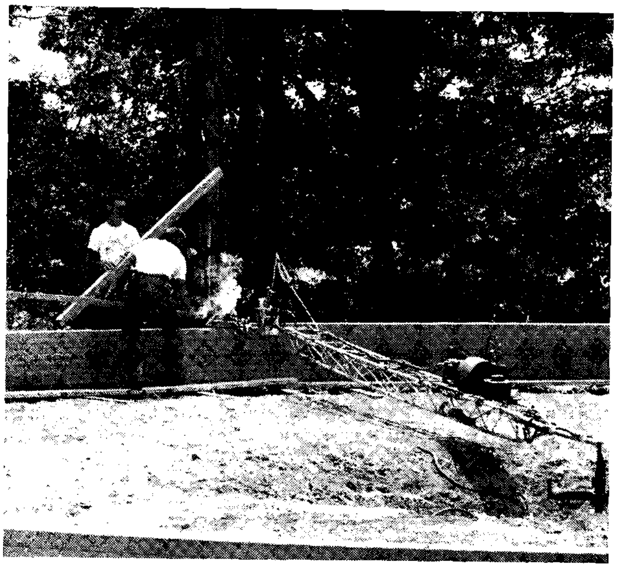

Fig. 1. Erection of a dome with polystyrene foam boards through Dow Chemical's "Spiral Generation" process.

polystyrene foam was attached to the ring and the "Spiral Generation" process begun (Fig. 1). Foam boards, 4 inches thick, with a density less than 2 pounds per cubic foot, were used, and the dome was erected in less than 12 hours by two men (Fig. 2). It was then lowered into the trench which was backfilled with earth, fully on the outside and partly on the inside. Openings were marked, cut and reinforced around the edges with fiberglass tape and epoxy resin. A cement floor slab was then poured and its edge anchored to the dome. The surface was coated with a mixture of latex paint and vermiculite. Partitions were installed in the openings. A flexible polyethylene gasket is used to create the joints between the dome and the glass fenestration.

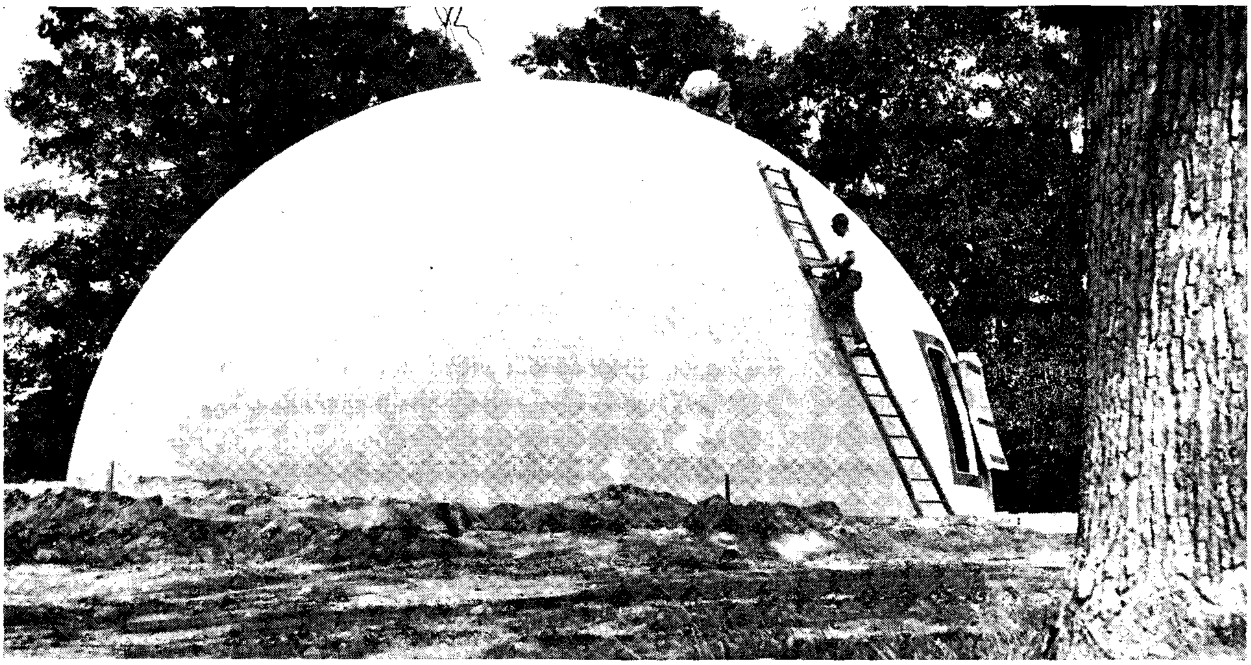

Fig. 2. Dome completed in less than 12 hours by two men and coated with latex paint and vermiculite.

b. Polyurethane foam board structure: This experiment, involving a two-story test structure measuring 16 × 18 feet in plan, has been conducted in collaboration with Union Carbide Corporation. The material is a panel consisting of a polyurethane foam core, $\frac{3}{8}$ inch thick with a density of about 2.5 pounds per cubic foot, and surfaced on both sides with paper skins. It is produced by a continuous process in which the skins, introduced in rolls, go through a machine at a rate that permits the liquid foam components to be evenly distributed between the skins; the components then expand into a rigid foam which adheres tightly to the skins.

The material can be scored and folded, thus lending itself to the making of folded plate structures. From a production standpoint it is desirable to develop structural systems which require merely the adding of equipment to the material production line. With these ends in mind, following an extensive testing procedure, a triangulated bent was developed. In the absence of regular production equipment, a templet was constructed for the assembly of the bents whose components are held together with polyester impregnated fiberglass tape. The surface was also coated with polyester resin. For the two-story structure, fiberglass tape and polyester resin were used to assemble the bents, all of which have the same uniform cross-section, and to anchor the complete structure to concrete footings.

c. Spray polyurethane foam structure. An essential element in polyurethane spray application is the form-giving surface against which the foam components are sprayed. For this purpose we devised a lightweight lattice armature, capable of being folded, easily transported to the site, and quickly erected by being pulled into a double-curved shape. A shell, covering a square floor area 22 feet wide, has been erected in collaboration with Wyandotte Chemicals Corporation.

The folding armature was placed on a concrete slab with four anchor plates. Then, using tension chords, the armature was lifted into place and anchored to the plates. The entire armature was covered with a stapled-on nylon reinforced paper skin and sprayed with the polyurethane components to a foam thickness of 4 inches with a density of 2.5 pounds per cubic foot. Stress levels in the structure can be controlled by the rise of the center portion and the stiffness of the edge members.

d. Rigidized flexible polyurethane foam structure: This experiment was intended to explore the possibility of erecting double-curved surfaces by rigidizing flexible foams with resins after they have been stretched to the desired shape. These materials could also be preimpregnated with an atmospheric curing resin in the factory and then transported to the site in a vacuum bag before being stretched in place and allowed to become self-rigidizing.

For the purposes of this experiment a reticulated flexible polyurethane foam produced by the Scott Paper Company was selected. A sheet, 56 inches by 16 feet and one inch thick, was impregnated by a moisture-curing polyurethane resin developed by the Wyandotte Chemicals Company. It was placed in a wooden frame and two points were pulled down to produce a structural component. Once cured, the component was sprayed with chopped glass fibers and polyester resin and fastened on top of tubular columns.

Conclusions. These experiments have shown that foam plastics structures are within the realm of technical and economic feasibility. Before any meaningful design data can be developed, however, more research is needed in the chemistry and production of these materials to eliminate present qualitative inconsistencies. Also, more data must be obtained as to their behavior and long-term performance in order to establish a better correlation between materials and structure. If properly stimulated by architects, the chemical industry can greatly contribute to the advancement of building technology through chemistry.

Acknowledgements

This research is being conducted with my colleagues; Harold J. Borkin, J. Sterling Crandall, Robert M. Darvas, James L. Haecker, C. Theodore Larson, and Willard A. Oberdick.

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Prefabricated buildings: wood and metal finished carpentry developments

By A. Pardon (France)

The object of these notes, which are very short in regard to the scope of the subject, is to review developments in prefabricated building wood and metal finished carpentry. Since the second World War, and particularly in the last ten years, major changes have taken place in respect of techniques, materials and organisation in the building carpentry industry. Such changes have affected all European countries. However, it is apparently in France that attempts to industrialise and commercialise finished carpentry have so far been the most successful.

In these notes, developments over the past few years will first briefly be reviewed; next, a number of present investigations will be submitted and, finally, future prospects will be considered in regard to prefabricated building finished carpentry, especially in the plastics field, together with the prime importance of wood and metal finished carpentry among the smaller building work contracts.

The relative importance of wood and metal finished carpentry among building trades

It is evident that the heavy work, i.e. in the main masonry, plays the leading part in building, covering about 55% of the total cost of a completed house; such percentage depends of course on the kind of material used. Wood and metal finished carpentry accounts, however, for 10 to 15% of total expenditure and thus comes first among the smaller building work contracts.

The extent to which wood comes into finished carpentry

As the heavy masonry work may be carried out using mainly such different materials as stone, concrete, brick, steel, wood etc., so too does finished carpentry not make use of wood only. However, as far as external finished carpentry is concerned, wooden windows and frames account for approximately 85% of total dwellings built in France. The proportion is, on the other hand, much lower when it comes to government and industrial buildings. As for internal finished carpentry, apart from a fairly high proportion of doorframes made of metal, wood and products derived therefrom are the main materials applied. These notes will, therefore, deal mainly with wood finished carpentry.

Shop-prefabricating possibilities

Building finished carpentry has always required a good deal of preparatory shop-work and, for external parts, erection on site has often come in for more than 10% to 20% of total cost. This was in fact the only building trade using raw materials. The feasibility of prefabricating windows, door-frames, doors, wall-cupboards, fixtures and fittings, in well sheltered and equipped shops, has enabled finished carpentry to consider industrialisation before most other building trades. Industrialisation is a condition of improved productivity which, in turn, leads to a spectacular reduction in production costs, and therefore in prices.

Developments in wood and metal finished carpentry techniques

Changes in carpentry patterns. Improved manufacturing techniques have made possible an evolution in the various kinds of finished carpentry used. Industrial research work on wood, in cooperation with the different Technical Centres, particularly in France has led to the development of new patterns with improved performance. Truly efficient solutions have been found to problems of weatherproof properties required of external finished carpentry. In regard to internal finished carpentry, research has been directed mostly to solving problems of strength, warping and better sound insulation. At the same time, the quality and aesthetical features of door and window hardware were very satisfactorily adapted.

Introduction of new types of carpentry. The development of new types went together with research work to improve existing ones. The prefabrication of front walls has provided new outlets particularly for wood finished carpentry and naturally, of course, for metal finished carpentry. Such new techniques have only progressed in the last ten years. They make it possible to incorporate prefabricated panels into the concrete or metal structure of buildings. Such panels are termed façade panels or curtain walls, according as they are, or are not, housed in the actual structure. These techniques have not yet been standardised, but this delicate problem will shortly be settled, thanks to action taken by specialised manufacturers, jointly with that of curtain wall Information Centres and Technical Centres. Flexibility in design with due consideration to modern architectural requirements will then be feasible. Finished carpentry contractors will make use of standardised and normalised prefabricated elements, and they will, if necessary, add joining elements of their own manufacture. By means of such techniques, finished carpentry may account for 30% or more of total building cost.

Windows and frames – developments. In regard to external openings, international trade connections have promoted the adoption by some countries of types popular in other countries; the former countries had so far been satisfied with using their own standard types. In France, for instance, the so-called "à la française" casement-window with hinged leaves with a groove to receive a cock-bead, still the most popular to-day, is no longer the only kind produced. Other types of frames have been introduced. Their design is to some extent inspired from foreign models, as for example Swedish swinging frames, British sash windows, German folding and swinging frames, and other frames simply called Italian, Australian, Canadian etc. frames. Major improvements have been achieved in the actual manufacture of casement-windows and frames. Wood sections have been reduced in size without detriment to strength. To provide greater lighting surface the wooden parts of hinged leaves have been made narrower but deeper. Corner-plates have been eliminated as joints are now stuck. Profiles have been designed to provide improved tightness. Hardware has been modernised, with the use of improved metals and of plastic materials.

Doors – developments. In regard to internal finished carpentry, door types have undergone the most significant changes. Before the war, they were mostly made of thick wood, particularly white deal. They were made in the form of panelling, with or without lintel course, the design of mouldings with large or small frames. Using ply- and laminated wood it has been possible first to eliminate massive door panels and then to produce double-panelled doors, the panels being stuck on both sides of a framework of pitted-core resinous wood. At the present time, most doors, at any rate in France, are of the isoplane type.

Door-frame models – improvements. Door-frames have traditionally been made of wood and in a classical style. In the course of the last few years more varied patterns have been developed, into which it has been possible to insert electric wiring, and sometimes also containing the batten door-frames. As a matter of fact, wood is now no longer the only material used; a substantial amount of door-frames are made of metal. As will be explained later, with the development of a new plastic wood material, it is possible to produce door-panels of which the profiles present the advantages of metal finished carpentry, that is to say that no encasing is required. The design of such door-panels enables the incorporation of many hardware (door-hinges, fixing cramps) and electrical fittings. They are easy to dismantle and they look modern.

Materials — developments

New wood-derived products. The improvement in finished carpentry designs has been substantially facilitated by the introduction on the market of many wood-derived products, mainly, ply- and laminated wood, fibre and particle building board. Great use has been made of these in applying the new technique for prefabricated façades, façade panels and curtain-walls, particularly since a certain kind of ply- and laminated wood is available for external walls. It is also by using ply- and laminated wood that door-panels have been developed to replace massive wood, and the complete lining of both sides of internal doors. Extra-tough fibre board, introduced some ten years ago, has recently been used in preference to ply- and laminated wood for doors, in a number of countries, including France. Other products, not derived from wood, are also used in finished carpentry especially in the prefabrication of façades technique. These include asbestos cement panels, stratified panels, etc.

New kinds of wood. In respect of external finished carpentry, principally and especially in France, shortage of good quality oak has led to the general use of tropical varieties as a replacement. There was first Niangon, then Sipo mahogany among African species, and dark red Meranti among oriental species. The advantages of these tropical varieties, particularly in finished carpentry, are their great diameter and their constant quality. As a matter of fact, they are practically devoid of knots and thus meet architects' and customers' requirements. They are easy to paint but may just as well be varnished in their natural shade. Nevertheless it would be a mistake to imagine that such tropical species could do without long open-air drying or seasoning in artificial drying cells.

Metal and light alloys finished carpentry

Major building schemes have prompted metal specialists also to produce external finished carpentry. In large towns, modern aesthetical trends have led to a preference for very large openings, for which metal provides leaf profiles that are not so voluminous as wood. For offices large swinging or sliding frames can be produced with metal; such frames are combined with basement panels often made of metal. Metal finished carpentry, particularly when making use of aluminium and light alloys, is considerably more expensive than wood finished carpentry; moreover, it requires expensive maintenance.

Finished carpentry applying plastic products not derived from wood

Tests with plastics in finished carpentry have recently been carried out. As far as external openings are concerned, it does not appear, for the present at any rate, that types offer present advantages which may compare with those of metal or wood finished carpentry. In some countries, particularly Germany and Italy, plastic materials are applied to lining windows traditionally made of wood. The cost of such windows is naturally higher.

Finished carpentry applying wood-derived plastic products

A new product was introduced at the BATIMAT building materials exhibition in Paris, in 1963. It is a plastic – moulded – made of very fine wood particles agglomerated with synthetic resins and strongly compressed, when heated, in casting moulds. This new product has the advantages of wood, of which it is made, in particular thermal and acoustic insulating properties. On the other hand, being far more mechanically resistant than wood, it is exposed neither to splintering nor to substantial dimensional variations. Its cost price appears to be in the region of that of wood, provided finished carpentry components are mass-produced, as should be the case for a plastic material, in view of the high cost of casting moulds and presses. The only elements so far produced are door-frames, but other finished carpentry items are being designed and have reached the laboratory stage, such as frames and windows. As already mentioned, it is possible with this new plastic to design door-frame profiles approximating to metal finished carpentry designs, enclosing many fixtures, at a price competing with that of wood finished carpentry. This product is of definite interest in regard to raw material supplies. Indeed, experts are agreed that timber shortage may one day occur in world wood supplies. Even now, importers fear that they will fall short of tropical wood varieties at present in demand by carpenters. For this new product, any kind of wood may be used, of all sizes, even copsewood and waste timber; there will always be an adequate supply of the latter, at very low prices. It seems that there is an unquestionable future for this product in building finished carpentry, even for other applications.

Building finished carpentry manufacturing organisation developments

Inevitable industrialised manufacture. Industrialised manufacture is compelled by the dual necessity to mass-produce building finished carpentry components for coping with demand, and to produce at low cost to reduce that of building.

This trend is evident in the majority of developed countries. It presupposes some degree of standardisation of patterns and sizes. As a matter of fact, such is the reason why mass-production started with internal doors, particularly since these are of the isoplane type. Doors may be designed with a limited size range. Furthermore the manufacture of plane doors becomes quite different from that of assembled doors, so that they have to be built in new work shops, where industrial production is fairly easily introduced.

As regards external finished carpentry, the wide range of models and sizes had so far been a definite obstacle in the way of real industrialisation. However, for about ten years now, large firms and finish carpentry manufacturers' associations have been going over to the production of windows and frames, even front-doors, as product-list items.

The dividing line between manufacturers and building finished carpentry contractors. The consequence of industrialisation is, sooner or later, the dissociation of the manufacturer's and of the contractor's activities. Almost all finished carpentry contractors hitherto produced in their own shop finished carpentry elements required on the building site. Now, the conviction is gradually growing upon them that they are henceforth not in a position to cope with such dissimilar activities as manufacturing and assembling.

Industrial manufacture of plane doors has already compelled them to purchase such components as they are no longer able to produce at the same price as specialised manufacturers. Soon after, a similar development occurred for windows. In France, as in other European countries, particularly Germany and following U.S.A., the specialised finished carpentry contractor acquires in the market all the available standard components and simply produces himself, to specifications, special items and fixtures and fittings.

Commercialisation of building finished carpentry. As an inevitable consequence of industrialisation, building finished carpentry commercialisation is now an accomplished fact and an irreversible process. It is clear that, as soon as a manufacturer turns out finished carpentry items on a product-list basis, the acute problem arises of a ready disposal of such goods and that the only good answer is efficient marketing. In most cases, manufacturers will only be able to sell their products satisfactorily through a fairly developed commercial network. Manufacturing specialisation plays henceforth a dominant part because low production costs require, preferably, the smallest possible production range. This calls for a choice.

An answer to specialisation: Manufacturers' Associations. As most firms in the building finished carpentry field are of medium or small size, specialisation may be a major problem for them. There exists quite a workable solution, that has produced excellent results, in France at any rate: Manufacturers' Associations. By this means, it is possible to assign the manufacture of a particular product to one or more factories, for instance, double-wing windows; another factory would take on the production of three-wing windows; yet another would make balcony doors, and so forth for all other finished carpentry items, such as front-doors, inner doors, closets, doorframes etc. In this way, productivity in each associated factory stands a fair chance of being at the optimum level. All the necessary attention may then be devoted to manufacturing techniques and output. It is of course the association's duty to allocate orders to the various factories. Each of these preserves its financial autonomy and own responsibilities.

Only commercial management of the factories is the responsibility of the association and it may, of course, successfully perform other duties. Among many other possibilities, it is indeed in a good position to assist factories in improving organisation and techniques, in designing and developing new models.

Conclusion—the future. It is always very difficult to foreshadow the future. Nevertheless, it may be assumed that finished carpentry will continue to develop along the lines mentioned in these notes. Ever evolving techniques will make it possible to develop improved designs, both from the aesthetical view point and that of imperviousness, thermal and sound insulation properties, and cost price. Advancement in the field of industrial chemistry will bring about new developments in products used in finished carpentry, giving them greater strength, making them more resistant to hygrometric variations and less sensitive to temperature changes. It is highly probable that such new and improved products will be found in the wide range of plastics, but it is not out of the question that wood may continue to be of prime importance. Anyhow, there is no risk that wood will be excluded from all manufactures that are not standardised or mass-produced.

Finally, manufacturing organisation will undoubtedly pursue its evolution towards industrialisation, specialisation and disassociation between the manufacturer's and the contractor's activities. Building finished carpentry products will be sold more and more as equipment, sanitary and heating items, which is perfectly reasonable. Architectural standards will have to be adapted to this new but sound building philosophy. In this way building costs will fall, for a better job of work, and this after all is the ultimate aim in all countries.

G 11

N. Petersons

Concrete quality control and authorisation of ready-mixed concrete factories in Sweden

By N. Petersons (Sweden)

The manufacture of concrete in Sweden has been largely mechanised and industrialised in the course of recent years. Nowadays, the concrete that is used on building sites is for the most part manufactured in ready-mixed concrete factories.

With a view to authorisation or approval of the commercial concrete plants that fulfil certain requirements which have been laid down for this purpose, a special procedure has been evolved for inspection and supervision of the standard of ready-mixed concrete factories as well as for quality control of the concrete supplied by these factories.

This authorisation procedure is described in the present paper, which also deals with some experiences concerning the approved commercial concrete plants and the quality of ready-mixed concrete.

Development of ready-mixed concrete industry in Sweden

About ten years ago, only a small number of ready-mixed concrete factories existed in Sweden. During the past ten years, the number of these factories has considerably increased. In 1963, the commercial concrete plants consumed about 47 per cent of the total cement consumption in Sweden that is, some 1500000 metric tons of cement, see Fig 1. This corresponds to about 4800000 m^3 of ready-mixed concrete.*) Since a certain part of the cement production is used in factories which manufacture precast concrete elements or concrete products, as well as on largesize building jobs, which often have self-owned concrete plants, this implies that the major part of the concrete employed for building construction is manufactured in ready-mixed concrete factories.

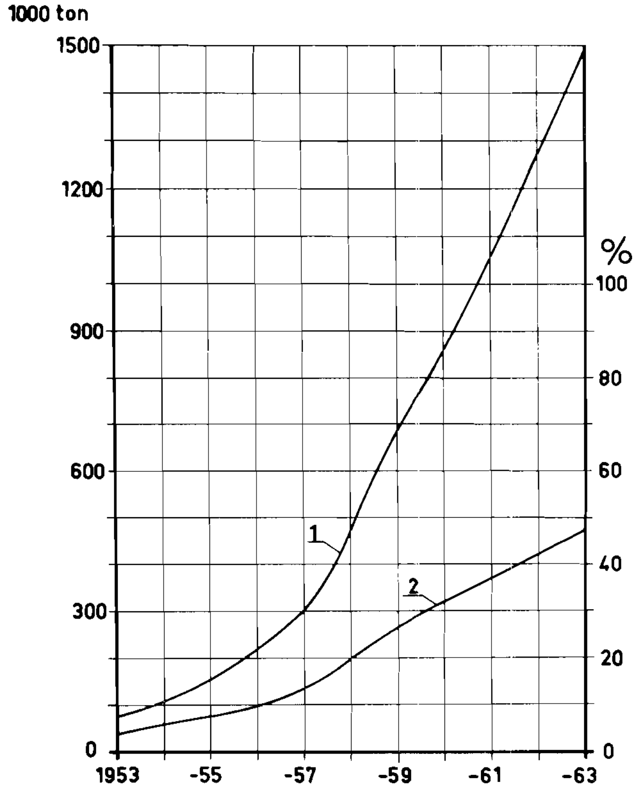

Fig. 1. Share of ready-mixed concrete in the total quantity of cement consumed in Sweden during the period from 1953 to 1963.
Curve 1. Quantity of cement used in ready-mixed concrete factories in metric tons.
Curve 2. Quantity of cement used in ready-mixed concrete factories in per cent of the total cement consumption in Sweden.

The Swedish Ready-Mixed Concrete Association (Svenska Fabriksbetongföreningen) was formed in 1959. This association is a private trade organisation. Its members, who own some 120 factories in all, produce about 90 per cent of the total volume of ready-mixed concrete in Sweden. However, the total number of ready-mixed concrete factories in this country is about 220, but in some of them the manufacture of ready-mixed concrete is only a side line, whereas their main business is, for instance, the manufacture of concrete products.

The primary aim of the Swedish Ready-Mixed Concrete Association is to promote a high standard of ready-mixed concrete factories in Sweden and to ensure a high quality of the concrete supplied by these factories. For this purpose, the Association has appointed a Ready-Mixed Concrete Factory Authorisation Committee (Kontrollnämnden för Fabriksbetong). The terms of reference of this Committee are to approve ready-mixed concrete manufacturers who can, and will, manufacture products of satisfactory quality. The activities of the Authorisation Committee are dealt with at some length in the next section. Furthermore, the sphere of action of the Swedish Ready-Mixed Concrete Association comprises professional training questions, contacts with research organisations, contacts with authorities and testing institutes, exchange of experiences with other countries, and issue of permits to authorised ready-mixed concrete factories to enable them to use a mark of approval or quality mark.

Authorisation of ready-mixed concrete factories

The Swedish State Concrete Specifications stipulate that concrete structures of some importance shall be constructed only of highquality concrete, which is designated as Class I concrete. In order to be allowed to supply concrete of this quality, the manufacturer must comply with certain requirements which are stated in the above-mentioned specifications. These requirements concern, for example, the mechanical equipment of the factory, the testing of the constituents of concrete, the composition of concrete, the results of tests on fresh and hardened concrete, and the competence of the management.

During the rapid development of the ready-mixed concrete industry in Sweden, a few individual manufacturers experienced difficulties in conforming to these requirements. With a view to assigning a special rank to those ready-mixed concrete factories which manufactured products of satisfactory quality, it was decided to institute the authorisation procedure referred to above. At the same time, this procedure was also intended to ensure that the public authorities should automatically regard an approved factory as a manufacturer of concrete in the highest class, e.i. Class 1.

To be authorised, a ready-mixed concrete factory must fulfil severe requirements. The private authorisation granted by the Swedish Ready-Mixed Concrete Association is based on the "Specifications for Authorisation of Ready-Mixed Concrete Factories", (Fordringar för auktorisation av betongfabriker, abbreviated FAB), see(1). These specifications have been drawn up by the Ready-Mixed Concrete Factory Authorisation Committee. The requirements for authorisation stated in the FAB Specifications are in line with the requirements for manufacture of Class 1 concrete stipulated in the Swedish State Concrete Specifications. However, the requirements in the FAB Specifications are more severe in some respects.

The quality control regulations contained in the FAB Specifications relate to the internal quality control exercised by the factory itself with the object of preventing the concrete manufactured by the factory from being rejected as substandard in the tests which are made on the building site in accordance with the Swedish State Concrete Specifications. In other words, the tests

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*) This corresponds to 418 kg cement or 1.25 m^3 concrete per inhabitant per year.

carried out at the works do not replace the tests on the samples taken on the building sites by an inspector who is appointed by the authorities. The purpose of the FAB Specifications is to safeguard the customers and the authorities against the supply of concrete whose strength is too low. Accidental substandard test results can be met with even in the best concrete plants, but the risk of such inadequate results should be slight.

A detailed review of the FAB Specifications lies beyond the scope of the present paper. For further particulars, the readers are referred to (2), which includes an English translation of the FAB Specifications. Accordingly, only the most outstanding features of these specifications are briefly outlined in what follows.

The supplies of aggregate shall be continuously supervised by a person who is specially appointed for this post. Aggregates originating from different gravel pits shall be stored separately.

The cement shall be subjected to a complete set of tests in conformity with the relevant Swedish standard specifications once per 6000 metric tons of cement, delivered, and, in addition, every time the cement is purchased from another supplier. Moreover, the standard strength tests shall be made once per 2000 metric tons of cement delivered.

Cement and aggregate shall be weighed on separate scales. A measuring device shall be provided for determining the total quantity of water added, and it shall also be possible to measure the quantity of water added for the purpose of adjusting the consistence of the concrete. The requisite accuracy of these scales is specified. It is stipulated that the scales shall undergo a thorough inspection and adjustment at least onceeach year. A simple inspection with weights shall be carried out at least four times a year. The consistence of the concrete in the mixer shall be checked by measuring the power input to the mixer. Continuous determination of the water-cement ratio is also required.

Minimum requirements are stipulated for the average strength of the concrete. In addition, it is obvious that the strengths requirements states in the Swedish State Concrete Specifications shall likewise be complied with. The mean strength of the concrete averaged over a long period of manufacture shall at least be equal to the values given in Table 1, where they are brought into relation with the specified nominal cube strength of the concrete.

TABLE 1. Requisite mean strength of ready-mixed concrete averaged over a long period of manufacture.

Specified nominal cube strength	K 150	K 200	K 250	K 300	K 350	K 400	K 500
Average over a long period kg/cm²	180	240	300	360	410	460	560

It is required that the mixer operator shall conform to a mixing schedule, which shall cover the details stated in the specifications. For example, this schedule shall also include the wattmeter readings which correspond to different sizes of batches and different consistences.

Furthermore, the specifications comprise rules concerning the longest permissible time of transportation (transit time), the operation logs to be kept at the works, and the details to be stated in the delivery sheets or consignment notes. Moreover, it is required that a consignment note shall accompany each load. Special requirements are stipulated for the competence of the factory personnel and the works manager.

The questions whether a factory is to be approved is decided by the Authorisation Committee, which has to ascertain whether the factory in question complies with the FAB Specifications. To begin with, the factory that has applied for authorisation shall reply in writing to a questionnaire, which comprises some 100 questions regarding the organisational set-up of the factory, its equipment, the manufacture and quality control of ready-mixed concrete, etc. After that, an inspector appointed by the Authorisation Committee visits the factory, and carries out an examination of the plant, together with the works manager. The results of this inspection are recorded in a written report. Then the inspector submits his report on the inspection to the Authorisation Committee. For this purpose, the factory is designated by a code number so as to ensure complete anonymity in dealing with authorisation matters. The Committee decides the question of authorisation on the basis of the report and its presentation by the inspector. The authorisation can be granted, postponed, or refused. The authorisation is granted for a period of up to 2 years. After the expiration of this period, the factory must be examined again.

On condition that an approved factory has signed a public liability insurance for at least 1 million Swedish kronor, the manufacturer is granted the right to use a special mark of approval or quality mark. This mark, comprises a stylised letter "K", which is intended to symbolise the Swedish word "Kontrollbetong", which means "Quality-Controlled Concrete"or "Approved Concrete".

During a current period of authorisation, an approved factory is sporadically reinspected, and its test results are checked so as to make sure that they still comply with the FAB Specifications.

The Swedish Ready-Mixed Concrete Association has commissioned the Control Department of the Swedish Cement and Concrete Research Institute, Stockholm, to inspect the factories which have applied for authorisation, and also to reinspect the approved factories on behalf of the Association.

The authorisation came into force for the first time on July 1st, 1963. Since that time, about 100 factories have been approved.

Some experiences

The Swedish State Concrete Specifications stipulate that one test specimen series consisting of 3 cubes shall be made on the site for each 100 to 300 m³ of concrete, according to the total volume of concrete to be placed, with the addition of one series for any part of the above-mentioned quantities. A basic condition for the site tests is that not more than 10 per cent of the total number of the strength values observed on the site may be lower than the nominal specified cube strength K. Therefore, the specified nominal cube strength K may be regarded as the 10-per-cent fractile, K_{10}, of the compressive strength value. In conformity with the elementary formulae of the calculus of probabilities, K_{10} is calculated as follows

$K_{10} = M - 1.28 \cdot s$

where M = the mean value of the cube strength, kg/cm²,
s = standard deviation, kg/cm².

For the sake of simplicity, the coefficient 1.28 is maintained constant, irrespective of the number of test series.

In connection with the preparation of the new Swedish State Concrete Specifications, the Swedish State Concrete Committee has had an investigation carried out in order to find what values of the compressive strength are obtained in the standard tests on concrete at some public testing institutes. The results of this investigation were found to be noteworthy in that an unexpectedly high percentage of test series had given substandard results, see Table 2. These results referred to samples which had been taken on building sites. The concrete was either made in site plants or supplied by ready-mixed concrete factories. At that time, the authorisation procedure had not yet been adopted.

TABLE 2. Percentage of cube strength test series which have given substandard results in the course of 1 year at 4 Swedish testing institutes. The results reproduced in this table date from the late 1950ies.

Specified nominal cube strength	Total number of test series	Number of substandard test series, in per cent of the total number
K 200	502	14
K 250	2199	19
K 300	1619	13
K 350	415	17
K 400	325	26

TABLE 3. Results of compression tests on concrete. The concrete was supplied by different authorized ready-mixed concrete manufacturers. The test cubes were made from samples taken on different building sites, and were subjected to compression tests at public testing institutes.

Specified nominal cube strength	Total number of test series	Results of compression tests				
		Mean value M, kg/cm^2	Standard deviation, s, kg/cm^2	Coefficient of variation, V, per cent	10-per-cent fractile, K_{10}, kg/cm^2	Number of substandard test series, in per cent of the total number
K 200	29	288	44	15,3	232	0
K 250	1108	327	48	14,7	266	2,6
K 300	812	383	51	13,3	313	2,7
K 350	376	433	53	12,3	365	4,0
K 400	366	463	48	10,4	401	5,7

The Control Department of the Swedish Cement and Concrete Research Institute has collected and analysed test results in a similar manner during 1964. This time the data under investigation related to the results of compression tests made on samples which had been taken in conformity with the Swedish State Concrete Specifications on sites where the concrete was supplied by authorized ready-mixed concrete manufacturers, and which were subjected to compression tests at public testing institutes. The concrete was delivered from some 50 authorized ready-mixed concrete factories, which were distributed over the whole of Sweden. The results of the statistical analysis of these collected data are given in Table 3.

A comparison of the numbers of substandard test series in Tables 2 and 3 shows a clearly marked difference. The number of substandard test series in the case of the ready-mixed concrete supplied by authorized manufacturers was much smaller than it had been prior to the introduction of authorisation. Furthermore, the number of substandard test series was smaller than that which would have been tolerated in accordance with the definition of the specified nominal cube strength K, which in fact refers to the 10-per-cent fractile, i.e. K_{10}. This value, K_{10}, was higher than the specified value, K, except in the case of the specified strength value K 400, but the above-mentioned requirement was fulfilled in this case also. In other words, this comparison showed that the concrete supplied by the authorized factories was of satisfactory quality, which was better than that of ready-mixed concrete before authorisation. This may presumably be attributed to the relatively extensive quality control which is stipulated in the FAB Specifications as a necessary condition for approval.

This brings us to the question of the tests conducted by the ready-mixed concrete factories themselves. Only a few aspects of these tests will be touched upon in this connection. The FAB Specifications require that the factory itself shall test the concrete for compressive strength, consistence, and weight per unit volume. One test series shall be performed on every 150 batches. These tests constitute a quality control function, and are to be regarded as a complement to the site tests made in conformity with the Swedish State Concrete Specifications. However, the compression test at the age of 28 days is of minor interest so far as the quality control during the manufacturing process is concerned, because the defects, if any, would be detected too late. An accelerated test, or short-time test, which would give reliable results at the age of a few hours or 1 day, would be more useful for the purpose of quality control in manufacture. On the other hand, the available Swedish experiences relating to such accelerated test are still limited. Therefore, by analogy with the requirements for Class 1 concrete in the new Swedish State Concrete Specifications, the FAB Specifications stipulate the determination of the water-cement ratio. The quantity of water added in the course of mixing shall be such as to produce the specified consistence, which may be expressed, for instance, in terms of the wattmeter reading that represents the power input to the mixer. Nevertheless, the total quantity of water added shall also be observed. Moreover, the water-cement ratio shall be determined every day with the help of the batched quantity of cement by determining the moisture content of the aggregate and by checking the measured quantity of water, including the water added for the purpose of adjusting the consistence. The object of these stipulations is to ensure that the changes, if any, which may influence the final strength of the concrete shall be detected at an early stage.

The results obtained from determinations of the water-cement ratio can be plotted in control graphs of a type corresponding to that of the graphs used for representing the results of strength tests.

Building construction in Sweden continues during the cold season also. Then, special measures must be taken in connection with the placement of concrete, particularly in the central and northern regions of Sweden. For example, the concrete must be protected from freezing too early, before it has developed an adequate strength to resist freezing. The fact that the concrete is nowadays manufactured in ready-mixed concrete factories has largely obviated the difficulties met with on building sites during winter construction. Cold weather concreting is also facilitated because the factories supply heated concrete in the winter-time.

The FAB Specifications require that the temperature of the concrete on arrival at the place of delivery on the site shall not be lower than + 5 °C. On the other hand, the temperature of the concrete that is sold under the designation "Heated Concrete" shall be 18 ± 8 °C on arrival at the place of delivery.

Ready-mixed concrete in Sweden is transported either in non-agitating lorries, provided with dump bodies, which are usually open, but can also be covered with lids, or in agitating lorries, which are equipped with rotary containers. The use of lorries with open dump bodies is the method of transporting which is

TABLE 4. Results of determinations of the water-cement ratio (Warris 1964)

Specified nominal cube strength	Number of factories	Water-cement ratio			
		Mean value	Mean value of maximum values observed at different factories	Mean value of minimum values observed at different factories	Mean value of the range between the highest and the lowest values observed during 1 month
K 200	13	0.77	0.85	0.66	0.05
K 250	28	0.70	0.76	0.64	0.06
K 300	21	0.62	0.74	0.50	0.04
K 350	7	0.55	0.60	0.49	0.05
K 400	13	0.49	0.56	0.43	0.02

most commonly employed, and which is also most advantageous from an economic point of view.

The time of transit is likewise dealt with in the FAB Specifications. If the concrete is transported in an agitating lorry, then it shall arrive at the place of delivery on the site not later than 1½ hour after the addition of water. If the concrete is transported in a nonagitating lorry, then the above-mentioned time of transit shall not be longer than 45 minutes.

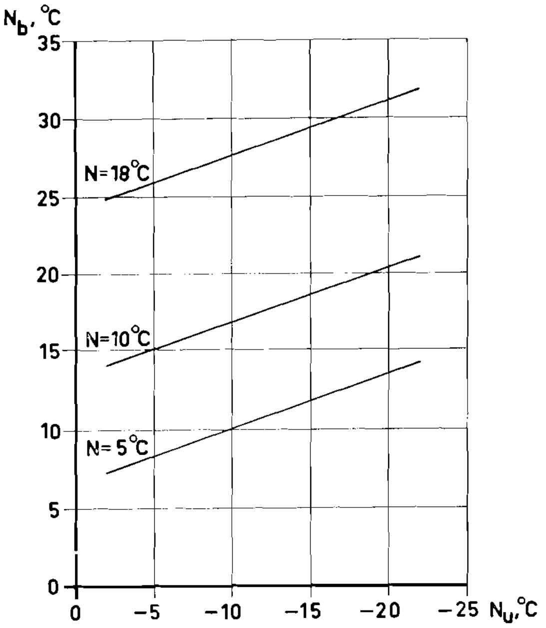

Fig. 2. Transportation of ready-mixed concrete in a lorry equipped with a rotary container. Time of transit 90 min. Relation between the initial temperature of the concrete, N_b, required at a varying temperature of the air, N_u, in order to ensure that the average temperature of the concrete on arrival at the place of delivery after transportation, N, shall be 5, 10 or 18 °C.

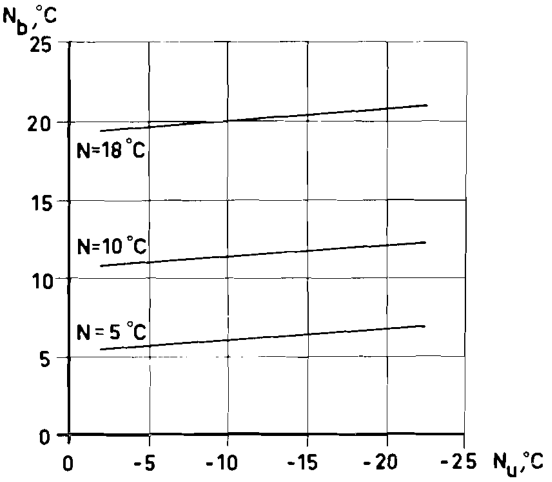

Fig. 3. Transportation of ready-mixed concrete in a lorry equipped with an open dump body. Time of transit. 45 min. Relation between the initial temperature of the concrete, N_b, required at a varying temperature of the air, N_u, in order to ensure that the average temperature of the concrete on arrival at the place of delivery after transportation, N, shall be 5, 10 or 18 °C. The oblique line marks that area of the graph in which the initial temperature of the concrete must be chosen in order to prevent the concrete from freezing on the surface.

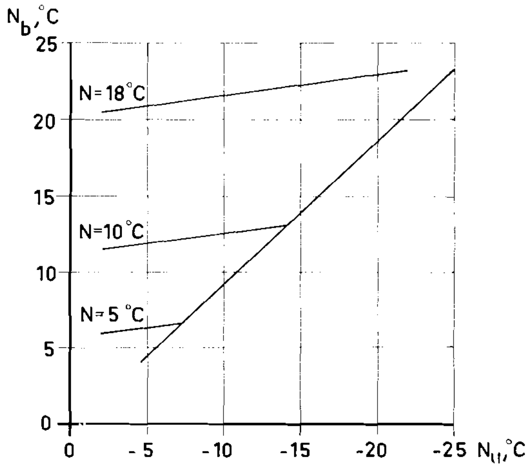

Fig. 4. Transportation of ready-mixed concrete in a lorry equipped with a covered dump body. Time of transit 45 min. Relation between the initial temperature of the concrete, N_b, required at a varying temperature of the air, N_u, in order to ensure that the average temperature of the concrete on arrival at the place of delivery after transportation, N, shall be 5, 10 or 18 °C.

With a view to investigating the extent to which the temperature of the concrete decreases during transit in the winter-time, the Contact Department of the Swedish Cement and Concrete Research Institute, at the request of the Swedish Ready-Mixed Concrete Association, has carried out measurements of the temperature losses involved in the various methods of transportation. The results of these measurements have been plotted in graphs which serve as a guide in choosing the initial temperature of the concrete to be transported in cold weather, see (4).

The measurements of temperature losses were made during transit in lorries equipped with rotary containers, open dump bodies, or covered dump bodies. The greatest decrease in temperature was observed during transportation in rotary containers. The smallest decrease in temperature was caused by transportation in covered dump bodies. No appreciable effect of the speed of transit on the temperature loss was to be observed.

The results of these measurements are reproduced in Fig. 2, 3 and 4. These graphs are used to determine the lowest requisite initial temperature of the concrete at the factory so as to obtain the specified average temperature of the concrete at the place of delivery on the site, when the concrete is transported at varying temperatures below the freezing point.

Furthermore, these graphs also show that the stipulated minimum requirements for the average temperature of the concrete on arrival at the place of delivery on the site, i.e. + 5 °C for non-heated concrete and + 10 °C for heated concrete, can readily be fulfilled by raising the initial temperature of the concrete, even when the time of transit in the winter reaches the maximum permissible value.

Conclusions. By instituting the authorisation procedure, the Swedish ready-mixed concrete manufacturers have sought to create a system which is intended to ensure that the users of concrete shall be supplied with products of satisfactory quality. The available statistics relating to the concrete supplied by the authorized commercial concrete plants indicate that the quality of ready-made concrete is really satisfactory, in fact better than it has been prior to the introduction of the authorisation procedure.

The development of the ready-mixed concrete industry in Sweden has also influenced the rationalisation of building construction. Winter concreting is substantially facilitated if heated concrete is supplied by a ready-mixed concrete factory. Moreover, it is no longer necessary to use expensive space on the site for the concrete plants and for storage of cement and aggregate. This has proved to be an important advantage, particularly in the erection of new buildings in central parts of urban areas.

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Attainments and prospects concerning the application of plastics in building

By L. Rechner (France)

At the present time, plastics manufacturers are agreed that building is one of the major potential markets for their products. The reason is that their method of transformation provides the possibility of highly industrialised fabrication and mass production.

First came the pioneers, now followed by those who promote the development of such applications. What is the present position? What are the future prospects? We shall attempt to make a factual survey of the situation, as befits a building engineer.

Attainments in the application of plastics in building

The following tabulation gives, under appropriate headings, the main types of fabricated building components actually used in France, showing the plastic products applied. The present stage of industrialisation is coded thus:

S.1: Industrial stage (mass or continuous production)
S.2: Semi-industrial stage (semi-industrial, semi-handicraft)
S.3: Handicraft stage
S.4: Experimental stage.

A. Application of plastics in façade panels, exterior covering, carpentry

1. Façade Panels

1. Sandwich panels covering with PVC plasticised plates and polyurethane foam core (S.1).
2. Sandwich panel asbestos cement covering and polyurethane foam core (S.2)
3. Sandwich panel polystyrene foam core and various coverings (S.1)
4. Sandwich panel covering with polyester laminated sheet and polyurethane foam core (S.2)
5. Sandwich panel enamelled iron covering and polyurethane foam core (S.1)
6. Sandwich panel covering with polyester laminated sheet glued to asbestos cement and polysterene foam core (S.1).

2. Exterior Covering

1. Polyester-coated concrete by moulding from an existing plate (S.3, S.4).
2. Sprayed polyurethane with sand and gravel agglomeration (S.2)
3. Epoxy resins and polyesters on various supporting media (S.4)
4. PVC plasticised plates (different types: spraying, coating, adhesive film) (S.1)
5. Polyester epidermis available as permanent shuttering (S.4).

3. Weather-Boarding

a) Corrugated sheets

1. Polyester (S.1)
2. Polyvinyl Chloride (S.1)
3. Polymethylmethacrylate (S.1)

b) Sections for assembling: PVC (S.4)

4. Windows

1. PVC casing on metal moulding (S.1)
2. Polyester laminated sheet on wooden moulding (S.1)
3. PVC-chlorinated polyethylene compound
4. Methyl polymethacrylate (S.4)
5. Polyester/glass fibre and phenolic foam core (S.3)
6. PVC/wood.

5. Rolling shutters

1. Plasticised PVC extruded sections (S.1).
2. Rigid PVC extruded sections (S.1).
3. Polyamide winding gear (S.1).

6. Blinds and sun-screens

Polyester, PVC (S.4).

B. Interior covering, floors and walls, ceilings, doors partitions

1. Interior covering

a) Wall lining

1. Adhering films—vinyl-coated fabric or paper—vinyl sheet doubling on fabric or paper etc. (S.1).
2. Sprayed lining—Polyurethane (S.3).
3. "Laminates"—Melamine and phenolic plastics—polyester (S.1)
4. Wall tiles—Polystyrene—PVC tiles or mosaic (S.1)
5. Coating—Polyvinyl acetate (S.2, S.3).

b) Floor covering

1. Asbestos plastic slabs (asphalt-tile type) (S.1)
2. Vinyl-asbestos slabs (S.1)
3. Homogeneous semi-flexible vinyl slabs (S.1)
4. Flexible, homogeneous or multi-layered vinyl slabs (S.1)
5. Homogeneous vinyl carpets a) stuck b) laid (S.1)
6. Vinyl carpets on felt (applied or coating) (S.1)
7. Multi-layered coating with cellular structure, on fabric (S.1)

Vinyl carpets on jute cloth (S.1)
Multi-layered coating on cork structure (S.1)

8. Thermosetting resin-based covering (S.3, S.4)
9. Rubber covering (S.1)
10. Synthetic fibre textile covering (polyamides, viscose etc.) (S.1)

2. Ceilings and counter-ceilings

1. Translucent—Polyester, PVC, polyamides, polyurethanes (S.1)
2. Opaque—Extruded polystyrene or vinyl copolymers, impact type polystyrene (S.1)
3. Lighting—PVC. Polymethylmethacrylate (S.1).

3. Partitions and doors

1. Translucent doors—Polyester laminated sheet on laminated polyester corrugated core or on non-opaque partitioning (S.2)
2. Opaque doors—PVC (S.3)
3. Translucent partitions—Polyester, sandwich plaster-work—Honeycomb phenolic cardboard or polystyrene foam, PVC sections for assembling (S.1, S.2).

C. Roof covering, tightness, domes and lighting elements

1. Roof covering

1. Flat or corrugated sheets—Polyester, PVC, Polymethylmethacrylate (S.1)
2. Curved sheets—Reinforced polyester (S.1)
3. Domes—Polymethylmethacrylate—Polyester (S.1)
4. Casements—Polymethylmethacrylate—Reinforced polyester (S.2)
5. Troughs—Glass/Polyester (S.4)
6. Gutters—Rigid PVC—polyester (S.2, S.3).
7. Down pipes—PVC (S.1)

2. Roof tightness

1. Polyisobutylene with or without glass cloth armature (S.1)
2. Butyl rubber (S.1, S.4)
3. Multi-layered bitumen with PVC films screens and armatures (S.1)
4. PVC sheet (S.4)
5. Weldless polyester (S.4)

D. Sanitary equipment and piping

Sanitary equipment

1. Appliances

a) Sinks—Polymethylmethacrylate—polyester—polyamides (S.1, S.3)
b) Basins—Polyester—polymethylmethacrylate—Polyester/glass fibre (S.3; S.1)
c) Baths—Polyester—polymethylmethacrylate (S.2)
d) Showers—Polymethylmethacrylate—polyester (S.2, S.3)

2. Pipe-work—PVC—Phenolics—ABS Terpolymer (S.1, S.4)
3. Fittings—PVC and ABS Terpolymer—Phenolic plastics (S.1)

4. Traps – Polyethylenes and polypropylenes – Polyamides (S.1)
5. Taps – Polyamides (S.1)
6. Water flushing – Polystyrene and copolymers – polypropylene – Polyester laminated sheet (S.1)
7. Lavatory seats – Polymethylmethacrylate – polystyrene (S.1) and copolymers, Polyethylenes (S.1)

E. Insulation

Insulating materials and applications for foams

1. Polystyrene (S.1, S.3)
2. PVC (S.1)
3. Phenolics (S.4)
4. Formaldehyde urea (S.1)
5. Polyurethane (S.1)

Prospects

a) In the near future: hereafter we enumerate a number of noteworthy trends and research work:

- concretes and mortars with thermosetting resin bonding agents;
- thermoplastic and thermosetting resin covering applicable to façades and concrete epidermis;
- new roof covering and roof tightening materials (accessory covering materials, tightness network), easy to place and standing up well to normal wear;
- large foam component units and new shaping techniques;
- developing techniques for quick shaping of plastics into large components;
- assembling and fixing processes more suitable for plastics;
- new developments in sanitary equipment and piping, applying thermoplastic and thermosetting resins;
- new developments in the way of shuttering and of elements in permanent shuttering.

At the same time as the above trends, mention should be made of research work concerning durability (obsolescence and wear and tear properties), better fire-resistance, dimensional coordination and standardisation of fittings (necessary for mass production and stocks) of industrially-produced materials and elements.

b) Required coordination: to avoid misguided action, it is essential to establish proper liaison between the plastics and building industries. In France A.E.P.B. is working on this. A.E.P.B. groups in particular the following organisations: C.E.M.P., C.S.T.B., C.T.B., F.N.A.B., the Engineer Corps, the Association of Architects, U.N.I., U.T.I.B.T.P. and a number of building proprietors.

c) Conclusions as to the more remote consequential effects of these developments.:

The engineer, to meet human demands in houses, will have provided the architect with new, complementary, component but mass-produced elements. In fact, the "20th century brick" will be a new wealth of functional building materials and components suitable for evolving techniques and architectural design.

The welded light girder

By Å. Risfors (Sweden)

For technical and economical reasons rolled steel beams with I-profile have during the last few years to some extent been replaced by welded steel girders. In order to make it easier for the constructor to calculate a suitable and economical beam-profile for large spans, AB Bröderna Hedlund have for some years worked out a light beam system, called the HSI-system, and made this the basis of rational manufacture on a large scale. The most characteristic feature of the beam is the saving of weight, since the relation between web depth and web thickness is relatively large, generally between 200 and 300, and since web stiffeners normally are only fixed at the support points of the beam.

The organisation of the HSI-system

The light beam is made of steel plate with a yield point $\sigma_s = 2.600$ kg/cm^2 and consists of web and flange plates of standardised dimensions united into an I-section by automatic welding in special machines. The designations of the system indicate all the dimensions of the cross-section. HSI-800-4-250 for example, indicates that the nominal beam depth is 800 millimetres, the web thickness 4 millimetres and the flangewidth 250 millimetres. The thickness of the flange is always 1/25 of the flange width.

The scope of the section range is, at present, confined to beams with standardised web depths from 600 millimetres to 1600 millimetres. As it is possible, with every girder depth, to vary the flange dimensions within wide limits, the system covers all moments of resistance from $W_x = 700$ cm^3 to $W_x = 22.000$ cm^3. In the same way the thickness of the web plate can be chosen as the shear forces vary. For manufacturing-technical reasons the smallest web plate thickness is at present 4 millimeters.

Research

The light girder has been preceded by extensive practical and theoretical investigations at our universities of technology. At Chalmers University of Technology, Gothenburg, under the direction of Professor Hjalmar Granholm, loading tests of some 40 beams have been made in order to investigate the thin web plate's stability in respect to moment buckling, shear buckling, a combination of those two and an eventual need of web stiffeners. The results of the investigations are very positive and may be summarized as follows:

Moment buckling. Bending stresses have in no case reduced the load bearing capacity of a beam loaded to a break. Neither have we in the literature about tested girders found any information that web buckling of moment alone, or in combination with transverse forces, has brought any decline of the load-bearing capacity of a tested beam. Neither have web buckles, as a result of the theoretical critical load being exceeded, reached such a size, that you could see them without difficulty. To require any formal safety whatsoever against web buckling of bending stresses, as is now the case in the Swedish steel standards, therefore seems to be completely useless.

Shear buckling Shear stresses can reduce the bearing capacity for a beam by having the web buckled. This decline of the bearing capacity seems to be more obvious for beams with a thick web than for beams with a thin web. For beams with a very thick web compared with the height, such as rolled standard profiles, where buckling of the web is unthinkable, the web buckling has no influence at all, but the shear ultimate stress is in that case decided by the material properties. For web-depth ratio where buckling is possible and where the theoretical buckling stress is not very small compared with the yield point of the material, the ultimate stress is generally independent of the web-depth and amounts to about $0.5\ \sigma_{\text{yield}}$. Beams with more extreme (and more economical) web depth conditions cannot reach this stress, but σ_{break} might be estimated as 3 times the critical load, calculated according to Timoshenko's theory.

During the tests the bucklings of the web plate have, in all cases, been small and difficult to see without special measurings up to about 90% of the breaking load. In no case was the break sudden but always progressive. Therefore it ought to be unnecessary to provide great breaking safety in respect to transverse force break; about the same safety as yield (about 1.7-times) seems to be correct.

Web stiffeners. The tests show that if a girder is loaded with a line load perpendicularly to the length direction of the beam, the press load can with good precision be calculated to $P_{\text{break}} = 0.85\ d^2$, when P is measured in tons and web thickness d in millimeters. This is applicable practically independent of the fact whether the girder at the same time is loaded with bending moments and transverse forces, and also seems to be independent of the beam depth. The breaks have also in these cases been progressive and it has not been possible to discover buckles until immediately before the break. It could be prescribed that the web stiffeners must be fixed if the girder is subject to a concentrated load $P > 0.4\ d^2$, while stiffeners can be excluded for smaller point loads. At end supports there must, however, always be stiffeners.

When the transition to very thin web plates for the I-profile was made, the stability problems for the flanges have also come to the front. Prof. Henrik Nylander at the Royal University of Technology in Stockholm has made very thorough theoretical investigations for the stability of the pressed flange and has published his works in two publications, "Stability of pressed flange at I-girder with a thin web" and "Stability of continuous I-girder with side-stayed overflange". In these two publications excellent dimensioning formulas are stated for tipping and torsional buckling for a pressed flange, and a formula for reduction of permitted stress, in the case when the beam web on the pressed side, after the exceeding of the buckling stress, does not participate on a full scale at the sustaining of the bending moment.

Production

As already mentioned the light girder is manufactured in special automatic welding machines. We shall here only consider in outline the way of manufacture, divided into three main groups, consisting of preparation, automatic welding and completion. The preparation includes gas cutting of the flanges, cutting of web plates, jointing of flanges and web plates to correct lengths and placing of these into the first welding machine.

When the flanges and the web plate have been fitted in their right positions the second operation starts, i.e. the automatic welding. Any time-absorbing tack welding in order to connect the web plate to the flanges in correct position does not precede the final welding together, but the web and flange plates are led into their right positions by hydraulic powered guide rollers.

The welding itself is made in two machines from the Swedish firm Pullmax. In the first machine the horizontal I-girder's web plate is welded to the flanges from above. When the whole beam has gone through the first welding machine the beam is turned in a special beam turner and then continues through the second welding machine, where the root welding is made. The design of this machine is exactly like the first one.

The welding speed in the two machines is about 1 meter beam a minute, which may seem to be a low speed. However, it appears that the bottle neck in the production line is the third operation, the completion of the beam. This operation consists of fix welding of web stiffeners, tapping and painting. Therefore, we have tried to use as few web stiffeners as possible, which means that they are mounted only at supports and where large concentrated loads will work. Another very strong reason why we try not to use web stiffeners is the great cost. As a base value we can state that the working cost for supplying a web stiffener is about as large as the production cost for one meter beam.

Properties and use

Compared with traditional girders the HSI-girder has high

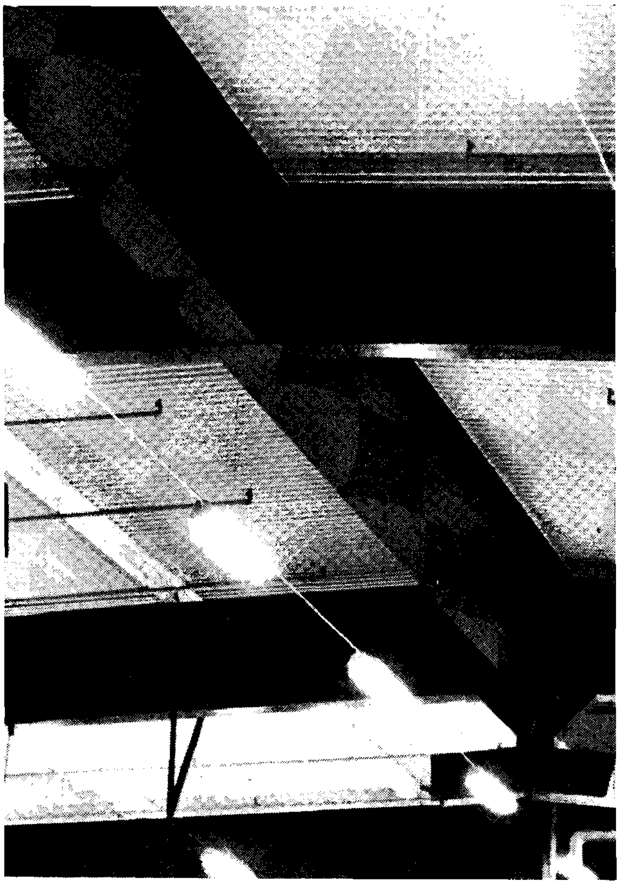

Fig. 1.

moment of inertia and moment of resistance. It therefore gives very economical constructions where spans are large and has turned out to be very suitable as the load-bearing trusses element in roof constructions for industrial and stores buildings, halls, garages, sports buildings, etc. Like traditional all-welded plate girders it can with advantage be made continuous across supports. In the case when you use HSI-girders both as primary and secondary beams in a roof construction you can easily obtain continuity for both primaries and secondaries and the crossing between them can be made as shown in Fig. I. The moment is then transmitted by continuity plates, which are welded to an over- and under-flange, while the transverse force is carried by an angle-iron cleat between the web plates. As the web plate of the beams is very thin you cannot with advantage use conventional bolt joints, as this requires too many holes caused by the pressure of the hole list of the thin web plate. Instead we have here chosen to use a friction joint, where the transverse force is transmitted by friction between angle-iron and web plate. The bolts then have to be tightened by a dynamometric wrench.

As already stated, the advantage of the light girder is the low construction weight. This is mainly due to the thin web plate and the possibility to choose a beam profile exactly for the load in question. For rolled profiles the rolling method decides the smallest web thickness, which means that the saving in weight for a light girder with the same moment of resistance will be very striking. For example, for the moment of resistance $W = 1.500$ cm^3 a welded I-girder weighs abt. 90 kg/m, while the weight for the light girder is abt. 45 kg/m.

The light girder can also be produced with curvature. This means that the scope of the deflection will not be dimensioning, as is usual for rolled profiles.

The possibility of choosing the dimensions of the flanges and the thickness of the web plate after the variation of the moment and the transverse forces means that large material savings can be made. This saving of material must, however, not be overdone. Normally, for example, only two types of flanges are used for a continuous beam, one type over support and one smaller type in the field. The joint is then placed between the flanges at the moment zero, where the demands for the execution of the joint welding are not so strict.

The total weight for a framework structure with the light girder as roof-trusses is very low, for example: a steel structure delivered in 1962 for a one-storey building with 40.000 m^2 floor area and with spacing between columns of 22 metres in both directions. The steel framework consists of columns, primary and secondary beams, type light-girder, and purlin beams of rolled I-profiles of c-c 3.2 metres. The weight of the water roof is about 30 kg/m^2 and the framework is dimensioned for a snow load of 100 kg/m^2. The weight of the complete steel frame was in this case as low as abt. 24 kg/m^2 floor area.

The transport of the light girder from the factory to the building site is normally done by lorry and as the weight per beam normally does not exceed one ton a relatively large number of girders can be shipped in each shipment. The low weight per beam avoids having to use heavy and expensive cranes. The erection can normally be made by usual building cranes at the building site.

Conclusion. The light girder with its thin web plate is a considerable departure from current Swedish steel standards. However, the Board of Building and Planning have for some years permitted the use of the girder and at present new steel standards are being prepared. The result from our practical and theoretical calculations at the universities together with the experience we have got during the three years that the beam has been manufactured will form the basis for the forming of new dimensioning rules.

The steel space frame as a practical approach to mass-produced closed-system construction

By J. Slayter (U.S.A.)

The following is a chronicle of a completed research and development program conducted under the direction of the author. The program was directed toward the development of a highly practical structural system for the factory mass-production of "closed system" residential and light commercial buildings.

Not included are the financial aspects of conducting such a program, nor experience in mass-manufacturing and marketing of the system, which is just commencing. Specific reference is drawn to other current mass-manufacturing in the United States of "closed system" residences.

"Closed System" for homes in the U.S.

Only 15% of the cost of a modern home in the United States is represented by the structural system. The remaining 85% of the home cost includes such "necessary" items as: floor covering, lighting fixtures, two or more complete bath facilities, central hot water systems, central heating, air conditioning, humidification and filtration equipment, automatic clothes washing and drying equipment, automatic cooking and baking equipment, garbage and trash disposal equipment, automatic dish washing equipment, refrigerators and freezers, complete high fidelity sound systems, paging and closed circuit communication systems, built-in color t.v., automatic radio operated garage door openers, remote relay electrical switching equipment, and in an ever increasing trend, draperies, furnishings, and other interior decorator items.

This trend to the inclusion of "environmental" items has become so extensive that the cost of the structural, or "shell" portion of the total home is lost in economic insignificance.

Competition continually forces the ratio for the "shell" proportion down. As an example, should a builder determine that a mechanical garbage disposal must be provided in his home to make it more desirable than that of his competitor, the addition of the disposal could add $ 26.00 to the total cost. In order not to increase his price, and consequently disqualify potential buyers, he attempts to engineer $ 26.00 out of the structural portion of his home, despite the fact that this portion has already been engineered to the limit of practical economies.

Some method must be found to reduce the in-place cost of the "environmental" mechanical and finish items. The builder himself is ill-equipped to accomplish this task. The major portion of this 85% cost is represented by the sub-contract of specialized mechanical and finish operations, and the direct purchase of "brandname" items over which he has no control.

"Closed system" technology concerns itself not only with the structural aspects, but also with the total environment created within the structure. This environment is by definition highly dependent upon those items of interior finish, decoration, and the mechanical systems from which it is created. It, therefore, follows that the economics of the composite total of structure and environment become the responsibility of the manufacturer of the system. Only through a "closed system" can the economies of mass production be applied to the environmental items which represent so major a portion of the total home cost.

Better "open system" techniques have little effect since even a 50% reduction in structural cost could only have a 7½% effect on total cost. (1/2 of 15%). It should not be concluded that a 7½% cost reduction is not significant, or that "open system" technology is not worth while in many areas, only that panelized "open system" methods of construction are now and will continue to be of less significance is the industrialization of residential structures in the United States, or other areas of the world, where similar trends towards luxury housing are taking place.

Although the reasoning behind the preceding argument has been based on the competitive aspects of a capitalistic economy, the true achievement being strived for is one of increased productivity which is a common denominator for judging any change in method.

Engineering freedom maintained throughout project

Few industrial research projects in housing are ever contemplated without undue orientation to a specific building material, manufacturing facility, or distribution system. In the belief that a complete home is a wise combination of materials and equipment chosen solely on their merits in achieving the most satisfactory end product at the lowest possible cost, no early liaisons were sought with basic building materials manufacturers or their associations. The personnel involved in the program were, therefore, allowed a degree of engineering freedom seldom found in other than a university atmosphere. This environment was maintained throughout the program.

Specific help was solicited and obtained from several major building materials manufacturers and associations, however, only after the suitability of their materials or services had been previously determined and justified by the program personnel. In no case was engineering accomplished purely for the sake of engineering excellence. In no case was any material or method pursued because of special promotional interest.

Objectives of program defined

Approximately 1/3 of the total research effort was expended in the establishment of program objectives and the performance requirements for the system that was to evolve from it. Two basic research program objectives were established:

- Design a structural system from which residential and light commercial buildings could be factory mass produced incorporating all of the internal environmental items appropriate to the end use of the building.
- Adequately test both the technology and practicality of the structural system through actual pilot plant manufacture of as many diversified residential and light commercial buildings as would be required for proof.

The following system performance requirements were established.

- In order to maintain a practical versatility, exterior and interior finish materials would be considered as esthetic environmental items and not calculated as structural components.
- To allow for freedom of interior partition placement, if any, no such interior partition could be considered structurally.
- In order to provide for maximum variations in building size, the span of the system would be the only dimensional limitation.
- To facilitate manufacture and transportation, the finished building would have to be divisible into economically transportable sections or segments.
- Each segment would be an individual structural entity deriving no additional support from its association with other segments.
- In order to minimize field construction requirements and, at the same time provide for the complete factory installation of environmental facilities, the manufactured unit would have to incorporate a complete floor system and as much of the foundation system as would be possible.
- Obviously the structural portion would have to be capable of meeting the majority of building codes, with respect to imposed loads.
- To insure maximum adherence to the principles of closed system construction, a figure amounting to only 10% of the total in-place cost, exclusive of land and landscaping, would be allowed for building site preparation, site foundation system, transportation, installation, and utilities connection.

Space frame most closely meets design criteria

The space frame was chosen for three primary reasons:

- 1. No interior supporting columns or partitions are considered.

– 2. As many space frames as required may be assembled to construct a building of unlimited size in one dimension, and limited only by the span of the frame in the other.

– 3. The floor system is automatically incorporated as part of the manufactured unit.

The first prototype space frame was created by combining a three-hinged arch with a floor truss. All members were standard dimension framing lumber connected by steel plates. Maximum advantage was taken of the bottom truss as both floor and foundation system to reduce the requirement for building supports. In this manner the site installed foundation system was simplified to four piers and two parallel steel "I" beams.

a) The 30′ span wood truss space frames were designed for 48″ on center placement, the standard United States building materials module.

b) Doubling of the frames at each 12′ module point allowed the completed structure to be separated into 12′ × 30′ segments for highway transportation. To allow sidewall materials to remain strictly environmental consideration, the plywood roof and floor sheeting was designed to resist all structural racking loads.

In compliance with program philosophy, all environmental items were capable of being installed within the structural segments.

Pilot model successful from functional standpoint

A complete four bedroom, two bath residence of 1,440 sq. ft. was constructed by this system in the spring of 1962. As four 12′ × 30′ complete structural segments, this pilot home was transported seven miles and site-installed in two days. The performance of the pilot was entirely adequate from a functional standpoint, thus giving substance to the theory behind the choice of the space frame segment. However, the wood truss approach to space frame design was completely unsatisfactory. Under constant static loading conditions the supposedly identical trusses all exhibited different deflection characteristics due to the inherently wide range of structural properties of the material "wood" itself. After undergoing the severe loads imposed by highway transportation it was extremely difficult to match one segment to the next. In addition, the steel plate connectors used to join the trusses, a common practice in wood fabrication technology, proved completely unreliable when subjected to these same shock loads and vibrations.

All steel space frame designed

As the result of the engineering data collected and observations made during the construction transport and erection of the wood frame prototype, definite criteria were established for the design of an all steel space frame. Steel was chosen for its high modulus of elasticity, making it possible to obtain the necessary stiffness in the space frame without resorting to excessive frame depths. In addition, the materials ability to withstand shock-type loads in excess of designed loads was a highly desirable factor in providing the necessary structural continuity to resist the abuse of factory handling, transportation and erecting. Of course, steel readily lends itself to mass production techniques.

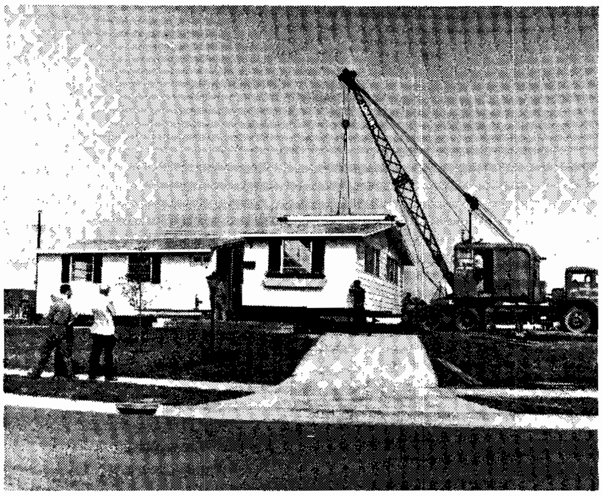

Fig. 1. Complete single family residence manufactured from a steel space frame. Site installation time; 3 hrs. 48 minutes.

At this point in the program, outside assistance was solicited from the United States Steel Corporation. Dr. Gerry Haaijer, chief of the Application Research Division of the Applied Research Laboratories at Monroeville, Pennsylvania, undertook the task of designing an all steel space frame incorporating the functions of rafter, sidewall and floor into one structural unit.

The basic technology of the steel space frame became relatively straight forward once the design requirements had been translated into specifications by Dr. Haaijer's group. In order to eliminate the requirement for frame doubling at the building segment division points, it was decided that all space frames would be, in fact, matched half-frames, thus allowing the building to be divided transversly in any multiple of four feet. It was also determined that the floor portion of the space frame should have a stiffness equal to three times that of the roof and sidewall portions. The same approach used throughout the entire program was also utilized in the design of the steel space frame; specifically, an objective of "optimizing cost, rather than a concentrated effort to minimize material."

An optimum combination of member size, material gauge, and yield point, was developed for all patterns of loading. The resultant design for a thirty-foot span space frame utilizes cold formed "C" sections throughout, $2\frac{1}{2}'' \times 6''$ roof and sidewall members are formed from twelve gauge, 50,000 psi yield material. The 3″ × 8″ floor member is formed from ten gauge 33,000 psi yield material. Two such frames are placed back-to-back to form the completed space frames. The frame is supported by the foundation system at two points on the floor member located a distance inward from the side members to take maximum advantage of the reverse bending phenomenon resulting from combination loading. Structural floor and roof plywood membranes are easily attachable to the light gauge space frames by power-nailing techniques.

Second protype building utilizes all steel space frames

In the fall of 1962 the first all steel space frame prototype building was constructed. A completely finished three bedroom, one bath home was transported from the factory to the field and installed in three hours and forty-eight minutes. None of the difficulties previously observed with the wood truss units were experienced with the new steel frames.

Thorough field testing

A program for the pilot-plant manufacture of fourteen additional buildings was undertaken for three basic purposes: First, to develop economic factors pertinent to mass production of buildings constructed from the system; Second, to develop the essential techniques of manufacture, transportation and erection that would enable the system to meet the design requirements; and Third, to demonstrate the versatility and adaptability of the system to various forms of residential and light commercial construction.

A four bedroom, two bath residence was manufactured from thirty-foot span steel space frames. The building was divided into five 8′ wide segments for highway transportation. This eight foot standard in width was adhered to for all additional buildings enabling the segments to be transported over the highways without special permission from authorities. Ten, low cost, residential buildings were constructed from 24′ span steel space frame segments. To develop the relationship of field-incurred costs with respect to overall in-place costs, these buildings were transported up to 70 miles and installed in most difficult terrain.

To demonstrate the versatility of the system in light commercial

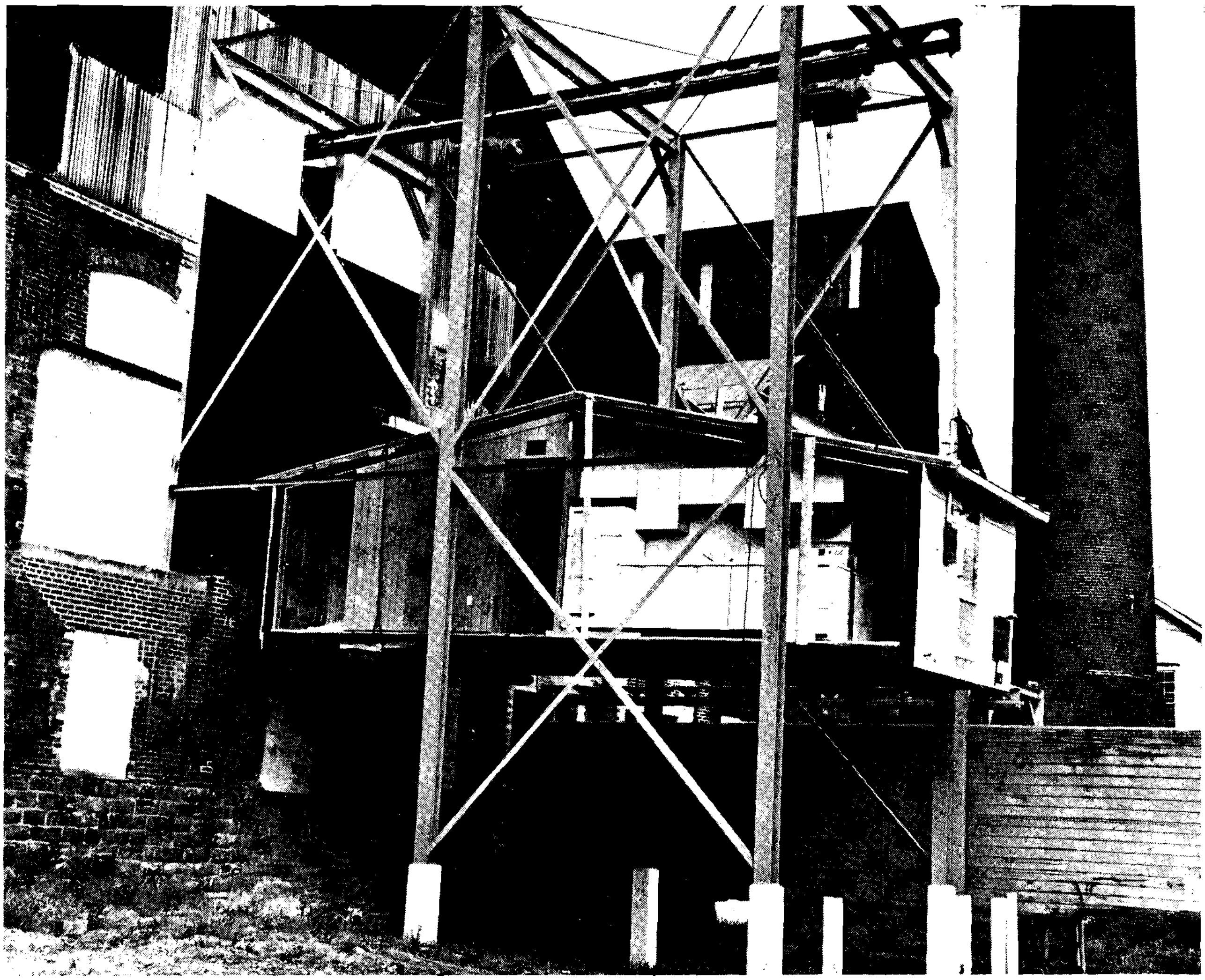

Fig. 2. Segment of steel space frame residence at factory. Complete kitchen is factory installed.

construction, two school buildings were manufactured and installed for use in a local public school system. The school buildings, containing two classrooms each, were manufactured from 30-foot span steel space frames and were divided into nine 8′ wide segments for highway transportation.

The field testing program terminated with the manufacture of a completely equipped office building, divisible into eight 24′ span × 8′ wide segments.

Results of field testing

During the manufacture, transportation and field erection of the sixteen space framed buildings, an abundance of valuable data was assembled regarding the mass production of buildings by this principle, as well as the overall economics of the structure as compared to construction by more conventional means. All buildings manufactured in the pilot program contained complete environmental facilities including one or more bathrooms, complete kitchens, and factory installed wiring and plumbing. Some of the buildings contained central heating and air conditioning plants, wood burning fireplaces, and complete interior furnishings. Excepting the first prototype, each building was completely field installed in less than one day. The most satisfying result of the field testing program was the portion of total cost incurred outside the factory: less than 11%.

Conclusions. It is the composite opinion of the personnel responsible for the program, and of the author who directed it, that the technical and economic practicality of a steel space-frame as the structural base for a "closed system" of construction has been definitely proven. It is felt that the practical and economic success of this particular steel space frame was achieved by optimizing total costs through analysis of the total product. An alternate and more common approach to the same problem, the engineering of each component individually to minimize material usage, would not have produced a satisfactory total system. It should be pointed out that total cost optimizing is achievable only when one organization has complete responsibility (design, engineering, manufacture, transportation and finance), for the total product, in-place and ready for use.

The wide acceptance of such a system, or buildings constructed to such a system, will be dependent only on the development of the proper distribution and sales organizations. In the United States tremendous momentum has been generated in the direction of "closed system" construction by the mobile home industry which is now producing in excess of 200,000 new, complete, single family residences each year. It is obvious that the integration of the much more versatile space-frame system into this already significant and growing segment of the construction industry, will be one of the next logical steps towards industrialised building.

Materials engineering as a tool in the industrialisation process

By T. Sneck (Finland)

Background

Today, the builder can choose among a vast amount of building materials and an infinite number of trade marks. The abundance of materials is an advantage, although the situation as a whole is not quite satisfactory. Owing to the lack of fundamental knowledge, some new materials may not be used at all, or are being used incorrectly. Both unhealthy pessimism and unwarranted optimism exist simultaneously.

The development of atomic energy, electronics and the flight into space provide examples of important things happening in other fields of endeavour. These achievements have been rendered possible by virtue of the tremendous development of materials. The difference between the building industry and these new enterprises is outstanding, but it may be said that the building industry has not as yet confronted the same kind of emergencies with respect to materials technology as some other industries.

Materials engineering

The traditional attitude towards materials consists of adapting a given material to a certain use, if necessary by force. For many reasons, even today this is the major trend in the building industry, but a change in the way of thought is slowly taking place. The old materials-minded orientation is being replaced by a new properties-minded orientation. For a given environment and function, there must be chosen a material with the right properties. The performance of the material in ultimate use, the end-product performance, is the determinant for the evaluation of materials. Within these sentences are outlined the general principles of materials engineering.

The scientific approach is based on the fact that all the properties of all materials depend on their *microstructure*, and as a result the science of materials is capable of treating the field of materials as a whole. The boundaries between different materials are broken down, and the foundation has been laid for a treatment based on properties.

A material has to fulfil the *functional requirements* of the building element concerned. A material possessing the optimal properties can be chosen only after a careful analysis of all the factors which affect the material in the conditions of use. Major emphasis has to be laid on the study of favourable and detrimental physical and chemical *processes* which may take place in the material. Both the properties of the material and its environment must be known before a successful engineering synthesis is possible. At this stage, there must also be considered *design*, methods of *application* and *economic factors*.

Knowledge of the properties of materials in different environments on the one hand, and the functional requirements on the other, results directly in the possibility of creating products with the highest degree of performance in a particular building or building element. The development of *tailor-made materials* is one of the highest aims of the study of materials engineering.

It is interesting to note how the vast machinery of different procedures for acceptance of, and agreement on, new materials or products works. A product enters the market, and research and materials testing procedures are then applied for evaluation of the material. Materials engineering operates in the reverse manner.

Impact on research

The acceptance of materials engineering as the dominant factor in the field of materials lays a heavy burden on building research. The main questions in such research are:

- why do materials possess their actual properties?
- how do they perform in different environments?
- how can the knowledge of these factors be combined most usefully to secure the fulfilment of the functional requirements of a material in a building element?

As was pointed out above, the relation of the properties to the structure of the material needs clarification; the end-use conditions have to be analysed with the micro and macro factors influencing the material taken into account, and an analysis is necessary of the different processes which may occur in the material. The knowledge thus obtained can be used in the selection and evaluation of existing materials and, particularly, as the basis for materials development.

Many of the problems involved are more or less unknown: a great deal more has to be learnt of the properties of materials and environments, and their interaction. The lack of knowledge is in some cases surprising, and often frightening.

The organization of materials research may bring about difficulties. There are well organized research laboratories for old materials, concerned with one-material research. These research institutes are often in a dominant position, and a research worker trying the materials engineering approach may find himself in difficulty with his denial of material boundaries. New materials are sometimes forced to start direct on the path outlined above, which may soon result in the acquirement of more basic data for these materials than for old ones. An interesting development is taking place as old one-material research centres start on the new path. This may lead to valuable results.

Materials research, and even the development of materials, is no longer a research object for the materials industry alone. If purely economic facts are taken into consideration, this research may sometimes become too heavy a burden for the industry. Against this, in some instances the industry may not be interested in research objects where the results may lead to the development of materials which will occasion difficulties in the marketing or the use of traditional materials. The principal building research organizations are thus faced with the fact that they must enter the field of materials development.

The development of the building industry needs dynamic and imaginative building materials research, with the fact being accepted that materials engineering simultaneously emphasizes both the need for basic research and the importance of engineering. An advanced formula for the transfer of one particular item from one condition to another is insufficient, but the means for practical applications must be discovered by the materials engineer.

Industrialisation

A rational materials engineering approach will prove a very valuable tool in the industrialisation process of the building industry, as to a very high degree this approach exerts an influence upon technology at all stages of the building process.

Nowadays, building materials research is lagging behind, but the situation must change. The development of materials cannot be foreseen but the rate of development might be forced. Materials engineering will be the dominating approach in other industries which use merely a small fraction of the tremendous amount of materials utilized by the building industry. If the same principles are accepted by the building industry, building materials researchers could be given the task of acquiring more basic information for the evaluation and creation of materials intended for a building process, of a higher degree of industrialization. This means that building materials research must be assigned to work with problems which have a closer connection with the future than with the problems of today or yesterday. A new materials technology suitable for industrialised building has to be provided by building materials research.

The following table summarizes the opinions expressed in this report on the different stages of the approach to materials engineering:

Functional requirements. Clarification of the end-use conditions. Analysis of all factors which may possibly influence the material in use. Drafting of general specifications for materials required.

Materials research. Establishment of the dependence of properties on structure. Investigation of the chemical and physical processes which affect the properties of the material. The results are employed to evaluate, select, modify and create materials.

Design. Consideration of the influence of the design of the building element. Estimation of the possibility of changing the end-use conditions by adapting new engineering design methods.

Application. Consideration of the methods of application taking into account special problems such as winter construction, mechanization etc.

Processing. Realization of the project by the building materials industry.

Building. If all stages of the process outlined above are carried out with the aim of getting the results most suitable for industrialised building, the products — from materials to building elements or prefabricated buildings — will contribute towards the industrialisation of the building process in general, and/or at a particular building site.

Remarks. The stages outlined are not independent, but continual interaction is necessary during the research and development stage.

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Constructional uses of lightweight aggregate concretes

By J. Ujhelyi (Hungary)

This paper is intended to survey knowledge available on lightweight aggregate concretes, and to outline possibilities of further development. A basis for this is created by the development of sand and gravel concrete.

Principal stages of the extension of sand and gravel concrete can be defined as:

a) Production of a binder (cement) of convenient quality;

b) Determination of the effect of aggregate properties;

c) Solving composition design problems, i.e. elucidating effects of water/cement ratio and compactness;

d) Development of special tools for concrete making (mixers, transporting and compacting equipment).

e) Extension of field of use by determining specific characteristics (deformation, elasticity, resistances against corrosion, freezing, and wear etc.) and by developing specific concrete types (no-fines, pre-pact, gunite, colcrete etc.)

Development conditions of lightweight concretes are similar to those for sand and gravel concretes. A difference however, involving difficulties, is that for lightweight concretes both density and strength are to be considered as equivalent characteristics.

Binder demand of lightweight concretes

Without aiming at completeness, it can be concluded that for normal sand and gravel or crushed stone concretes at 100 to 500 kg/sq. cm of compressive strength, "ordinary" Portland cement characterised by an earth-moist mortar strength of 500 to 600 kg/sq. cm (plastic 350 to 450 kg/sq. cm) is convenient. For these concretes, loads are carried essentially by aggregate skeleton, aggregate inherent strength exceeding significantly cement mortar strength.

It can, however, be demonstrated that for lightweight concrete structures, load bearing capacity of the cement mortar skeleton is of primary importance, aggregate inherent strength being sometimes no more than a few kg/sq. cm (1). If therefore maximum strength for a given concrete density is to be ensured, concrete is to be made with a high cement dosage or with a special high-grade cement. The lightweight concrete industry needs cement of a greatly increased strength (800 to 900 kg/sq. cm when tested in earth-moist mortar). Relevant basic relationships are plotted in fig. 1 (1).

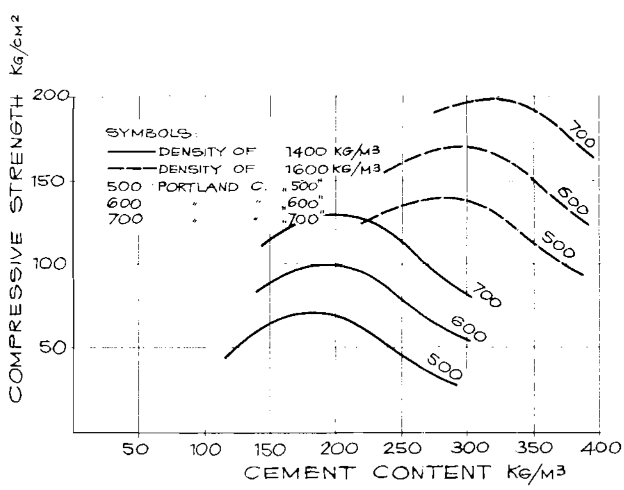

Fig. 1. Relationship between cement content, density and compressive strength of foamed slag concrete, for variable cement grades.

Lightweight concrete aggregate quality

Sand and gravel concrete aggregates are characterised by grading, inherent strength, particle shape and surface characteristics. Their qualities are properly defined by fineness modulus and specific surface area. As basic principle, development of an aggregate skeleton with minimum voids, using a relatively low proportion of fines, is required.

Lightweight concrete aggregates are characterised by grading, strength, bulk density, particle shape and surface properties. The effect of these characteristics is known from the relevant literature(2), (3), (4); nevertheless, up to now, aggregates with optimum characteristics could not be obtained. The author feels that these requirements can be met by expanded clay of a relatively high production cost: for a high inherent strength it has a low density, rounded particle shape and a relatively smooth surface.

Relationship between bulk density and inherent strength – defining at the same time field of uses – is plotted in fig. 2 (5). It appears that further work is needed to increase inherent strength and to reduce at the same time bulk density.

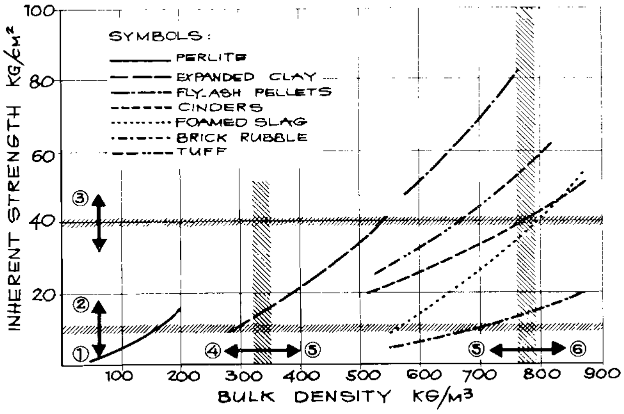

Fig. 2. Relationship between bulk density of aggregate 7 to 15 mm size and its inherent strength determined by compressibility.
1) Aggregate convenient for concrete of a compressive strength of $\sigma \leqq 35$ kg/cm^2
2) σ = 50 – 140 kg/cm^2
3) $\sigma > 140$ kg/cm^2
4) Aggregate convenient for concrete of a conductivity coefficient $\lambda \leqq 0.25$ kcal./m.h. °C
5) λ = 0.25 to 0.65 kcal/m.h. °C
6) $\lambda > 0.65$ kcal/m.h. °C

Lightweight concrete design

After having developed relationships for water/cement ratio and compactness, gravel concrete composition can be designed with exactness after the method of Feret and Bolomey. For lightweight concretes, strength cannot be determined by water-cement ratio due to the aggregate water absorption, nor by pore volume due to the variable proportion between bulk voids and grain pore content. There are cases where these factors have contradictory effects, there being desired a low density and a high strength.

The author feels that – for given cement and aggregate grades – lightweight concrete strength and density are characterised by workability coefficient and pore volume of cement mortar, hence a design can be based on these factors (6), (7). Workability coefficient (B) is the product of cement content (C) by compaction degree (t). Compaction degree is most simply to be determined from the ratio between bulk density of concrete mix (γ_K) and density of compacted fresh concrete (γ_B) as

$$t = \frac{\gamma_B - \gamma_K}{\gamma_K} \cdot 100,$$

the workability coefficient being $B = C \cdot t$.

Besides design we must consider aggregate bulk density and proportion of fines 0 to 1 mm size. A complete design nomogram developed for foamed slag concrete is shown in fig. 3 (6).

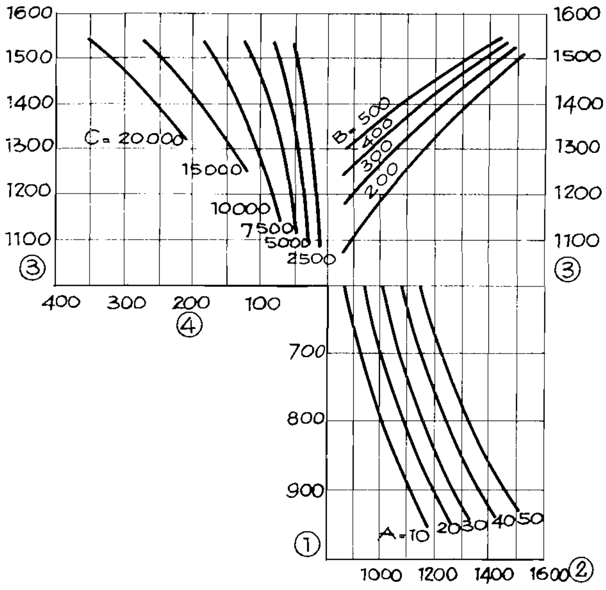

Fig. 3. Design nomogram for foamed slag concretes
1) Bulk density of particles 7 to 15 mm size, kg/m^3
2) Bulk density of mixture 0 to 15 mm size, kg/m^3
3) Loose bulk density of concrete mix, kg/m^3
4) 28 days compressive strength, kg/cm^2
A. Percentage by weight of fines 0 to 1 mm.
B. Cement content, kg/m^3
C. Workability coefficient

Concrete making tools

For particular lightweight concrete products a lot of mixing, conveying, compacting and moulding tools have been developed. These equipments permit an industrial production of units ranging from low-size masonry units to large slabs or even box-like houses and from special insulations to high-strength structural units. Equipments meeting optimum product quality requirements cannot ,however, be developed before conclusively defining basic characteristics.

Extension of field of uses

Fields of uses can be classified in a well-known manner. According to Hungarian specifications lightweight concretes can be either thermal insulating, $\lambda \leqq 0.25$ kcal/m.h. °C, $\sigma \leqq 35$ kg/sq. cm; or mixed thermal-insulating-structural $\lambda \leqq 0.65$ kcal/m.h. °C, $\sigma \leqq 140$ kg/sq. cm; or structural $\lambda > 0.65$ kcal/m.h. °C, $\sigma > 140$ kg/sq. cm.

Limiting characteristics of lightweight concretes to be obtained according to actual knowledge are: a minimum of $\lambda \approx 0.06$ kcal/m.h. °C, and $\sigma \approx 5$ kg/sq. cm and a maximum of $\sigma \approx 600$ kg/sq.cm and $\gamma \approx 1800$ kg/cu.m. As to most important concrete characteristics, reliable data are available on deformability, on corrosion resistance, on elasticity, on flexural strength, on reinforcement bond and on thermal resistance.

The following conditions are of importance in order to extend the field of uses:

– In the field of *research development* of industrial production of a high-grade binder, of a low-density, high-strength, rounded grain aggregate; development of a uniform method for concrete composition design, and definition of specific concrete characteristics.

– In the field of *design development* of building types and structural systems for which materials corresponding to the above limits are needed and of economical use.

– In the field of *construction* an attempt to minimise scatter, finding optimum mixing and compacting conditions, meeting special requirements, or to develop specific manufacturing technologies.

Principal possibilities of use are (in order of importance): In building construction, masonry units or in-situ monolithic wall structures, insulating units or in-situ thermal insulating concrete. In regions lacking natural aggregates, high-strength concretes for building and civil engineering construction. Concrete for chimney stacks, thermal resistant and refractory concretes. Insulation of pipelines, sound absorbing cladding, filter concrete, lining concrete, fill concrete for bridge structures, paving concrete, prestressed concrete etc. Their utilisation in these fields could be afforded by detecting or improving specific properties.

Conclusions. Lightweight concrete development perspectives can be estimated on the basis of binder consumption for lightweight concretes, of aggregate requirements, of the development stage of concrete composition design methods, of production tools, as well as by analogy of sand and gravel concrete development. Correspondingly, conditions of increased use and of improvement of lightweight concrete properties are as follows:

a) providing a high-grade cement;
b) increasing aggregate inherent strength and at the same time reducing density;
c) development of a design method for lightweight concrete composition based on the workability coefficient and on the mortar pore volume;
d) detailed investigation of particular properties;
e) developing specific production methods.

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A. Wadowski

Multi-storey partly durable buildings (BCT), as a means of lowering primary costs of residential building investment

Basic conceptions of BCT and the economical comparative criteria

By A. Wadowski (Poland)

The problem presented in this study was initiated by the Designing Committee of the Polish Association of Building Engineers and Technicians in connection with the works of the XIVth Problem Conference of the Association, devoted to the problems of lowering investment outlays on building. Then, in 1964, the problem was taken up by the Institute for the Organization and Mechanization of Building in Warsaw.

This study is an attempt at determination of economical conditions for programming of technical realization of erection of partly durable multi-storey residential buildings. The introduction deals with the basic notions and description of partly durable building as the building which fills the gap between the durable (capital) and temporary (provisory) building. The aim of this type of building is to lower the primary cost of the investment, to change the use and structure of building materials and in result to put off the burden of full outlays for about 30 to 40 years.

Basic notions and dependencies

To each residential building the following traits can be attributed:

1. technical duration, 2. usable duration. The autonomous notions are: 1. technical wear and 2. social wear.

Modern multi-storey residential buildings are erected from durable materials. Their technical duration is limited by the unchangeability of technical and structural properties of ceramics, concrete and steel. Practically, the duration is of many centuries. Technical wear shows in the secondary elements such as: installations, floors, woodwork etc. and is counteracted by conservation and repairs. The period of technical wear has been accepted as 100 – 120 years. The usable duration of a residential building depends on: a) technical duration, b) concurrence of usage conditions with social requirements, i.e. user's requirements.

The usable duration decreases in time because of the increase; i.e. the social wear* comes in. The social wear can be counteracted by the modernization of the building. We can assume that the usable period, that is the period during which the social wear will appear, is within the 25 – 40 years limits (the age of one generation period of productive ability).

The comparison of the periods of technical wear (100–120 years) with the period of usable duration points to a disproportion in the buildings under discussion. Contrary to permanent buildings, the temporary buildings erected with materials with limited technical duration, such as timber, timber-derived materials etc. have the period of technical wear close to the period of usable wear. But by technical-material conditions they are limited to one or two storeys. Such a low build-up is uneconomical from the point of view of urban development (low exploitation of sites, lengthening of thoroughfares, of network of city installations etc.) The basic property of multi-storey partly durable buildings (BCT) is the division between the durability of structural skeleton and of filling elements. Main repairs consist in removal of old filling materials and filling up the structural skeleton anew. Such repair allows complete modernization of interiors and this modernization can be included in the costs of general repairs, because it does not require any structural changes. We can assume that the modernization may entail installation of new appliances or fittings not used before (e.g. air conditioning). Filling with materials of limited technical durability allows a certain lowering of primary costs. In result, we achieve a temporary coincidence of technical and social wear of the building; in other words there is an outlay of appropriate funds in reasonable time instead of investing for 100 years without the guarantee of full usefulness of the investment in 30 or 40 years.

Principles of the partly durable building

Building elements of multi-storey buildings are divided into two kinds:

1. Durable elements of the structure that decide the safety of the building – that is: vertical bearers, floors, stiffenings and the structure of the communication of building i.e. structural skeleton.
2. Filling elements that decide the conditions of durability.

– Durable elements have to be made from durable materials and therefore we assume their technical wear for 100–120 years;

– Filling materials may be made from materials of limited durability, near to period of social wear (25–40 years);

– The use of materials of limited durability may lower the primary cost of the investment;

– As the criteria of profitability of partly durable building we have accepted full investment costs on durable buildings as discounted on the first day of exploitation;

– We assume that technical designs of partly durable buildings must ensure the unchangeable exploitation costs in comparison to durable buildings.

The character of investment costs

The investment costs on residential building consists of three groups:

a) initial cost of the investment,
b) cost of periodical and main repairs,
c) modernization costs.

The analysis by the TERN (Technical-Economical Scientific Council) for residential buildings in Warsaw proved that in the period of technical durability of modern buildings, i.e. in 100–120 years, the repair costs amount to 100–115% of the initial cost of the investment. The repair costs include the removal of technical wear of finishing elements of the building and small modernization without any structural changes i.e. in electrical fittings, plumbing etc. The lay-out in time of costs for multi-storey buildings with modern structure is illustrated by fig. 1.

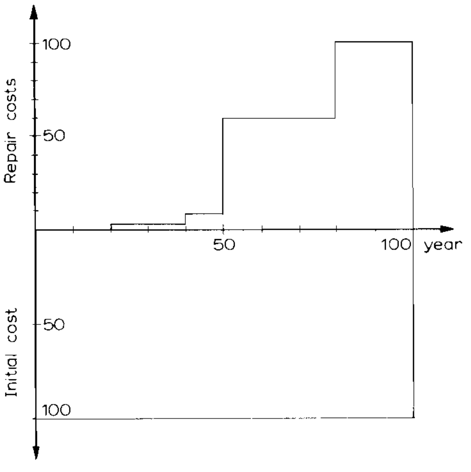

Fig. 1. The "normal" lay-out in time of investments costs.

The outlays for main repairs are connected with the return to primary technical durability. When the system of complete exchange of filling of the building is applied – which tallies with the finishing and fitting works – the outlays can include the modernization of usable area of apartments. New appliances, mechanisms etc. used for modernization increase the usable value of

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* By analogy it can be compared to the outdating of machinery in industry.

an apartment and it seems right to exclude from the comparative analysis the additional costs of modernization, as:

1) It is difficult to foresee;

2) Its size and kind will be decided on by the next generation.

The initial cost of the investment in partly durable building can be approximately assessed as 5–10% lower than in durable building.

Comparative analysis of investment costs

1. The analysis accepts as basic the joint consideration of initial costs and repair costs. The joint discounted costs are determined by discount on the data of the first day of exploitation according to the expression:

$$N_S = N_P + \sum_{i=1}^{i=m} N_{R_i} \left(\frac{1}{q}\right)^{n_i} \tag{1}$$

where

N_S — discounted costs

N_P — initial investment costs

N_{R_i} — successive repair costs

$i = m$ — number of successive repairs

q — rate of percent of the costs (discount) and n_i — percentage period.

The analysis is carried out by comparing the discounted costs of BCT* (indicated by N_S^{I}) to the discounted outlay of BT** (indicated by N_S^{II}) This proportion constitutes the criterium of profitability (effectiveness) of BCT in comparison to BT. The point of profitability (effectiveness) will be the value of criteria answering the appropriate discounted costs. Hence the postulate:

$$K_0 = \frac{N_S^{I}}{N_S^{II}} \cong 1 \tag{2}$$

2. Examples of calculation of discounted costs.

For BT the formula /1/ transforms through suppositions

$$\frac{N_{R_i}}{N_P} = a_i$$

$$N_S^{II} = N_P \left[1 + \sum_{i=1}^{i=m} a_i \left(\frac{1}{q}\right)^{n_i}\right] \tag{3}$$

Accepting the lay-out of outlays as in fig. 1, described as normal lay-out and e.g. $q = 1.03$ we determine the value N_S^{II}

$$N_S^{II} = 1.1909\, N_P$$

To determine the discounted costs for BCT we have to pose the question; what will be the lay-out in time of investment costs? According to principles:

- The volume of successive repair outlays is permanent;
- The relative repair costs have been accepted as equal to the share of finishing works of about 50% of the initial cost of durable building (difference between N_P^{II} and N_P^{I} equals the demolition costs)
- The repair period is near to the period of technical wear of filling (two variations of 30 and 40 years are considered);
- The lowering of N_P has been accepted as 5–10% while the lower value should be related to a longer period of technical wear.

The lay-out of BCT is illustrated in two variations by fig. 2

$$N_S^{I} = bN_p + \sum_{i=1}^{i=m} N_{R_i} \left(\frac{1}{q}\right)^{n_i} \tag{4}$$

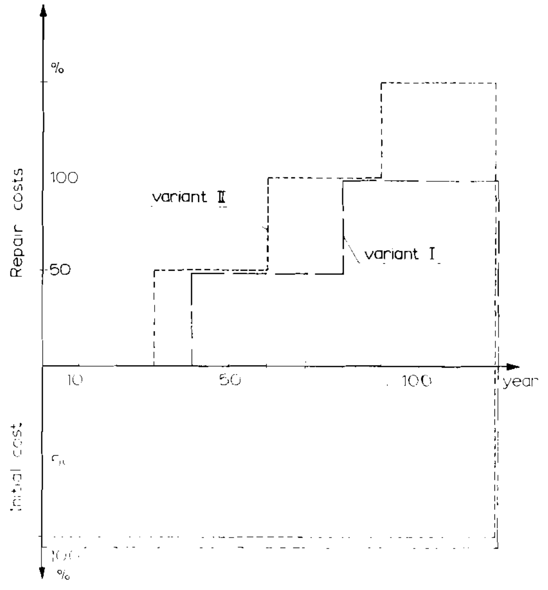

Fig. 2. The "BCT" lay-out in time of investments costs.

where $b = \frac{N_P^{I}}{N_P}$ and on substituting $\frac{N_{R_i}}{N_P} = a_i$ we obtain

$$N_S^{I} = N_P \left[b + \sum_{i=1}^{i=m} a_i \left(\frac{1}{q}\right)^{n_i}\right] \tag{5}$$

On accepting for $q = 1.03$ for both variations ′ and ″ we obtain

$$N_S^{I\prime} = 1.154\, N_P$$
$$N_S^{I\prime\prime} = 1.234\, N_P$$

On checking the criteria of profitability we obtain

$$K_0' = \frac{1.154\, N_P}{1.1909\, N_P} = 0.97 \quad K_0'' = \frac{1.234\, N_P}{1.1909\, N_P} = 1.03$$

When the BCT building is considered in a definite investment plan the solutions $K_0 > 1$ have to be also taken into consideration. These solutions may be profitable when the increase of national income is taken into account. We have to remember that at the 0.07 angle of increase, the national income doubles every 10 years. Such operation could be called a "loan" from the coming generation.

Conclusions. BCT can be realised in the given economical conditions but certain methods of erection of structural skeleton have to be used and the experiences of temporary (provisory) building, as to the use of building materials of limited durability, exploited. The preferred solutions is the pole-slab skeleton realised e.g. according to engineer J. Osterman's system (Warsaw) or engineer Branko Žeželij's (Belgrade) system or the system of skeleton with lift slab floorings because of facility of transformations of building interiors. The economical effectiveness of BCT depends to a large degree on long-term economical planning. BCT may prove of special usefulness in time of sudden increase of demand for residential resources and limited investment means. It certainly has certain advantages over the durable building as far as the possibility of modernization is concerned.

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* BCT – Partly Durable Buildings

** BT – Durable Buildings

G 18

H. Waisblat

French experience in the use of stainless steels for the industrialised construction of sashes, roofing and façades

By H. Waisblat (France)

The use of stainless steels in architecture has shown over the past few years important and original developments in France. Such successes are not due to a passing fashion but reveal significant and irreversible progress in the art of building.

Steel has always been used for the covering and trim of structures to assure long life which is a prime consideration of all architects. However, manufacturing technique has limited its use in practice, for several decades, to prestige structures in the United States. Façade coverings of a few New-York skyscrapers in the thirties, such as the Empire State Building and the Chrysler Building illustrate this period. To-day, in France, stainless steels are no longer considered as luxury materials and enter into the composition of façades and roofing of many buildings, due to architectural design ideas perfectly adapted to the material and to appropriate workmanship techniques.

Stainless steels

Manufacturers make available to the builder two sorts of stainless steels, as follows:

a) *Ferritic alloy steels* with chrome only (17%) which are always magnetic, not hardened by tempering, with only moderate hardening when cold worked. Ferritic alloy steels are used for roofing and interior decoration.

b) *Austenitic alloy or 18-8 steels*, chrome nickel, which are more corrosion resistant and are not magnetic in a tempered state. They are used for all façade applications.

Of all metals used, stainless steels are the only ones to have all the characteristics of a metal perfect for the architect. Among these we may note, in particular, the following:

– Resistance to corrosion: the presence of a "film of passivity" which is invisible, non porous and stable, created with the oxygen of the air on the metal, due to the action of the alloy elements, confers a true unoxidizing quality to the mass. Behavior of stainless steels in rural, city and industrial surroundings is to-day recognized through studies in experimental stations (tests over long periods), and confirmed by examination of buildings, the oldest of which, in France, are from to 25 to 30 years old. For example, in Paris, in the air around the Saint-Lazare railroad station, the windows of an office building put up in 1937, are still shiny after simply being cleaned with pumice powder.

Fig. 1. EDF building, Paris. 800 window frames in stainless steel, erected in 1937, and undergoing cleaning.

– Excellent mechanical characteristics: all such grades of stainless steels have mechanical characteristics appreciably superior to those of other metals currently being used in architecture. For example, 18—8 steel, the most commonly used, will have a tensile strength of between 55 and 65 kg/mm^2 in an annealed state, and a yield point over 20 kg/mm^2 with an elongation before breaking over 45% for a tensile modulus of 19.700 kg/mm^2. Such characteristics make it possible to use lighter thicknesses than for other metals with consequent savings.

The why and how of using stainless steel

The builder benefits from a large number of advantages, as follows:

– due to their rust resistance, stainless steels may be used with any other materials or metals. They, therefore, make it possible to work out, in an easy manner, all problems of contact. There are no worries about galvanic phenomena with other metals, nor chemical reactions with the cement of mortar or concrete, or the various mastics and jointing products. The absence of rust makes it possible to avoid run-outs and damage to adjacent materials.

– their excellent mechanical characteristics make possible, however, due to exceptional malleability, easy shaping, using the most highly industrial techniques such as shaping with roller machines, press shaping, stamping, etc...

– their low expansion factor, particularly for the chrome alloy steels ($10.6 \times 10^{-6}/°C/m$) very appreciably reduces movement due to temperature variations, and this feature is particularly of advantage for roofing.

– their high resistance to abrasion, the highest of any metal used in architecture, and the hardness of stainless steels makes them the preferred metal for all items subjected to intensive use, such as working surfaces, hand-rails, plinths, doors and vertical coverings for streets and passageways.

– easy maintenance makes it possible to preserve the beauty of the metal at little cost over many years without using a protective coating. Washing is only to remove soot deposits and, in many cases, rain does this naturally.

All these features are advantages of this material. However, since it still remained expensive, it was made competitive due to the success of research carried out with a triple objective, to;

– use stainless steel in the lightest thicknesses possible

– reduce labour requirements

– adapt cost computing methods.

Thicknesses between 0.4 and 1.5 mm are currently being used. Such thicknesses require appropriate techniques. The lower limits in seeking to decrease thickness are attained by conditions of appearance rather than by conditions of mechanical strength in general i.e. problems of optical distortion become of prime importance with thin elements and one must know how to avoid architecture that looks like the tin-foil wrapping of a chocolate bar. In order to make defects disappear in evenness it is advisable to design pieces whose flat portions have a width to thickness ratio which is not too high and properly selected in terms of the finish of the surface. In practice, the metal sheet has to be stiffened by grooves or pressing, or by curvatures of large radius, or by fastening to a support such as a panel of wood or fiber, of rigid foam or of concrete. Various techniques thus make it possible to use stainless steel with a thickness of as little as 0.4 mm for covering large façade areas.

A considerable reduction in labour costs for stainless steel items has been obtained for surface treatment. In particular, the placing on the market of prepolished stainless sheet i.e. given a satin finish at the plant using automatic machines, makes possible the manufacture of items without reworking the surface of the metal following shaping. Hand polishing by costly labour may, therefore, in many cases, disappear since the cost of polishing on an industrial basis, for large surfaces, may be up to 10 times less than that of polishing by hand. However, the use of prepolished sheet requires greater care at time of shaping. So as not to scratch the metal, various protective techniques are used. In addition, some methods of assembly, particularly by welding, should be avoided because this may require costly refinishing, thus losing all the benefits of prepolishing. It is therefore advisable, from the design stage on, to make allowance for the use of prepolished sheet.

Finally, where a material is new, the calculation methods selected to arrive at a selling price are those for similar materials. This can result in serious errors. It is absolutely necessary to calculate the installation cost accurately and realistically. Simple methods of calculating selling prices used, such as factors applied in percentage on the basic price of the metal are to be rejected. Only an accurate revaluation of the actual cost prices should be used.

Accomplishments in France

Typical applications of stainless steels are now described.

Roofing. There exist to-day in France over 400.000 m^2 of buildings covered with chrome alloy stainless steel 0.4 mm thick. Such recent development – the first roofs were placed ten years ago – is, qualitatively as well as quantitatively, something new. For roofing of upright joining or cleat type, stainless steel is used in strips of a single length per slope assembled either on cleats with cover-strips or with upright joints crimped with pliers. Special very simple tools have been developed to execute this, and all roofers who know how to use metals are to-day able to execute stainless steel roof structures. The long strip makes it possible to reduce roof slopes and reduce installation time. There also exist preshaped stainless steel roof panels, completely fashioned at the plant, using a press or a roller machine. They are supplied in long lengths at the job and installation is very simple.

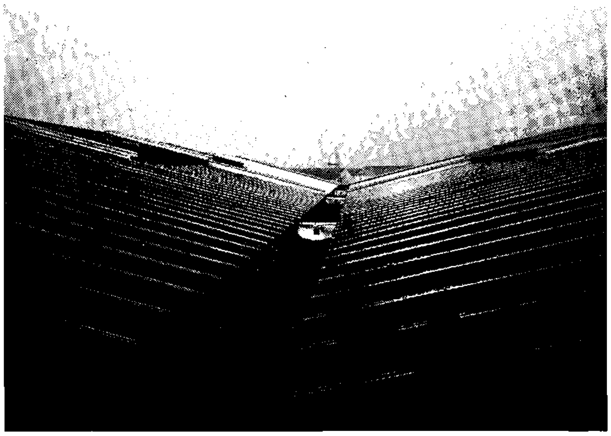

Fig. 3. Use of stainless steel in roofing.

Joinery and façades. As opposed to the case of roofings, 18–8 steel is always used for façades, since it is the best adapted to functional requirements. There are to be found on the French market, all types of sashes made of 18–8 steel at competitive prices. Made from thin strap (0.7 to 1.5 mm), the shapes of which it is made up are obtained either by pressing or roller shaping and owe their rigidity to their design or tubular section. Assembly of such shapes is a specific problem of the material, which is treated by manufacturers according to various techniques at present perfected to a considerable degree.

The techniques of light façades are particularly indicated for

Fig. 2. Pliers for closing upright joints.

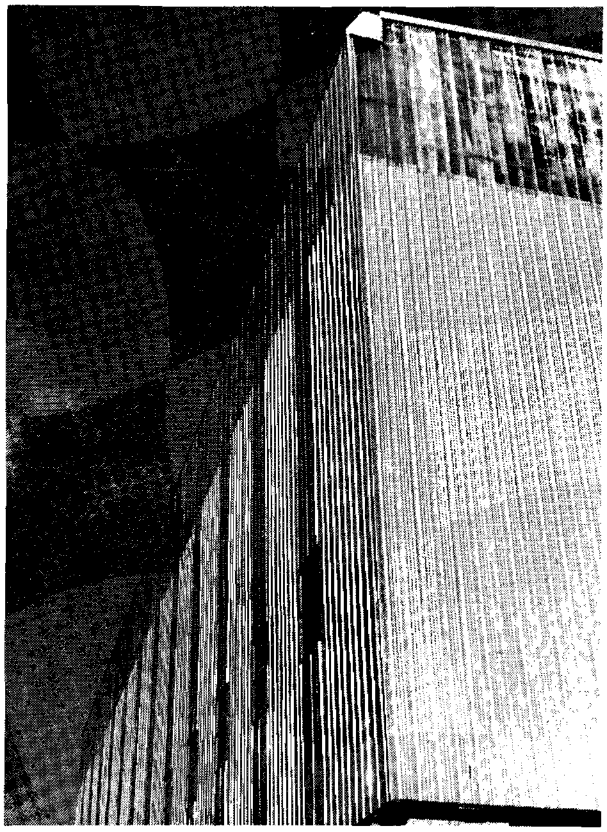

Fig. 4. Industrial building at Montoir-de-Bretagne (France), showing prefabricated stainless steel sheet.

stainless steel, either as a structural or trim element, or as panel covering. At the present time there exist in France over 100,000 m^2 of façades using stainless steel to an appreciable degree.

In the form of panels, several types for low cost housing have been used. For example, the Tracoba process consisted of manufacturing, at the plant, panels with a stainless steel exterior skin, with insulation made up of polyurethane foam injected and solidified. Another example is the case of three tower buildings at Bagnolet, Seine, for which the masonry contractor used heavy type panels, pouring reinforced concrete into a very thin stainless steel box, the bottom of which, forming the façade, was provided with fine pressed grooves, then received panel insulation. Such first examples of the use of stainless sheet steel, associated with reinforced concrete elements, prefabricated at the plant or at various working sites open up a field of interesting possibilities in association with conventional materials.

Finally, stainless steel is at the service of industrial architecture for roofing, large-size eaves gutters and particularly siding. Siding consists of thin panels (0.4 to 0.6 mm), very long, which may be installed very rapidly.

Conclusion. Thus, development of the use of stainless steels for construction was only made possible due to correlative progress made in getting building on a production line basis, and this material resulted in new requirements and new possibilities. Stainless steels lend themselves very well to production manufacture. Items turned out in this way are accurate and easy to install. The only reservation we might have, regards the rules for manufacture and installation, specific regarding the material, which should be followed so as not to damage the surface when it is being handled. Progress in the use of stainless steels in architecture is rapid. A recent market survey made in the United States came to the conclusion that the building trades were going to consume more than the automobile industry. This trend begins to be noticed in France with present-day application of the material.

Tests on lightweight concretes and the design of buildings

By R. Wieloch (Poland)

The author of this paper gives the results of testing and experiments on two kinds of lightweight concrete;

1. No-fines concrete (hollow concrete)

2. Structural concrete on lightweight-aggregate.

For both kinds of concrete, new design methods of composition at fixed strength were applied which have been tested in laboratories in the building industry. Also, for some of these concrete mixtures the thermal insulation properties have been tested and examined.

Laboratory investigation tests on these concretes have been made in the Concrete Plant at the Gdańsk Technical University during the years 1958 to 1963 and on various building-sites in North-Poland (district of Gdynia–Gdańsk–Bydgoszcz).

Test procedure and results

No-fines concrete (hollow concrete)

No-fines concrete is composed of one or two-sizes aggregate fraction and cement paste, which should ensure the agglutination of each particle of aggregate. As to no-fines concrete two rudimentary requirements must be met, i.e. sufficient strength and assurance of adequate thermal insulation. When applying aggregate of a constant self-porosity we can regulate the quantity of holes throughout the mass, independently of the volume of the aggregate holes or the quantity and combination of fraction, as well as independently of 'hole fill' and compaction of the fresh concrete.

The main feature of no-fines concrete consists of the ratio of cement paste quantity to the real 'holes-quantity' of the aggregate, which in case of hollow-concrete contains no sand or fine aggregate. This relation we call the "filling modulus" of aggregate holes with cement paste, and it can be expressed by the formula

$$\varphi = \frac{V_c}{V_h} = \frac{C/G_c + W}{V_h}, \qquad \text{where}$$

C = cement (kg)

G_c = specific gravity of cement (3.15) W = water

V_h = volume of holes

$$\varphi = \frac{\text{volume of fresh cement paste}}{\text{volume of aggregate holes}}$$

On the basis of the Bolomey formula the author has derived the formula on the 28-days strength of no-fines concrete in the following solution:

$$R_{28}{}^{\varphi} = (a\varphi - b) \cdot K \cdot A\left(\frac{c}{w} - 0.5\right).$$

The function $f(\varphi) = (a\varphi - b)$ expresses the effect of filling aggregate holes with cement paste at which $a = 1.0 \div 1.21$ and $b = 0.0 \div 0.24$. The coefficient K expresses the effect of the humidity and the quality of the aggregate, estimating it by experience. The value A depends on the cement class and kind of aggregate.

The strength expressed by the formula $R_{28}{}^{\varphi}$ was experimentally examined in laboratories on the aggregate of the fraction 20–10 mm i.e. gravel, crushed brick and agglomerated carbonaceous shale in dry- and strongly saturated state and at 6 different coefficients φ = from 0.2 to $\varphi = 1$. The investigations have proved the formula to be right in its solution within the limit of about 20%, which considering the quality of hollow-concrete, is quite satisfying.

In practice the hollow-concrete, also called "poured-concrete" has been, since 1958, mostly produced of crushed brick. On several buildings, near Gdańsk, site testings have been made on crushing strength R_c, unit weight G_c, and the thermal conductivity coefficient has been tested in laboratory. On the basis of the value derived in laboratories in comparison with site results the author has made classification tests on several kind of no-fines concretes according to the formula

$$\vartheta = \frac{R_c/G_c}{R_b/G_b}$$

which represents the criterion of the quality of no-fines concrete.

In the formulae and classification the following values apply:

R_c/G_c = the ratio of the strength of the concrete wall to the unit weight

R_b/G_b = the ratio of the fixed strength of the brick-wall to its fixed unit weight

(λ_b/λ_c) = the ratio of the fixed thermal conductivity for the brick wall to λ_c of tested concrete

K = 0.7 to 0.9 coefficient allowing a greater heterogeneity of the no-fines concrete in comparison with the brick wall depending on the degree of the heterogeneity of concrete and the production quality. In comparison with the brick wall, it is always $K < 1$. For the brick wall $\vartheta = 1$.

We can for instance, for the brick wall fix

$R_b/G_b = 60/1.8 = 33.3$ = constant and $\lambda_b = 0.70$ = constant

With $\rho_c = R_c/G_c$, we obtain in this case: $\vartheta = 0.021 \cdot \rho_c \cdot 1/\lambda_c$.

For complete classification of the detailed no-fines concretes we should take into consideration additionally the economic value, comparing it with the value of other materials, applied in building walls. But to deduce a general formula seems not to be advisable, as there are too many differences in the economic

TABLE 1. Classification of tested no-fines concrete

Aggregate (size 20/10 + 10/4)	Cement kg/m³	av. R_{28} kg/cm²	av. W_{28} kg/dm³	ρ_c	λ_c	$0.021\,\rho_c \cdot \frac{1}{\lambda_c}$	K	ϑ
1	2	3	4	5	6	7	8	9
Bank run gravel	192 (0.30)	62.8	1.81	34.6	0.85	0.85	0.85	0.73
Crushed calcareous stone	200 (0.31)	64.3	1.62	39.7	0.75	1.11	0.85	0.94
Granulated blast furnace slag	200 (0.24)	47.2	1.47	32.2	0.45	1.50	0.75	1.12
Crushed brick	202 (0.26)	30.0	1.22	24.6	0.35	1.48	0.70	1.04
Agglomerated carbonaceous shale	236 (0.30)	26.8	1.03	26.0	0.35	1.55	0.70	1.08

factors, production methods in various countries and sometimes also in certain districts of the given country.

In table 1 is given the classification of the tested no-fines concretes of various aggregates with optimum grain composition of two fractions.

Explanation of table 1

1) Portland cement class "350" has been used.

2) av. R_{28} = the average crushing strength of concrete, measured on 6 cylindrical specimens (16 cm high and 16 cm in diameter) after 28 days hardening (7 days under moist curing, the rest under drying conditions at local temperature of 18 °C).

3) av. W_{28} = the average unit weight of the concrete, measured on 6 cylindrical specimens after 28 days curing as above mentioned

4) $p_c = \frac{\text{av. } R_{28}}{\text{av. } W_{28}}$

5) λ_c = thermal conductivity coefficient (Kcal/mh °C)

6) K = experimental coefficient explained as above.

From the table it can be seen that at the fixed ratio R_b/G_b for the brick wall, only no-fines concrete of gravel and crushed calcareous stone has $\vartheta < 1$; that means they are of worse quality in regard to strength, weight and heat than the brick wall.

Structural dense-concrete made with agglomerated carbonaceous shale

Aggregate is produced from carbonaceous shale of bituminous coal, which is a by-product in the coal separation process. The following shows the production cycle of crushing the shale, preparation of pellets 5–10 mm size, sintering on moving hearths (1200 °C), crushing and screening of aggregate on fraction 20/10–10/3–3/0 mm. The average bulk specific gravity calculated on a natural humidity, and loosely poured, amounts to 850 kg/m³.

Portland Cement – class "350" (compressive strength 350 kg/cm²).

The design of concrete mixes. There are several methods of concrete design both theoretical and practical, as well as combinations of both. Numerous tests made in the Concrete Plant at the Gdańsk Technical University have shown that the best results have been achieved by a design method of optimal composition by means of consecutive iteration of cement paste into aggregate, until the required consistency and workability of concrete is reached.

Results of laboratory tests

1) Optimal grain-size distribution containing 3 or 2 (extremal) fractions gives maximum crushing strength

2) Amount of cement (class "350") minimum 300 kg/m³ to obtain the compressive strength not less than 140 kg/cm². The cement can be replaced with fly ashes to an amount 20% of the dry aggregate-weight.

3) Crushing strength and unit weight. Crushing strength at 28 days ranging from 200 to 250 kg/cm² can be obtained by vibration at the optimal composition of aggregate fraction by using Portland cement (class "350") in amount of about 350 kg/m³ plus an adequate amount of fly ashes. For these concretes the unit weight in airdry state ranges from 1.60 to 1.65 t/m³.

4) Application of fly ashes as micro-filler has the following effect. It decreases the consumption of cement without noticeably lowering the crushing strength, improving to a considerable extent the workability of the concrete mass, and lowering simultaneously the shrinkage during drying.

5) Shear Strength R_s = 30–40 kg/cm²

6) Tensile Strength R_t = 18–22 kg/cm²

7) Bond Strength between the concrete and the reinforcement R_b = 40–60 kg/cm²

8) Modulus of Elasticity E = 150–170 t/cm²

9) Thermal Conductivity coefficient λ = 0.45–0.55.

10) Drying Shrinkage 0.10–0.15%.

11) Absorption, percent 8–15%.

12) Freezing Resistance: good.

Experience acquired in prefabrication plants and on building sites

In prefabrication plants within the district of Gdańsk–Gdynia experimental tests have been conducted on the adaptability of the agglomerated carbonaceous shale to structural concrete in prefabrication elements. The author has examined on the cracking – moment (M_{cr}), the breaking moment (M_{br}) and other properties of following elements: floor slabs 1.50 m × 6.60 m for industrial building, floor slabs 1.20 × 5.70 m with different openings for apartment houses, eccentric loaded columns, prestressed beams with cables and other elements.

The tests have shown, that for practical purposes the strength can be achieved sufficient for prefabricated elements ($R_c \geqslant 200$ kg/cm²), and for prestressed constructions, the minimum of required compressive strength ($R_c \geqslant 300$ kg/cm²). It was found that the moments (M_{cr}) and (M_{br}) were regularly higher than when theoretically calculated.

On industrial sites (stores) lightweight concrete has been efficiently applied for prefabricated elements as floor slabs, beams, columns and frames. Lightweight concrete for floor slabs, elements and structural walls, in the form of poured concrete in climbing shuttering, has been applied on sites of appartment houses. During the years 1962–1964 the scientific worker of Gdańsk Technical University assistant prof. W. Gaca, has conducted research work on the large area of new buildings, within the district Gdańsk–Oliwa, where lightweight concrete with agglomerated carbonaceous shale ("Knurów") has been applied for walls and floor slabs.

Experimental results achieved on sites

1 The concrete strength on sites has been usually higher than that designed and achieved in laboratories.

2 Unit weight is lower than in laboratories.

For instance measuring after 6 months on wall-cut specimen for R_{cr} = 70 kg/cm², unit weight W = 1.3 T/m³ but for laboratory specimens it was W = 1.5 T/m³.

3 Thermal insulating tests. For purposes of comparison 4 different walls have been examined:

- a) gravel concrete (15 cm) + gas concrete (12 cm)
- b) brick masonry (41 cm)
- c) no-fines concrete on crushed brick (43 cm)
- d) agglomerated shale concrete (27 cm)

All walls have been plastered in the same way at both sides and cured in the same climatic conditions. The following results have been obtained by measurement and by collecting information from the inhabitants of experimental buildings.

Thermal insulation properties of the wall of type (d) are approximately similar to those of type (a), better than the walls of type (b), but a little worse than the walls of type (c). But it must be stressed that the difference of wall thickness is in favour of the wall of type (d).

Conclusion. Research work in laboratories and experience on building sites for two types of lightweight concrete has achieved satisfactory results thanks to efficient collaboration of scientific staff with workers of prefabrication plant and on sites. It has been shown, that such collaboration has ensured constant progress in the field of building. The author stresses that an adequate organisation and a staff of technical and economic experts should be engaged in the elaboration of uniform and tested methods on an international scale. A permanent system for the exchange of research work and experience would contribute to the increasing progress in the field of building technics and a lowering of production cost.

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Use of brown coal ash for production of lightweight aggregates

By M. Zachara (Poland)

Polish Energetics is starting to utilize huge deposits of brown coal and therefore considerable amounts of brown coal ashes will be available. This paper shows possibilities of using light weight aggregates sintered from brown coal ashes and their application in building. The paper discusses properties of raw material, technology of sintering on a semi-industrial scale, estimation of the properties of the aggregates obtained and their application for light weight concretes.

Properties of the ashes and sintering process

Preliminary tests of the ashes received from several electric power stations have shown that the best are ashes derived from brown coal deposits of the Zytawa region used by the Polish Power Station "Turów" and the German Power Station "Friedensgrenze" as far as their chemical composition, sintering process and properties of obtained aggregates are concerned. The laboratory scale investigation on the waste material ashes and fly ashes (the ashes – obtained from the boiler; the fly ashes – waste materials obtained from electrostatic precipitators) of brown coal "Turów" has proved the sufficient homogeneity of it as a raw material for future production. The chemical composition of the ashes and the fly ashes used for sintering test is given in Table 1.

TABLE 1.

Components	Component contents in %	
	Ash	Fly Ash
SiO_2	51.20	47.84
$Al_2O_3 + TiO_2$	35.69	30.86
Fe_2O_3	6.48	6.19
CaO	0.64	0.52
MgO	1.21	0.81
Others	0.205	0.415
Sulphur Total	0.325	0.315
Sulphur as sulphides	0.137	0.198
Sulphur as sulphates	0.188	0.117
Loss on calcination	3.95	13.05

Analysis of brown coal used as fuel in sintering process is given in Table 2.

TABLE 2.

Components	Moisture %	Ash %	Carbon %	Hydrogen %	Heat of combustion in calories per kg.	Heating value in calories per kg
Contents	31.82	7.02	40.12	1.97	4030	3730

The ash and coal were reduced in size below 3 mm, and the fly ash was left in natural state.

Particle size distribution of raw materials is given in Table 3.

TABLE 3.

Particle size mm	Particle contents in %		
	Fly Ash	Ash	Coal
10 – 3	–	2.3	4.1
3 – 1	–	30.4	50.7
1 – 0.4	1.1	26.9	17.4
0.4 – 0.2	2.9	15.4	7.2
0.2 – 0.1	16.7	9.0	9.4
0.1 – 0.06	61.3	15.4	12.2
below 0.06	17.8	–	–

The average moisture content of raw materials after mixing was 8% with the result that the crushing process and transport took place without dusting.

The mix was moistured with a water spray in granulating drums and its average moisture content after granulation process was 19.3% (scatter from 14.0 to 28.0%).

To find out the best parameters of the sintering process several tests on laboratory and industrial scale were made. The components of a mix were changed within limits as follows:

– moisture content	from 14 to 28%
– fly ash content	from 30 to 70%
– ash content	from 30 to 70%
– brown coal (natural state)	from about 8 to 25%
– return fines	from 0 to 30%

Bulk density of a mix changed – depending on its composition within limits from 740 to 850 kg/m³, and permeability of a sintered bed changed from 4.0 to 7.5 seconds for a bed of 200 mm height.

The conditions of sintering process were changed within limits:

- suction from 180 to 330 mm
- sintering time from 7.0 to 16.0 mm, thus
- sintering rate was from 12.5 to 28.6 mm/min. and
- gas temperature from 150 to 300 °C.

Ignition temperature was constant at 1150 °C, time of ignition 1 minute, and height of a sintered bed 200 mm.

At all changed parameters a light weight and highly porous aggregate, but differing in strength and bulk density, was obtained.

The best parameters of sintering on a strand were stated to be:

- Fly ash content in a mix 40%
- Ash content in a mix 27%
- Brown coal content in a mix 13%
- Return sinter cake 20%
- Ignition temperature 1150 °C
- Time of ignition 1 minute
- Height of sinter bed 200 mm
- Moisture content of a mix 20 – 25%
- Permeability of sintered bed 4.5 – 5.5 sec.
- Suction in mm H_2O 250 – 300 mm
- Time of sintering at least 10 min.
- Gas temperature 250 °C

Test on properties of aggregate obtained

Test of a sinter cake

Tests of a sinter cake were made on several lumps taken from a pit.

a) Macroscopic description: the sinter cake is a highly porous, light weight and strong material similar in appearance to furnace clinker. Macropores are open and therefore the sinter cake cools quickly. The colour of a cake differs from light grey, brown, to rose and red.

b) Density (measured on cubes) is on average 0.85 g per cubic cm but is within limits from 0.62 to 1.15 g per cubic cm.

c) Compressive strength (measured on cubes) varies from 21 to 86 kgms per sq. cm, what means that the scatter is a very great one. The size of test cubes is from 2.5 to 5.0 cm.

Test of sintered aggregate

All the sintered material (about 70 tons) was crushed in a roller crusher. The tests conducted on an average sample gave the following results:

a) Average bulk density of a fraction:

Fraction	Average bulk density in kg per cubic m.
20 – 10 mm	330
10 – 4 mm	440
4 – 0 mm	660

Bulk density of a mix 0–20 mm (rough coals) after crushing in loose state 570 kg per cu.m.

in compacted state 700 kg per cu.m.

b) Aggregate strength tested in steel bell after British method was 26.7% to 31.2% (The British Standard gives as a minimum for concrete aggregate 25.0%).

c) Specific gravity of aggregate tested by application of distilled water was from 2.622 to 2.648 g per cu.cm.

d) Porosity of corn aggregate was 67.8% on average (scatter from 56% to 77%)

e) Saturation of aggregate by weight is within limits from 36 to 55%. Saturation of aggregate by volume is from 30 to 47%, which demonstrates a comparatively low degree of saturation from 45 to 69% the pores being closed up, giving good frost-resistance.

f) Deleterious mixture content contained by aggregate is very small, namely:

- loss on ignition 0.82% on average
- Sulphur Total (as SO$_3$) 0.017% on average
- including sulphur as sulphides (as SO$_3$) 0.004% on average
- including sulphur as sulphates (as SO$_3$) 0.013% on average

g) Quality coefficient of aggregate expressed as a ratio of a strength (measured in cubes) to density is within limits from 0.034 to 0.075. This coefficient is more advantageous than for expanded blast furnace slag (0.020 to 0.050).

h) Comparison of properties of aggregates obtained and already manufactured on a full scale in the USSR. Two kinds of light weight aggregates are manufactured now on a full scale for building purpose, namely:

- expanded blast furnace slag in Lenin's Steel-works, and
- aggregate "Aglite" in Knurów from shales

Properties of these two kinds of aggregate and of a new aggregate "Turów" are given in Table 4.

TABLE 4.

Ordinal No.	Aggregate properties	Sort of aggregate Turów	 Aglite	 pumice
1 Bulk density in kg/m^3	20–10 mm	330	504	750
	10– 4 mm	440	626	816
	4– 0 mm	660	860	890
	rough coal in loose state	570	698	820
		700	960	1150
2 Rw%	as per British method	29.1	39.0	–
3 Nw%	weight increase	45.5	40.9	25.0
4 Volumetric weight	in g/cm^3	0.85	1.05	1.15
5 Detrimental admixtures in %	carbon C	0.32	1.72	–
	general sulphur S	0.017	0.21	1.000
	losses on calcination	0.82	1.70	0.30

Testing of light concretes on cement and gypsum bonds

Light concretes on cement bonds. For making concrete mixtures there were used the following ingredients:
2 sorts of cement: of steel-works brand "250", and

of Portland brand "350".

Both concretes were in compliance with requirements of proper standards. Pipe water was being used as dilution water. Light aggregate from technical test of characteristic is quoted in item 3 of the present report. For some mixtures there was applied an addition of volatile dusts of the ingredient given in item 2, Table 1.

Particle distribution of dusts is as follows:

fractions	contents in %
0.0 to 0.125	78.0
0.125 to 0.25	16.0
0.25 to 0.5	5.0
0.5 to 1.0	1.0

Dust volumetric weight amounted in loose state to 0.740 kg/cm^3, and in compacted state to 0.885 kg/cm^3. Specific gravity, in dependence on the liquid used for measurement (benzene, alcohol, water) was within the limits from 2.082 to 2.290 g/cm^3.

Testing of volume stability showed size shrinkage:
after 14 days of maturing - 0.06 $^0/_{00}$ and
after 28 days of maturing – 0,08 $^0/_{00}$

Water demand for dusts according to Vicat – 68% and specific surface according to Lea-Nurse – 4750 g/cm^2.

In the program for examination of light concretes based on a new aggregate, the following sizes were accepted as alternate ones: two sorts of cement in quantities of 250, 300, 400 and 450 kg/m^3 of concrete, aggregate sand points 37% and 45%.

Examinations of concrete, covered determination of volumetric weight as well as compression resistance after 7, 28 and 90 days of maturing, testing of weight increase and frost-proofing. (Concretes designed by experimental method as per N. A. Popov's rules).

Quantities of ingredients for 1 m^3 of concrete were the following:

Cement brand "250" and "350"	from 250 to 450 kg.
aggregate in dry state	from 605 to 725 kg.
water	from 250 to 313 kg.

Concrete mixtures had, in fresh state, a dense and plastic consistence. Sample compacting was being done on a vibrating table of oscillation frequency – 3000 per minute. Volumetric weights were being changed depending on concrete ingredient and maturing time within the limits:
after 28 days from 1150 to 1380 kg/m^3 – in natural moisture state
from 950 to 1125 kg/m^3 – in dried state

after 90 days from 1015 to 1305 kg/m^3 – in moist state
from 950 to 1125 kg/m^3 – in dried state.

The detailed results of examinations showed the dependences:

a) Volumetric weight of light concrete in proportional to cement contents in 1 m^3

b) Volumetric weight of concrete increases slightly in the course of maturing time, which should be interpreted by setting of water at the period of cement hydration.

c) Volumetric weights of concretes dried to constant weight are very low and after 90 days of maturing do not exceed 1200 kg/m^3.

Compression resistance of concrete (rolls 16 cm) was as follows:

after 28 days – cement "250" in quantity of 250 to 450 kg/m^3
a) in moist state R$_{28}$ from 30 to 100 kg/cm^2
b) in dried state R$_{28}$ from 42 to 112 kg/cm^2.
for cement "350" in quantity 250 to 450 kg/m^3
a) in moist state R$_{28}$ – from 40 (p.p. 37%) to 150 kg/cm^2 (p.p. 45%)
b) in dried state R$_{28}$ – from 50 (p.p. 37%) to 185 kg/cm^2 (p.p. 45%)
After 90 days – cement "250" in quantity 250 to 450 kg/cm^3
a) in moist state R$_{90}$ – from 36 to 123 kg/cm^2
b) in dried state R$_{90}$ – from 48 to 134 kg/cm^2
for cement "350" in quantity 250 to 450 kg/m^3
a) in moist state R$_{90}$ – from 52 (p.p. 37%) to 190 kg/cm^2 (p.p. 45%)
b) in dried state R$_{90}$ – from 64 (p.p. 37%) to 219 kg/cm^2 (p.p. 45%)

When analysing the detailed results one could see the dependences:

a) Resistance is being increased in course of maturing time.
b) Resistance is proportional to volumetric weight.
c) Raising the sand point in mixture from 37% to 45% causes a considerable increase of resistance. Compression resistances after 90 days of maturing are from 15 to 35% higher than resistances after 28 days.

For this reason R_{90} should be acknowledged as giving competent results.

Increase of weight of concrete declines with the rise of contents of cement in one cubic meter of concrete and for both kinds of cement, it lies in the limits of 19.0 to 23.3%.

Resistance of light concretes against freezing is satisfactory, and after 15 cycles of freezing, up to −20 °C, shows a decline of strength in comparison with other samples:
a) by applying cement "250"—from 12.3 to 18.3%
b) by applying cement "350"—from 9.2 to 16%

The coefficient of elasticity of light concrete, in its natural state of humidity amounts to about 7%: by using cement of the kind "350" in a quantity of 250 to 450 kg/m³—43000 kg/cm²—100.000 kg/cm², and compressive strength after 28 days 40—150 kg/cm² respectively.

Comparative indicators for concretes made on various light aggregates. In order to elucidate the quality of light concretes made on aggregates "Turów", below, there is a comparison of indicators for concretes from different light aggregates, produced in this country.

a) As an indicator of constructional quality there is a proportional strength after 28 days of maturing to volumetric weight

Some sizes of indicators—for orientation—are shown on Table 5.

TABLE 5.

No.	Kind of aggregate	Cement "250" from	Cement "250" to	Cement "350" from	Cement "350" to	Contents of cement in kg/m³ of concrete
1	Pumice (stone) from Lenin Steel Works	0.012	0.040	0.009	0.007	200—400
2	"Aglite" Knurow	0.038	0.106	0.046	0.143	200—400
3	Slag in granule from Lenin Steel works	0.009	0.022	—	—	150—250
4	Aggegate of "Turów"	0.024	0.066	0.032	0.059	250—400

TABLE 6.

No.	Kind of aggregate	Cement "250" from	Cement "250" to	Cement "350" from	Cement "350" to	Contents of cement in kg/m³ of concrete
1	Pumice from Lenin Steel Works	0.075	0.182	0.070	0.322	200—400
2	"Aglite" Knurow	0.285	0.455	0.330	0.600	200—400
3	Slag in granule from Lenin Steel Works	0.075	0.143	—	—	150—250
4	Aggregate of "Turów"	0.154	0.125	0.148	0.195	250—400

b) As an economical indicator of resistance, the relation of R_{28} to the quantity of cement in kg/m³ of concrete, has been accepted. These data are compared in Table 6.

Cement concretes with added furnace ashes

Tests similar to those formerly effected have been made with light concretes by adding furnace ashes from "Turów". The quantity of ashes used was in the range from 200—300 kg, so that the ashes and cement could amount up to 500 kg. Kinds of cement used—were "250" and "350" as before. The quantity of "Turów" aggregate of p.p. 45%, oscillated between 620 and 630 kg and water quantity amounted from 340 to 350 kg in 1 m³ of concrete. The concrete consistency is dense plastic. Concentrating is created by vibration. Volumetric weights change according to contents and time of maturing of ash concrete, within the following limits: after 28 days from 1365 to 1450 kg/m³ in natural state of humidity; from 1225 to 1245 kg/m³ in dried state.

After 90 days—from 1335 to 1395 kg/m³ in damp state; from 1235 to 1250 kg/m³ in dried state.

From detailed results a conclusion could be drawn that the addition of ashes do not show real influence on volumetric weight of ash concrete—which in a dried state do not exceed 1250 kg/m³.

Resistances against compression after 90 days (on rollers of 16 mm) were forming as follows:

Cement "250"

Cement 200 kg/m³, ashes 300 kg/m³, p.p. 45%, volumetric weight = 1235 kg/m³ R_{90} = 175 kg/cm²
Cement 300 kg/m³, ashes 200 kg/m³, p.p. 45%. volumetric weight = 1240 kg/m³ R_{90} = 180 kg/cm²

Cement "350"
Cement 300 kg/cm³, ashes 200 kg/m³, p.p. 45%, volumetric weight = 1250 kg/m³ R_{90} = 245 kg/cm²

Increase of weight (saturation) of light concretes containing ashes, lies in the following limits: from 21.5 to 24.2%—by larger contents of cement the weight declines.

Resistance against freezing of light concretes with ashes is satisfactory. The fall of strength after freezing is in the range from 5.4 to 6.3%. Therefore it is suggested that the addition of volatile ashes strengthens the resistance of light concrete against freezing.

Execution of multi-sized elements

The Wroclaw Establishments of Concrete and Reinforced Concrete executed several large ceiling-plate elements, using as filling thick sintered "Turów" aggregate. These elements have been embodied in several buildings, and are now being observed. So far after one year, no disadavantages have been observed. The weight of separate elements was found to be lower at about 15%, in comparison to similar types, produced from furnace slag, in the Chemical Establishment "Rokita". Resistance and thermic parameters proved to be more advantageous.

Light concretes based on gypsum bonds

In order to make a gypsum-concrete composition, the same components have been used as formerly, with the difference that two kinds of cement have been substituted by building gyspum, produced by the Establishment, "Dolina Nidy". Gypsum as a bond appeared to be suitable, and met the standard requirements —PN/B—30310.

The following variable parameters have been accepted: in proportion of gypsum and aggregate as 1:1, 1:2 and 1:3, and the proportion of water and gypsum as 0.6, 0.8 and 1.0.

The tests comprised determination of volumetric weights of gypsum-concretes, resistance to compression, to weight increase and the influence of humidity on resistance.

Volumetric weights of compositions being dried to a stable weight, in a temperature of 45 °C, by relation of gypsum to aggregate from 1:1 to 1:3, and relation of water to gypsum from 0.6 to 1.0 were in the limits from 1295 to 990 kg/m^3.

Resistance to compression after 7 days of maturing, by variable contents of gypsum-concrete, as above, oscillated in the following ranges:

in state of natural humidity from 46 to 13 kg/cm^2 whereas
in dried state from 110 to 42 kg/cm^2.

The obtained results point to a great influence of moisture upon resistance; therefore these gypsum concretes can be applied to carrying and partition elements in places not exposed to atmospheric influences.

Weight increase of gypsum-concretes for ingredients as above, lies within the limits from 11 to 32%. The detailed results show, that weight increase lowers with the increase of the contents of aggregate in gypsum concretes.

Conclusions. The examinations which were carried out proved, that it is possible in practice to make use of furnace waste materials, left by brown coal, the raw material for aggregate sintering. From the point of view of economy, one should anticipate, in a prospect of planning, building of many sintering plants, at the Power Stations, based on larger deposits of brown coal. Further examinations should reach other deposits of brown coal, and go in the direction of refining of the starting raw material, establishing optimum technological parameters of sintering, as well as proper application of sintered aggregates in the building industry. The detailed conclusions on waste materials from "Turów's" coal field, can be formulated in the following way:

a) Furnace waste-materials left by brown coal from the Power Station "Turów", with regard to their quantity, quality and their being homogeneous, are a proper starting raw-material for production of light, sintered aggregates.

b) Technological process of sintering is simple. Sintering parameters are setting in an advantageous way with respect to economy.

c) Sintered aggregate "Turów" may be regarded as useful for traditional and industrialised building, as the respective light concretes at low volumetric weight, (below 1300 kg/cm^3) obtain the resistance of about 200 kg/cm^2.

d) Application of the addition of volatile dusts to concrete mixtures is useful, since it increases concrete resistance, along with saving of cement.

e) Gypsum-concretes on light aggregates "Turów" may be applied in dry places, as materials for carrying elements, up to 110 kg/cm^2, as well as for partitions.

G 21

Z. Zuchowski

Effects of industrialisation on development processes in the building materials industry

By Z. Zuchowski (Poland)

Industrialised building techniques in Poland

The following basic techniques, considered as industrialised building techniques, are applied to housing construction:

- building with large units (a room wall is made of a few wall units);
- building with large-size panels;
- building with monolithic supporting walls and large-size components for floors, stairs and roofs.

It should also be mentioned that, in the course of the development of industrialised processes in housing construction in Poland, the application of load-bearing cross-wall techniques was introduced on a large scale. This resulted in the first place from the development of the production and use in Poland of cellular concrete, an excellent material for building external nonload-bearing walls.

In industrial construction, mostly using reinforced concrete, the basic processes of industrialisation of building techniques are:

- erection of reinforced concrete structures, using heavy prefabricated components;
- monolithic building, by means of mobile sliding shuttering, using quick-setting cement, and possibly other concrete hardening accelerators.

A fairly important advance has been registered in Polish building in the following fields:

- building with thin-shell reinforced concrete;
- prestressed concrete.

The consequent requirements of industrialised building in respect of building materials and developmental processes in basic branches of the building material industry in Poland

The growing application of industrialised building techniques involves changed requirements in respect of building materials. The trend of this change is towards ever more technically effective and cheaper materials.

This trend was particularly evident in regard to wall materials. The change over to the supporting cross-wall technique has brought about the development of two groups of materials with distinct properties:

- materials for supporting internal walls;
- materials for non-supporting external walls.

The materials in the first group must typically be highly resistant; the thermal insulation factor need not be exceptional. A typical material in this group has proved to be ordinary concrete. This material has not so far been used for walls in housing construction; it is at present used more increasingly, particularly in the form of large-size wall components, in industrialised building.

The materials in the second group must typically be of low bulk specific gravity and they should have good thermal insulation properties, resistance requirements being less important.

Experience in Poland has proved cellular concrete to be a typical material in the second group. This material has already been mentioned. It was formerly made in small 24 × 24 × 49 cm units and now, more and more often, as large-size external wall panels, for industrialised building.

As building with large-size prefabricated components develops, so does the scope of application of external multi-layered supporting and curtain walls ("sandwich" panels).

The growing use of multi-layered walls involves as increasing demand by the building trade for materials with a range of thermal insulation properties; first of all, foamed plastics; (styropian, piomirol, PVC foam have so far been used in Poland). Again, the necessity for proper tightness of external wall large-size panel joints means a new demand for cross-bars with a suitable expansion factor, for mastics, impervious fittings, glues, mostly made from synthetic products (PVC, Polyethylene, polyester resins, epoxide resins etc.).

Building technical developments also entailed the modernisation of the ceramic and silico-calcareous product range. This evolution has materialised for example in the reduction of the bulk specific gravity of elements (thin-shell ceramic products, perforated silico-calcareous materials), with a proportionate increase in size. A typical line of modernisation is the development of fabrication of large -size ceramic and concrete components, of wall panels as well as the beginning of the production already under way, of silico-calcareous large-size wall panels.

Polish building is making growing use of binding and plaster products, mainly used for partition wall panels. In regard to cement production, there is a tendency to turn out ever better quality, including quick-setting cement. The latter makes it possible to organise on a rational basis the production of prefabricated reinforced concrete components, without saturated steam curing, and also to speed up to a considerable extent the pace of erection of monolithic concrete structures.

In view of the difficulty encountered in obtaining adequate supplies of natural aggregates, gravel etc. for the preparation of concrete, including the better qualities, the industrial production of light artificial aggregates has been started in Poland. These include: foamed blastfurnace slag, sintered carboniferous shale-based light aggregate, keramzyt. The production of aggregates from sintered fly-ash is in preparation.

Likewise, the production of reinforcing steel for ferroconcrete is marked by a definite tendency to use steel having a higher plastic limit (e.g. over 45/kg/sq.cm) and by a noticeable development of the manufacture of steel prestressing rope and cable.

It is anticipated that growing use will be made in building of components made with cold rolled thin-shell structural steel sections (door and window frames, light roof structure etc.).

Industrialised building in Poland is developing pari passu with the growing application of plastic materials, products and components. The following large-scale applications have been registered in recent years: plastic flooring (small plates and PVC rolls for flooring, polyvinyl acetal resin-based mastics and others), thermal and waterproof insulating products, installation materials and equipment, paints and varnishes. Covering materials, mastics, glues etc. made from synthetic resins are increasingly applied.

Finally, industrialised building in Poland has made it possible to restrict the use of timber; in the conditions now prevailing in the country (war-time ravaged forests), this is essential to national economy. On the other hand, a substantial growth has been registered in the production and application of wood derived materials (wood fibreboard, wood-chip board, wood-grain board etc.).

No. Materials Specification	Share in % in the years				
	1960	1965	1970	1975	1980
1. Concrete bulk specific gravity 1800–2200 kg/m³	16.4	16.5	22.2	25.7	27.0
2. Light concrete bulk specific gravity 500–1200 kg/m³	8.0	16.4	22.2	27.6	32.8
3. Silico-calcareous materials bulk specific gravity 1600–2000 kg/m³ (with perforated elements)	6.8	9.8	8.1	6.7	5.5
4. Building ceramic materials bulk specific gravity 1000–1500 kg/m³	(65.2)	(52.5)	(43.2)	(35.2)	(29.2)
(incl. thin-shell	6.2	10.0	15.0	20.0	22.0
products 1600–1800 kg/m³)	59.0	42.5	28.2	15.2	7.2
5. Other materials (incl. gypsum-plaster products)	3.6	4.9	4.5	4.8	5.5

The application of aluminium in the Polish building trade is on the increase, though to an inadequate extent; however, this material is not yet used in mass-production. The situation in this field of building will be remedied in future years.

Features of the anticipated changing pattern of application (expressed in %) of some groups of building materials in Poland

a) Wall materials To indicate trends the following tabulation is given showing the anticipated changing pattern for wall materials over the years 1960–1980. (See table page 376)

Share percentages of different groups of wall materials, as shown in the table, feature trends; they are subject to amendment as a result of subsequent surveys. The table is therefore meant rather to show the lines along which the relative share of different wall materials is developing, as a result of technical building evolution. The materials mentioned under items 1 and 2 concern mainly prefabricated components, to a lesser extent monolithic structures.

b) Floor materials To indicate trends the following table is given showing the anticipated changing pattern for floor materials (excluding country building).

Years	1965	1980
Wooden floors & floors made of wood-derived mat.	38%	20%
Plastic flooring	42%	71%
Mineral floors (concrete, floor gypsum-plaster, xylotite etc.)	20%	9%

c) Synthetic products and materials. To indicate trends the following table is given showing the anticipated planned development of the application of plastic building materials and products.

Years	1960	1965	1970	1975	1980
Plastic building prod. & materials in '000 Tons	10	90	290	650	1100
Rate of increase	1.0	9.0	29.0	65.0	110.0

Group H
Functional Requirements

Final report from the group rapporteur Dr. G. Sebestyén, Director of the Hungarian Institute for Building Science, Hungary.

This subject has already been treated at the 2nd CIB Congress held in 1962 in Cambridge and the Congress publication contains reports by Messrs. G. Blachère, L. Holm and A. Pott. A special consideration is due to the lecture by Mr. Blachère on "How to determine and satisfy user requirements: methods and consequences", essential statements of which are still valid. These three lectures quoted will not be reproduced or even abstracted here; those interested in this subject may read them in the publication of the 2nd CIB Congress.

It is important however to reproduce here determination of some principal notions given in the Blachère lecture. According to him, circumstances required to prevail in a building or in e.g. a dwelling are to be determined. Therefrom functional requirements for building result, specifying indoor conditions needed for man to live and work in comfort. Realization in a given building of functional requirements established as above is to be checked in external conditions of occupancy (e.g. density) considered as normal. This means that first of all conditions of occupancy and climatic conditions of the given area (temperature, rain, wind, isolation etc.) are to be known. In addition, knowledge of results arrived at by a given technical solution in certain external conditions is also necessary. This requires a certain knowledge, in particular that of building science. If for instance, particulars of a wall structure and level of external noise are known, acoustics will help to compute noise level in the room. Penetration into circumstances due to the interaction of various technical solutions and external effects requires a substantial knowledge of building science and even development of new branches.

In spite of the fact however that the quoted positions of 1962 and others are accepted as valid along their chief lines, in a certain respect a further development took place during the last period, while in some respects a more clear elucidation became imperative.

In 1962 already *human requirements, user's requirements and functional requirements* had somehow been distinguished. In fact, these terms have no identical meanings and extensions. Lack of elucidation of their differences has been responsible for the fact that the overall denomination of lectures in this group was *Functional Requirements*, in the English program to the 3rd CIB Congress, and *human requirements* in the French version.

In general, when establishing the requirements, a starting point was always given by problems of dwellings or houses. In this case *human requirements and user's requirements* are of the same content, users of the dwelling being human beings themselves. *User's requirements* however are of a more extended meaning, these covering other building types beside houses and dwellings. Of course, in most buildings, human requirements are of outstanding importance. This is the case for schools, offices, hospitals, hotels etc. User's requirements include also other than human requirements. In an industrial building or in agricultural premises for keeping cows or pigs, in addition to providing for optimum working conditions for man, it is of extreme importance to provide for optimum circumstances for the given production process. Hence the industrial building must be convenient for an unobstructed industrial production process; agricultural premises have to provide for optimum living and development conditions for cows and pigs.

As a consequence of process mechanization and automation, an ever increasing number of buildings is constructed, not always regularly occupied by human beings in normal conditions, and not at all in extraordinary cases, for instance during standstills or breakdowns. In such cases human requirements are fully eclipsed as compared to the special requirements of the premises, such as mechanically operated silos, tanks etc.

Instead of user's requirements often *purchaser's* requirements are spoken of. These two terms are of nearly identical meanings; nevertheless user's requirements is considered more adequate, being of a general validity, while purchaser can essentially be spoken of, if the person ordering and using the building differs from its designer and constructor. Although this is usually the actual case, it is not absolutely true and, therefore, introduction of the word purchaser would needlessly involve a term referring to the organizatory form.

Thus, it can be stated that building has to meet user's requirements, which are partly direct human requirements, and partly requirements connected with various requirements of human beings, which however may appear independently of men. Evidently, in a more wide sense, also requirements of factory production or of cow breeding could be considered human requirements, since these appear as a consequence of human or social activity. This however would mean an artificially wide extension of human requirements. In various fields some user's requirements appear with ever increasing independence, which although derived from the development of human society, appear as ever more independent categories. This process, as shown by the above examples, first appears in the field of productive work (industry, agriculture, etc.). With the development of up-to-date technique, however, it penetrates the field of services, and actually such requirements are found for buildings connected with human activity but of no productive character such as schools, hospitals, hotels, office buildings. Let us consider an up-to-date hospital as an example. It is fully intended to maximally meet human requirements. Hospital therapeutic processes however have become complex, involving technical equipment certainly not less than for a mediumsize plant. Practical requirements of various therapeutic processes, the most correct arrangement and interconnection of rooms, appear as independent requirements, although, as it was seen, they have the final object of satisfying human requirements at a high standard.

To correctly determine requirements, man and society are to be analysed more substantively and scientifically; in addition, natural conditions, features and influences of the outside world are to be considered.

This deepening of the recognition process brings requirements up to now unknown, for instance radiation problems, non-existent before this century.

Functional Requirements

Up to this point, correct use of the term stands clear. Let us consider now *functional* requirements. In this respect several interpretations are encountered. We have already seen the one used by Blachère. Other authors however apply this term differently. Birkeland (H.1) for instance describes conditions in which a part of the building (wall, roof or floor) is functioning. There is an obvious connection between functional requirements taken in the first (Blachère's) and in the second (Birkeland's) meaning (respectively). If our knowledge was complete we could find the "functional requirements" taken in the second meaning out from the functional requirements taken in the first meaning. Our knowledge is however far from complete.

Human, or more generally, user's requirements, and natural conditions, can be more or less exactly determined in a given region, in a given period. The chief object is to design and to construct buildings meeting these requirements. In countries with a highly developed building industry, an accentuated attempt is manifested to restrict requirements for the construction to meet those of its final users, i.e. men. In knowledge of features of building materials and structures and of different equipments, a highly qualified designer or constructor can find design and structural solutions to meet requirements. Practically however this means of satisfying requirements could not be generalized up to now, and I wonder whether it even will be in a short time. We are compelled to give detailed specifications for each building material and structure. It is clear by now that this is but an auxiliary means. Namely what is needed, is not to provide for incorporating constructions with given features, but to ensure final requirements to be met within the building erected of determined elements.

Mr. V. Bryant (U.S.A.) in his contribution evaluating the American school construction experiences, reported the fact that manufacturers are willing to design new products to meet performance specifications. These performance specifications were based on educational needs.

According to the above, requirements for materials and structures are of a conditional validity. When establishing them, it is always stated that meeting user's or human requirements for the entire buildings should be ensured when material and structural requirements are satisfied. It is often found that in certain development phases, a method even more detailed than this is applied. Hence, instead of specifying concrete compressive strength or thermal insulation of the wall, concrete composition and method of manufacture or minimum wall thickness etc. is specified. In the light of the above this type of control is clearly erroneous: it must only be permitted temporarily, in transitional periods where requirements of this formulation help qualificational and educational objects. In fact, such specifications are not considered real specifications any more, but technical knowledge, and final material and structural characteristics are required instead of specifications controlling their manufacture and design. In fact, as it has been stated, this is only a transitional stage, and requirements for the finished construction will be abandoned in favour of those relating to entire premises or rooms.

According to the above consideration, functional requirements are understood as the features, required characteristics of materials and structures corresponding to different functions. In this meaning the term "requirements" will thus become conditional. In fact, features and characteristics are spoken of, instead of real requirements. Real requirements remain invariably human or user's requirements. Therefore in this interpretation functional requirements of materials and structures are, viewed in this way, not functional requirements any more but are simply identical to the sum of our knowledge on materials and structures. At this point the subject of requirements makes contact with those of communication of knowledge and of regulations.

Functional requirements can however be interpreted more widely than the above, to involve users' or human requirements.

Finally, a specific interpretation of functional requirements is found in the building design practice, where an architectural ground plan of a building is meant to function well if there are good and practical connections between rooms, complying with user's requirements. In this meaning, functional requirements are a part of general requirements, governing architectural design.

There are different stages of study on user's or human requirements in each country. In some developed countries there have been carried out quite comprehensive studies in this field, while in other countries the stage of development of industry and the building industry does not require such profound analyses to be made. For instance problems of acoustic requirements, of atmospheric pollution requirements are typical for houses in large central towns, while for houses in rural, less urbanized regions these are of a lesser importance. Among user's requirements the human requirements are elaborated the most comprehensively. However even these are especially for housing. A relatively large amount of data refers to schools, and there are some special studies concerning other building types (such as office buildings, factories, agricultural buildings).

Human requirements

Human requirements are partly of an individual and partly of a social (collective) character. Both categories follow in part general particularities of human existence, and in part the existence of man as a social being.

Human requirements are therefore of
- physiological,
- psychological,
- sociological and
- economical

character.

Part of human requirements, especially some physiological ones, are absolute. Other requirements are however conditional. They depend on the climate, on the manner of life, education, habits of human beings and society, and on economy standard. They differ for each country. Floor area requirements for instance are vastly different in various regions of the world. There are nevertheless some common, fundamental criteria to be considered throughout.

The new Working Commission W45 of the CIB will work on the problems of *human requirements*.

A list of the kinds of human requirements which ought to determine building design (adopted at the first session of the W45):

1. *Anthropometric aspects:* the dimensions, areas and volumes required for human activity and movement in buildings.
2. *The tactile senses*
3. *Vision:* The conditions required for the efficient execution of tasks and movement, and for the visual enjoyment of the interior environment, and for the perception of the world outside.
4. *Hearing:* The conditions required for audibility: acceptance levels of noise and acoustic privacy and protection against noise annoyance from other rooms and other dwellings, and from outside.
5. *Sensitivity to vibration*
6. *The quality of the air:* its physiological purity; odour.
7. *Thermal environment, humidity and air movement.* Conditions needed to provide human comfort.
8. *The effects of electrostatic and electromagnetic phenomena.*
9. *Hygienic aspects:* body hygiene, water supply; food preparation and storage; waste disposal; cleaning and disinfection; protection against animal intrusions and vectors of disease.
10. *Social aspects:* facilities and equipment provided and patterns of use, needs and motivations, social values.
11. *Human safety:* consequences of structural failure and of fires, flooding, escapes of gas and explosions, use of mechanical and electrical equipment, requirements of special groups like young children and old people.

An ever increasing importance is due to various, immeasurable requirements and to research into them, such as sociological problems, aesthetical effects, quality problems. The study and satisfaction of functional and human requirements has to be realized in connection with the process of industrialisation, but in such a manner as to permit satisfaction of a variety of exigencies at an ever increasing level, and to construct pleasant-looking buildings. Therefore a special stress should be given to the importance of social requirements along with the industrialisation process. Again, in our dwelling houses built with industrialised methods, conditions of development of organic and harmonious human communities are to be created. This is a duty for the building industry, the greater since requirements vary with time and, in general, they tend to increase. Requirements for up-to-date dwellings are higher than those for buildings built 50 or 100 years ago, and this historical development will no doubt be continued in the time coming.

Professor Van Den Broek (Netherlands) emphasized in his contribution during the discussion that the greater part of the reports in this group deal with functional requirements in the sense of technical and physical aspects. Few of the papers deal with the human requirements in the field of housing, but they are of great importance for good living in housing. The variety in forms and types of housing is a fact of human needs. The different forms and types represent a variety in the way of living, that is essential for the free development of human life. The lay-out of flats should provide not only a variety of types but also for future alterations. Architects ask the industry for such production methods that ensure sufficient flexibility in forms of housing and living.

Vouga (Switzerland) spoke about sociological problems that can be observed in some new housing estates built very quickly. In such estates a social community could not be established yet and there is no real social life. The need for sociologic studies was also expressed by several other speakers (Thiberg, Sweden; Manning, United Kingdom; Macura, Yugoslavia; Christiaen, Belgium).

Some of the speakers spoke of the rapidly changing conditions and human needs. Manning (U.K.) (H.12) foresees a danger that by concerning ourselves with the means of industrialisation (rather than the ends) we finish up with a built environment adequate for the needs of a past age but inadequate for man's requirements of the future.

Sulzer (Western Germany) spoke of the changing composition of the different family types which will have to live in the buildings which we are producing to day. This calls for very flexible methods of design. The scheme of functional units worked out by a team in Germany makes alterations possible during the lifetime of a building with simple technical means.

Jones (Ireland) stated that industrialised buildings are often quite incompatible with new domestic appliances. Often there is no place to install a new machine, e.g. a dishwasher. Therefore new buildings may lose value faster because of this inflexibility. As a result he urged immediate research into the compatibility between the present building components and the expected new methods of

- heating food,
- refrigerating food,
- washing dishes,
- washing clothes,
- disposing of waste
- cleaning floors and walls,
- redecorating,
- lighting,
- home entertainment, etc.

According to Saelman (Netherlands) new methods in building also imply new methods of installation. As even the installations carried out *today* do not meet the *present* requirements it will not be difficult to guess what result will be in the near future, if we do not take action now. There is a most urgent need to achieve a closer cooperation between authorities, architects, building engineers, electrical designers, electrical consultants, contractors and the appropriate organizations, in order to achieve installations that will meet the needs of the future.

Constructional physics, constructional meteorology

In the past decades we have witnessed an ever widening research into natural conditions, to improve building features. Hence examination of temperature, acoustic, weather etc. conditions is given an increasing significance. An ever increasing number of publications appears on these problems.

According to our previous discussion, knowledge and requirements in this subject can be divided into three categories:

- natural (climatic) conditions,
- human (user's) requirements,
- structural requirements to meet user's requirements.

Actually there are but a few countries to attempt to treat separately knowledge and requirements in these three categories. In general, technical literature and specifications for a given sectional field deal with common knowledge and requirements pertaining to all three categories. For instance, among functional requirements for thermal insulation, winter and summer outside design temperatures are specified on the basis of a study of climatic conditions among human requirements e.g. lowest or highest room temperatures, and desired thermal insulation of structures (walls, floors, etc.) are specified. Especially in connection with the third category, the conditional character is apparent. As to thermal insulation, quite different external walls are needed in cases of continuous than of intermittent heating, in cases where air conditioning equipment exist, in cases where appropriate screens (shading devices) etc. exist. For a determined period, functional requirements for constructions can of course be specified so minutely as to consider all design varieties. This solution may however lead to only temporary results, because it has often happened in recent years that new, up-to-date structures, giving for instance the same or even greater thermal comfort, fell short of earlier specifications. This type of control is only temporary and needs revision from time and time.

Apart from these considerations, it can however be stated that in this field a new branch or branches of science have developed, that can be denominated by a common term as constructional physics or constructional meteorology. This new, young branch of science is strongly developing at this time and beside its classical branches (thermal and acoustic problems) there are newly developed fields (driving rain, radiation, air pollution etc.). Changes in building materials and conditions raise also new problems such as ventilation and fire problems in multistorey houses. Actually there is no uniform classification for some problems in this field of science. Several authors made different proposals in this respect.

Lectures on constructional physics and meteorology submitted to the 3rd CIB Congress, as well as related oral contributions could only cover some sections of this widely extended scientific field. Neither is this introductory summary intended to give a comprehensive description. Nevertheless some remarks should be made in this connection.

There are well-known computing and test methods for thermal insulation of walls and floors. Generalization of lightweight thermal insulations, reduced thickness and weight of constructions, as well as use of large vitreous surfaces raised new problems. In this field the French research institute Centre Scientifique et Technique du Bâtiment carried out a highly valuable research work. Previous research work on thermal insulation had been fully based on the assumption of stationary heat flow. Introduction of new, thin section wall and floor constructions raised interest in variable (non-stationary) heat flow conditions. This requires, of course, more complex calculations but leads to more realistic results. It is generally known that thin walls even if significantly better insulating than thick ones are not absolutely convenient for human comfort. Heat storage, heat storing capacity, initially applied for this purpose did not prove a sufficiently delicate instrument. Following the work of Soviet and other researchers, test and check methods for these complex conditions have been developed. On their basis Hungarian research workers took reduction of thermal variation amplitudes (thermal damping coefficient) or delay of thermal variation penetration (phase lag) as basis of correspondence for non-stationary heat flow conditions of walls and floors. This new thermal research work requires a further international experience exchange to be made.

Both acoustic and construction designers have been faced with the immense problem of designing structures with good sound insulating properties from lightweight materials used with little structural thickness.

Similarly, generalization of up-to-date large-size wall slabs with cast in façade surfacing gave rise to the development of joint sealings against driving rain and wind. In this respect very much work has been done in Scandinavian and Western-European countries, which suffer the most from driving rain. Their results led to joint designs convenient for introduction in several countries abroad.

Quite special problems arise in hot climatic regions, both wet and dry.

In the above, as well as in some other contributions during the discussion, only a few problems have been mentioned. However these are sufficient to support the proposal to intensify international experience exchange, and hence the activity of the CIB.

Conclusions

This summary reflects, in small measure, the opinions and proposals of those taking part in the discussions on functional requirements, user's requirements and human requirements. 23 Congress participants at the discussion of this group called attention to the extreme importance of these requirements and to the highly important role some or other partial requirements play.

Building industrialisation, construction of our buildings with new materials, by new methods, economically, aesthetically and in a manner to satisfy social requirements, calls for investigation of many new problems. These have been identified as human requirements, user's requirements, functional requirements. In the field of determination of these requirements, a lot of valuable work has already been done in several countries, but it clearly appears that much work remains. The character of the problems awaiting solution makes international cooperation essential, and important possibilities for this are present within existing and future CIB working committees.

The use of systematic funtional analysis in developing improved constructions

By Ø. Birkeland (Norway)

If we wish to develop new building types and new constructions in buildings, theoretically the best course would probably be to "forget" what our present constructions are, and instead, start from base and settle the questions: What climate do we want in the building? What are the loads to be carried? What other stresses are derived from the use of the house? If, then, we were acquainted with the climate stresses outside, we could determine to what stresses the different parts of a building would be exposed.

If, further, we were familiar, with the physical laws which determine how the constructions behave under the stresses they are exposed to and the properties of the materials, we could then, with due regard to the technique of production and economy, design new constructions from the very beginning. By means of the calculations and/or methods of testing we could examine whether the constructions functioned as postulated under the ascertained stresses.

Our knowledge today is not sufficient to carry out such a process of reasoning consistently. In particular, it is difficult to fix the indoor climate and to ascertain what stresses this brings on the individual parts of the building. Fortunately it looks as if it is possible to attain quite a lot by taking the individual building parts directly, analyzing the stresses on these, and studying how these act under the stresses. Such ideas have more or less consciously lain behind the work of many building research institutions. This came prominently to view at the CIB Congress in Cambridge, most clearly in the opening address of the chairman, Dr. Lea. The present paper is an attempt to present some Scandinavian, more particularly, Norwegian, experiences.

The process of reasoning and the results which can be obtained by such systematic analysis are best illustrated by an example. The example chosen is external walls. This has been selected because it is one of the building parts which are relatively best known and which has been the subject of special study at the institution which the author represents. A very brief summary is presented of what we know about the stresses on an external wall, how they act, existing methods of testing and calculation, and the basis for qualitative comparisons. The account is based on a very comprehensive literature on the various questions. As the purpose of this paper is not primarily to discuss external walls, no reference to this literature is made.

How does an external wall function?

An external wall is exposed to a whole series of stresses, which may be divided into the following groups:

Climatic stresses

"*Rain penetration*" is caused by driving rain and wind which strikes the wall. The ordinary meteorological observations say little or nothing about the stresses on a wall. Several countries have now direct observations of the amounts of driving rain and at the same time of wind at unobstructed weather stations. They have calculated the corresponding data on the basis of the normal meteorological observations. The conditions at an unobstructed meteorological station are different from the conditions a building is subjected to. Investigations of these conditions are carried out by CIB members and our knowledge on this point increases slowly. Most of the available driving rain observations give the total for a long period. For rain penetration through joints and cracks, the intensity of the rain has a great significance, and in this respect we have as a rule few observations to build on.

We have reached a general conclusion as to what happens when rain strikes a wall which is at the same time exposed to the attack of wind. But we are far from being able to calculate in figures what actually happens. We are left to the method of making experiments which imitate what happens under a real attack of driving rain. For an interpretation of the test results we have to make comparisons with experience derived from experimental houses and practice. There exist now a number of laboratories which have sufficient experience to make it possible on the basis of tests to foresee how a construction will behave in practice in the climatic regions with which the laboratory in question has worked. These laboratories have a sufficient amount of experience to make it possible to grade constructions qualitatively.

"*Wind penetration*" is determined by the pressure difference over a wall under the action of wind. In many countries there exist relatively good wind statistics. But wind measured at a meteorological station is not the same as wind pressure on a building, and wind pressure on a building is not the same as the pressure difference over a wall. In this respect also research is being carried on which is slowly increasing our knowledge. We are, however, even now able to form an idea of the pressure differences in question. On the basis of experimental investigations we know also to some extent what determines the windproofness of a wall. We cannot calculate the air leakage through a wall for a specific pressure difference, but it is relatively simple to investigate leakage by tests. The windproofness of timber frame walls has been relatively well investigated and there exist a number of scattered experiments with curtain walls and concrete element walls. On the whole we know so much that we can qualitatively grade an investigated wall with respect to direct air leakages. Far less do we know about the conditions which determine whether the wind can cause air currents in the insulation materials and in this way substantially reduce the insulation. And here a qualitative grading of the wall is difficult to effect.

The *heat insulation* of a wall forms one of the relatively well investigated fields of study. We are in the main familiar with the stresses -the temperature difference over the wall and we can, thanks to our knowledge of the properties of the materials, calculate the heat insulation of a wall and, thanks to EDB-machines, pay regard to thermal bridges. We have ample material for comparison, which enables us to grade wall constructions qualitatively. Yet there are still factors which are insufficiently known, e.g. the influence of moisture in materials, and convection currents.

The *temperature difference* over a wall causes not only a heat flow through the wall, but also temperature stresses in the wall, which in some cases may be very large. In principle, we are familiar with the stresses and can calculate the distribution of temperature and the resulting strain, although these are not calculations of the kind which are often carried out.

Protection against solar radiation has been less investigated. In most places data are available for calculation of sunlight intensity and of the effect of shadowing devices. In order to calculate the heat transferred to the building surface we need data concerning radiated solar heat and meteorological information concerning the sky covering. On the basis of this the temperature conditions due to solar radiation in the building can be calculated, or determined by electrical analogical models or by similar methods. The investigations are relatively complicated, as not only the outer wall itself, but also the heat capacity in the whole of the rest of the building enter into the picture. Investigation has not been undertaken of so many cases that we have a basis for evaluation of exterior walls with respect to the protection from the sun. The question has special significance in northern countries where the solar rays strike the walls more than the roofs. In these countries not even the air temperature of midsummer will as a rule be inconveniently high, so that it is exclusively direct solar radiation which causes difficulties.

Other climate stresses have been little investigated. The external surface of the wall is broken down by frost, mechanical wear from rain etc., chemical atmospheric attack, sunlight etc. In part it may only be a question of change of colour, loss of gloss, accumulation of dirt, formation of disfiguring marks etc., which do not affect the wall's ability to fulfil its function. But in part it may also relate to a real destruction of the wall. In general we know so little about these circumstances that it is impossible to define what climatic factors are relevant with respect to the attacks to which the wall is subjected. The conditions will also depend on such things as the shape of the wallsurface, viz. how the rain is distributed and runs off etc.

We are very far from having the necessary testing methods in order to examine these conditions. We shall depend on accelerated tests, which in certain degree are bound to be different, not only for different stresses, but also for different materials. The development and interpretation of accelerated tests is a very complicated matter. The type of attack in question here is on the whole so little known that extensive research is needed to enable us to define the individual problems which should be taken up.

Stresses which are derived from the use of the house

Vapour and air pressure differences over the external wall can be established in broad outline. Vapour penetration is, however, dependent not only on vapour pressure differences over the wall, but also on temperature-differences, level of vapour pressure and temperature. Airpenetration through the wall is of decisive importance for the accumulation or removal of moisture in walls like curtain walls and timber frame walls. Although extensive research work has been carried out in this field we are still very far from being able to calculate or by experiments to determine, whether there is risk of harmful moisture collecting in a wall. We have some practical rules which can be used to guard against harmful accumulation of moisture, but these are very far from being satisfactory, and they do not by any means afford a satisfactory qualitative grading of the construction.

For measuring the results of *accidental knocks*, occasioned by the use of the building there exist quite a number of methods, although the stresses on the wall are little defined. The institutions which have developed such a method are usually of the opinion that the method is satisfactory and can interpret the results. Such an interpretation has as a rule been reached by comparing known walls which are deemed to be satisfactory. It may be said, however, that there is no definite method which is generally recognized, or any generally recognized qualitative grading.

The *suspension* of objects on a wall creates special problems. Although the stresses are better defined, there are not many test methods which characterize the properties of the walls and make it possible to grade them in respect of quality. This relates both to the strength of the wall and to the resistance to the withdrawal of screws etc.

The *risk that marks will be formed* on the wall on account of stresses from use depends on stresses which are little defined. Nevertheless, ballimpression tests etc. are applied with occasionally good results for ascertaining the risk of marks from certain stresses. Such tests seem to afford possibilities for a certain qualitative grading of the surfaces. Test methods which characterize the risk of a scraping up of a wall face seem to be lacking.

In respect of *fading and risk of defilement* we lack both testing methods and the possibilities for a qualitative grading of the wall. At present we find ourselves at a stage like that relating to the corresponding external stresses, where we cannot even define the research problems which should be solved.

Structural problems

In this case the stress consists in part of loads from the use of the building and from dead loads; in part it relates to climatic stresses like wind, weight of snow and fluctuations of temperature. The stresses are as a rule well defined and established in regulations etc. In most cases it is possible to examine structural properties by means of calculations, or by direct loading tests. We have as a rule a good basis for comparing the strength properties of constructions.

Resistance to fire

Here we find ourselves in a field where the stresses are little defined and where we have only test methods for a part of the properties which determine a wall's fire-technical properties. When it relates, for example, to the risk that a fire will spread through the wall from storey to storey, we are dependent on tests on full scale with several stories over one another. Such methods are costly and scarcely suitable for commercial testing. In spite of this fact certain traditional criteria for assessing the fire resistance have been developed. Such a judgment does not, however, rest on a rational understanding of what happens. Research work with a more ambitious goal seems now to be under development in several research institutions.

Sound insulation

The need for insulation against sound frome outside is relatively little defined. The methods of measuring sound insulation properties are well developed. In practice it is mostly the windows which determine the insulation against airborne sound from outside. The circumstance which is least under control is the flank transmission through an external wall.

What can the analysis be used for?

It is obvious that such analysis as described furnishes the only serviceable basis for assessing external walls and comparing them with one another. As far as possible we can in this way obtain a partly numerical-qualitative statement on each single requirement, which the wall is to fulfil. In this way we get also the necessary basis for formulating the requirements of building regulations and other specifications, as functional requirements (in part expressed numerically) independently of the individual, actual constructions. Formulated in this way the regulations do not signify a hindrance to new constructions, as they may well do today. (New building regulations for external wall constructions, based on functional requirements, have just been drawn up in Norway). The analysis gives the best insight into the function of the whole construction, and thereby the necessary guidance in designing a new wall construction. A structural engineer today designs a reinforced concrete beam on the basis of structural calculations and his knowledge of the properties of the materials. Correspondingly, the aim is that an external wall construction shall be designed on the basis of calculations, laboratory tests, and knowledge of the properties of the materials. It is only when we have reached this aim that we can arrive at the rational constructions we need.

Based on our knowledge of the stresses on the wall, and an understanding of the action of the wall under these stresses, we can arrive at the stresses upon the materials used in the wall. This should enable us to formulate test-methods which give a realistic picture of the stresses the materials are exposed to in the wall. Some test methods in use today may lead to the development of properties of materials which perhaps are not the most important in practice.

A real understanding of the stresses on the materials also enables us to write out specifications for a desired material and to ask the industry to produce the material. For instance, we lack today a good interior cladding material. It is a tempting task to write out specifications for the material we desire and give the building materials industry the assignment of developing the material. Other branches of industry to some extent work deliberately in this way in order to produce the new materials they need. The building trade should also begin to do the same.

Finally, such an analysis enables us to select the research problems which it is most essential to solve. In the case of external wall, for example, the heat flow problems have been exhaustively studied. There is, of course, very much more we should like to know about the heat flow through a wall, but it is manifest that there are a number of other important factors which have been far less investigated.

In the opinion of the author of this paper, such analyses as have been suggested in the preceding part are the method we shall have to follow if in the building trade too, we are to reach a conscious development of new constructions and materials.

How to make the analysis

It is obvious that we must begin by ascertaining exactly the stresses on the part of the building structure in question by stupying the reaction of the construction under these stresses, developing methods of testing and calculating, and procure the necessary basis of comparison for a qualitative assessment. It is simple enough to say this, but it raises a number of enormously comprehensive problems—problems which probably cannot be solved by any institution alone. Such analysis ought, therefore, to be typical cooperative tasks, well suited for such organs as a CIB Working Commission. By collaboration between widely experienced staff members from a number of building research intitutions it should be possible, in respect to a part of a building such as a roof, a wall etc. to prepare surveys of what types of stresses they are exposed to, what we know about the behaviour of the constructions under the stresses, what existing methods of calculation and testing we have, and what basis we have for a qualitative comparison. Such surveys conclude naturally with a survey of unsolved problems which can form a good basis for indicating research tasks which should be taken up by members of CIB, and possibly also as a basis for a division of work between the members.

Conclusion. It is necessary that we also in the building trade, in order to carry out a deliberate development of new constructions and materials, endeavour by systematic analyses to obtain a thorough understanding of the way in which the individual constructional parts act under the stresses they are subjected to. This can be achieved most easily by cooperation between several research institutions.

H 2

K. Blach

The list of functional requirements as a tool for creative building design

By K. Blach (Denmark)

Until recently the way of living and the art of building were nearly static. The means and the knowledge to fulfil our needs were inadequate. What tradition has shown to be feasible, was accepted as "good enough".

Today the way we live and methods of building are rapidly changing. And the possibilities of having even new needs and wishes fulfilled are abundant. Modern technology allows building materials, building components etc. to be created according to "specification", in the same way as products in other industries.

These specifications should neither be mere guesswork nor a slightly varied version of "how it has always been done", but they should be based on properly formulated *functional requirements.*

Choosing the right approach

The key words in this connection are that functional requirement must be properly formulated. If they are not, they can never become the desired – and necessary – tool for creative building design.

Functional requirements have long been known and utilized in planning. But formerly they were often based too much on assumptions and "tradition". And the important feed-back function (from production/management to requirements/planning) was nonexistent or extremely slow.

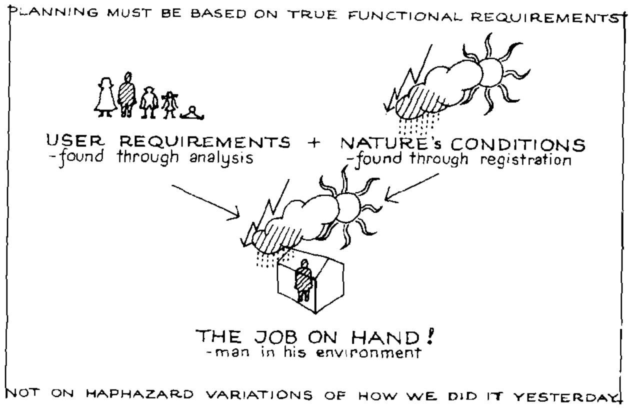
The procedure is today often as follows: A number of typical, well known solutions are sought out and registered. These solutions are then analysed, and – somehow – their functional ability is commented upon. A list of functional requirements are then agreed upon, and supplemented as far as possible with directions for calculations, testing methods etc.

In this way, the feed-back function is no doubt properly considered, but as the job as a whole begins with the "typical, well known solutions", the resulting list of functional requirements too often turns out only to be a tool for avoiding common mistakes or for producing solutions a little better than those of yesterday.

A more correct approach is probably to leave for the time being the "typical, well known solutions" and go right back to basic conditions. These can roughly be divided into two groups:

- *User requirements*, which can be analysed and which will change for example with a mounting welfare.
- *Nature's conditions*, which can be registered and which will vary from region to region and with the seasons.

The two sets of conditions will merge into the job on hand: man in his environment. By thus going right back to the basic conditions, it is ascertained that the functional requirements to be formulated can take as a starting point a clear conception of what the problem to be solved–through creative building design –really is; (example: A wall between two dwellings does not necessarily have to be heavy, even though it is the case with the typical, well known constructions of accepted quality. The basic functional requirements in connection with such a wall are that it should be strong enough, fire-proof enough and sound-proof enough. Consequently, a list of functional requirements should be phrased so that a wall of sandwich construction with light-weight materials can also get approval – as long as the functional requirements are satisfied).



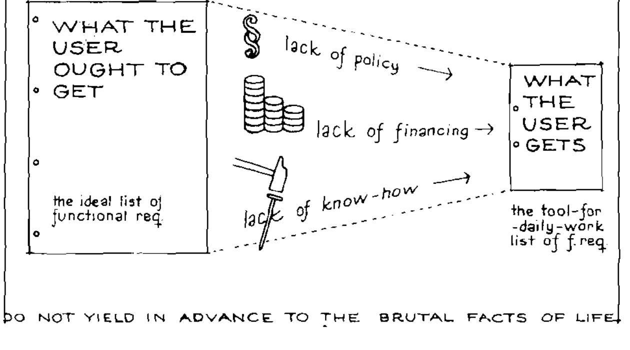
Aim at betterment of the end-product

Formerly, the accepted standard of quality was mostly what tradition had proved could be obtained. If walls were cold and damp, this was accepted as satisfactory, because no one knew how to apply heat insulation.

If we maintain, that methods and materials today to a great extent allow for solutions to be created according to "specifications" (= maybe even rather utopian wishes), there is good reason to aim at a much higher standard of quality and betterment of the end-products. Otherwise the new solutions will only be a little better than the old ones – which maybe were completely unsatisfactory.

At least the basic, ideal lists of functional requirements should aim very high – as high as we are able to imagine the standard of tomorrow will be. Then, due to economic factors, to lack of know-how, to retarded building codes, etc., it may be necessary to accept a list of functional requirements, which does not aim quite so high. The latter list can, on the other hand, be the approved practical tool for the work on hand today.

The two different lists of functional requirements should always go side by side. The cut-down list will often be approved by building authorities as a list of minimum requirements – and "understood" by planners and designers as maximum requirements. As soon as circumstances permit, the cut-down list



of functional requirements must therefore be revised so as to aim at a higher quality level.

Formulation is important

Many get lost when they try to write down functional requirements. Theorists, working on a list of basic functional requirements, often end up with a phraseology of broad, general terms which are quite impractical fur use in daily work. On the other hand, "realists", working for example on a list of functional requirements for a building code, often tend to over-simplify matters, so that the formulation – although concise – becomes a mixture of functional requirements and "what we know is possible".

A survey of existing lists of functional requirements seems to indicate that it may be desirable to have these written down in three different "languages".

A. In broad, general terms. Long-lasting definitions; no materials, constructions or figures mentioned; world-wide applicability.

B. In ordinary, daily language. Definitions mentioning well known, characteristic groups of materials, constructions etc.; no figures; applicable in regions with similar characteristics.

C. In "legal" terms. Very concise definitions of limited time-validity; specific materials and constructions mentioned; figures given; applicable only in smaller, specified regions with same characteristics throughout.

Especially when a team of specialists – as is often the case – collaborate on the formulation of a list of functional requirements, some kind of agreement as to "language" is necessary to ascertain a uniform presentation.

Examples of lists of different purposes

A list of functional requirements written down in any of the above mentioned three "languages", may again be used for several different purposes. The purpose will vary according to the job on hand and to who is going to do the job. A survey of work procedures in building shows that at least the following kinds of lists may be convenient:

a. The "memory" list. In this kind of list, functional requirements are stated without any special indication of what quality standard or degree of fulfilment it is desirable to aim at. The list may act as a kind of "memory" during a job of designing, so that no important aspect is forgotten or neglected (– and in many cases this is quite enough to ascertain a substantial betterment of the end-product).

b. The checklist for comparison. The functional requirements are often, for this purpose, listed in diagrammatic form and formulated in such a way, that items can be checked for degree of fulfilment simply by answering "yes – partial – no". It is not necessary to indicate desired quality in absolute terms, but it should be possible to judge relative quality with ease. This type of list is especially convenient, where the job implies a choice between alternative solutions, viz. choosing between offered prefabs.

c. The direct design guide. This is by far the most fully developed list of functional requirements. It should contain basic definitions in general terms and clearly state the standard of quality to be aimed at. Figures should be given as far as possible, and calculation methods and testing methods should be fully explained. The list may be given the form of a manual or textbook, a code of practise or a more simple list used only for control.

Experience shows, that any kind or form of list of functional requirements will show some gaps. This is unavoidable, as human knowledge and ability to think have their immediate limits, but this should not be deplored, as these gaps will clearly show where future research and development work is needed.

Conclusion. Planning and design must be done to meet functional requirements. For each item to be treated, it is desirable to establish a list of functional requirements. Such lists may have to serve various purposes and will consequently have to be phrased in different ways and given different shapes.

As much work is already being put into establishing lists of functional requirements all over the world, the time is due for a coordination of efforts. Such a coordinating effort may manifest itself in the form of a manual on the establishment of lists of functional requirements. As a manual of this kind would be international in character – its contents directly applicable in many countries – it is proposed that such a manual be made the subject of a CIB working group.

References

Directives communes pour l'agrément des Façades Légères (curtain walls) – UEAtc, Paris 1961 – contains a new type of code of practise, known as "agrément", formulated as functional requirements and jointly approved by Belgium, France, Holland, Italy, Portugal and Spain. Type of list: Direct design guide and checklist (memory- and control list). Only functional requirements deemed relevant now and in a foreseeable future are stated. Figures, calculation methods and testing methods are given to the extent possible.

Element Design Guide – *Architects' Journal* Information Library, London, 1961–64, a series of loose-leaf sheets—contains very detailed checklists for building elements, with references to major works and building codes. Type of list: Checklist (memory) for planning and design, but does not directly state desired quality of end-product.

The Danish building manual BYGGEBOGEN – Nyt Nordisk Forlag, Copenhagen, 1948–64, appr. 550 loose-leaf sheets – contains lists of functional requirements for ordinary building elements and installations, and for the dwelling. Type of list: Direct design guide, though only few figures and testing methods are indicated.

General considerations on standards, "agrément", and the assessment of fitness for use

By G. Blachère (France)

Under the same name, "standards", and in the same form, we have definitions whose substance, object and scope are different. We shall leave aside in what follows all those aspects of standardisation relating to the assembling of two distinct items; these are dimensional standards. Among existing standards, there are those which are laid down for and by manufacturers, and others which are laid down for and by users. The latter, less numerous than the former, exist in fields where the users, or at least one among them, are powerful and competent. But is is clear that they could exist in all fields, since every product has a manufacturer and a user. The necessity of coordinating and, if possible, of merging manufacturers' standards and users' standards will not be dealt with here.

What is certain is that in the building industry users' standardisation is developing alongside manufacturers' standardisation. The object of manufacturers' standardisation is to define a product exactly, mainly with the aim of:

1) Clarifying transactions and hence avoiding unfair competition, eliminating bad manufacturers, and sometimes also "freezing" a technique for a certain length of time.

2) Limiting, in view of productivity, the variety of items that users can order.

Since a product is always made with its possible uses in mind, there is a link between the standard and these uses. But the link is often vague. Users, on the other hand, through standardisation as through all technical specifications, seek to be assured of the fitness for use of what they buy and use.

Let us note at this stage that this fitness for use can be recognized in various ways. There can be a definition of the conditions to which all items in a given category must conform in order to be fit for use; this is a general standard. More specifically, there may be a recognition that a type of product, principally that in a given manufacturing series, is fit for use. Such recognition corresponds to the French "agrément" or the German "Zulassung". Thirdly, there may be a recognition of the fitness for use of each product. It is rarely possible to guarantee that every product in a given series is fit for use, for it would mean being able to use a non-destructive testing process and testing every product! Only high-cost items can be subjected to such a control. In reality, in very many cases the user is satisfied to know, for example, that the series is controlled by the manufacturer by a specific procedure, and that this control is itself checked by independent experts, those "sages" whose role is becoming more important every day, in proportion as the complexity of control and reception operations makes it impossible for an isolated individual to form a judgement.

This procedure corresponds to marks of conformity to standards and the "agrément", following them.

So we see that, apart from the exceptional case where each product can be tested, what conformity to the standard, acceptance, and the mark of conformity provide, is not in the nature of a guarantee, but in the nature of an item of information, more or less rich depending on whether the conformity applies to the individual product, the type, or the category.

In the building industry, as in all other sectors, users want to know about the fitness for use of any given material, building element or assembly process. The term "fitness for use" must be understood in the sense of fitness for a *clearly defined* use or uses. This, in the building industry, means fitness for use in the construction of *clearly defined building parts*. If a material or process is fit to be used in the manufacture of a building part it means that the structure in question, thus built, meets the quality prescription imposed on that structure so that subsequently the building as a whole shall satisfy *human requirements*, which is the aim of every builder (cf. the paper "Proposed legislation based on human requirements for the construction of dwellings" – report 1 in Group D, of the *CIB* Congress).

As we know, these quality prescriptions may be expressed:

- scientifically, usually in the form of design rules;
- technologically, descriptive of the proper manner of proceeding, in the form of courses of lectures, codes of practice, standards or "agréments";
- functionally, or in requirement terms, which amounts purely and simply to a repetition of the requirement from which the standard of quality derives, or more precisely to an indication of the natural or semi-natural test proving that the requirement has been satisfied.

A scientific quality prescription provides the optimal situation: This is the case, for example, in the fields of stability or of thermics. This scientific expression, if perfect, leaves no place for any arbitrary choice of materials or techniques; it imposes conditions in terms of accurately defined physical magnitudes. So there is no need of standards. But the user wants to know if a structural element which he buys ready-made (prefabricated, as it is called) and not a raw material, satisfies the rule: this is an item of information which he requests so as not to have to search it out himself: the "agrément", the "Zulassung", the marks indicating the conformity with the rule, will provide it.

He also wants to know, without having to measure them, the values of the physical magnitudes relating to a raw material. This is provided by a *data-sheet* or by virtue of the fact that the product satisfies a standard which imposes certain values on these physical magnitudes; the mark indicating the conformity with this standard then provides the information required.

All quality prescriptions cannot be expressed scientifically, for at least one reason: among the requirements that these quality prescriptions translate, is the requirement about durability (which is, moreover, strict in the building industry: 50 years). The science of building durability, which is not very highly developed, will probably never enable the behaviour of new structures to be predicted on the basis of instantaneous measurements or calculations. The affirmation of durability is that the structure will not perish in any way. May not an innovation induce new ways of perishing which cannot be predicted and prevented by knowledge available at the moment? This is in any case the present situation: durability is deduced from more or less lengthy experiments on the object itself. It is also deduced from the result of previous experience; that is often empiricism; that is in any case the field not of science, but of technology. Durability is not liable to design rules, but to technological prescriptions: codes of practice, descriptive standards and "agrément".

It is impossible to prove directly a 50 years durability, for on the one hand it would mean too long a checking on a new item, and on the other hand if carried out today on an old item such a checking would give us information about that very object, which is different from what is made nowadays. Consequently, where durability is concerned, judgement always comes in.

Even in the case of a new fabrication belonging to a standardized category, we must ask ourselves:

1) Whether the product is indeed covered by the standard,

2) Whether the particularities of the product were in fact taken into consideration when the standard was laid down.

The answers to these two questions can be supplied by the user himself (in the case of standards without marks of conformity, for example). But it may be supplied by "sages" who say that in their opinion the new type of product is quite fit for use and is covered by the standard in question (that is the case with the "Zulassung", for example). Judgement must come in even more so in the case of a new product or process; but individual judgement is impossible, for it demands too high a degree of competence and too great resources; only a collective judgement by "sages" is possible. This is "agrément".

Technologically expressed standards of quality are encountered where science has not advanced sufficiently to allow calculation, but where empiricism has made it possible to lay down technological rules. These rules are what may be called established practice. They may be given in didactic form in university courses, or during apprenticeship, or in monographs and manuals The need has been felt to codify this established practice in order to separate what is sound from what is doubtful and to eliminate contradictions, not only to assure successful building but also, and even more so, to make it possible to settle disputes and fix responsibility. There are the codes of practice which state what must necessarily be done or not done in erecting a construction. These specifications are usable only in a given technological situation, for they apply to structures as they are currently built. To define the materials to be used, the codes of practice refer to standards; whenever the building is of a traditional type, i.e. is erected by the contractor using raw materials, the standards referred to are manufacturers' standards, that is descriptive standards which give information about the identity of the product, but which do not include any information as to its fitness for use; it is in the code of practice that this notion is included. It is the code of practice which tells how to erect a proper structure using the materials the nature of which is specified by the standards.

The code of practice also deals with the erection of structures using components* or elements** purchased by the contractor. These components or elements, if they are sufficiently known, are the subject of users' standards which give information on their fitness for use, that is to say the possibility of erecting correct structures using these products, whose behaviour the purchaser cannot determine when he buys them ready-made. The user's standard must thus give the conditions to be complied with by the product (component or element) in order for it to be durable; either manufacturing or acceptance conditions.

This standard may also give prescriptions on how to give knowledge of the values of the physical magnitudes involved in the calculations necessary for verifying scientifically-expressed quality prescriptions, and also the results of natural or semi-natural tests aimed at checking conformity with functionally-expressed quality prescriptions. In both fields, this standard can lay down compulsory values or results.

Thus the user's standard makes it possible to check whether a product is suitable for a structure erection, provided it is used in conformity with the codes of practice and design rules. It is increasingly frequent for codes of practice to insist on the use of products bearing the mark indicating their conformity with standards. Even if this is not the case, the user likes to take advantage of the additional informations given by procedures like "Zulassung" or conformity marks.

The development of industrialisation is leading to a growing use of ready-made components and elements. Codes of practice will therefore make increasing reference to users' standards, which moreover will tend to simplify them. When building work is carried out using new methods or new materials, established practice no longer exists, consequently neither do manufacturers' or users' standards. This is where "agrément" comes in. It provides, where durability is concerned, the opinion of the "sages", based on experimentation and observation not only of the category, but also of the type, of product. It necessarily gives the conditions of manufacture and acceptance which make it possible to identify the products in question with those which have been examined. It also gives, as does the user's standard, the values of the physical magnitudes to be taken into account in design calculations. In the case of materials, it must give the conditions of use, and in the case of processes, the specification of materials. It is based on the standards of all kinds applicable to materials, components or elements involved in what is submitted to "agrément".

Functional or requirements quality prescriptions give rise to the codification, i.e. standardisation, of the semi-natural test conditions by which they are verified. The corresponding standards may be either special, or integrated in a user's standard. Codifying dispositions may also be included in a code of practice or in an "agrément". In this way are constituted and co-ordinated the various technical documents intended to provide the user with information on the materials, elements, components and processes which he uses for building.

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* By component is understood a product made for incorporating in a structure, belonging to one or several categories. For example, a door or a concrete block are components of a wall.

** By element is understood a product whose setting in place (or assembly) constitutes a complete structural unit, such as an outside wall complete with windows, or an inside partition wall.

Sound insulation problems in prefabricated blocks of concrete flats

By O. Brandt (Sweden)

The problem of sound insulation is attracting much attention in many countries—in Europe, the question is being considered in Germany, Holland, Great Britain, Scandinavia and some other countries. Two main points are dealt with in this paper:

1. An attempt to express through the ISO (International Organization for Standardisation) sound insulation requirements and recommendations in a similar way, so that builders, architects and consulting engineers can plan their products or systems for an international market. As a secondary result of this work it is probable that a number of countries will adopt similar standards for airborne and impact sound insulation.
2. Main points which have emerged from studies of modern Swedish building systems for multifamily concrete housing.

Grading curves for airborne and impact sound insulation

At present, sound insulation requirements are not comparable because insulation values are expressed in different terms and based on different definitions.

In a number of countries, the requirements for sound insulation are plotted as a grading curve. These curves give the minimum insulation required at different frequencies. Fig. 1 shows some grading curves for *airborne* sound in use in several countries. In general, measured insulation should be at least as high as indicated by a curve at all frequencies, but as a rule some values below the curve are also accepted provided the sum of the deviations is less than 30 dB (Germany and some other countries) or 16 dB (Scandinavia).

The *impact* sound values measured beneath a floor on which a standardised tapping machine produces impact noise must be *below* the grading curve. The quality figures are thus counted in the opposite direction, i.e. good insulation is indicated by a low curve while bad values lie above the grading curve. In fig. 2 impact grading curves in use in a number of countries are given. Deviations are calculated in the same way as for airborne sound but in the opposite direction.

An attempt is being made by the ISO to get agreement on reference curves to be used as the basis for a single figure of quality. Fig. 3 shows the reference curves being discussed in this connection. If these curves are accepted it will be possible to express the insulation as is done in Germany, by calculating the movements in a positive or negative direction required to comply with the reference curve. If a case where the airborne or impact sound insulation is just satisfied is represented as O dB, buildings with better insulation get plus values, while those with inferior insulation have negative values. It has been proposed to call this quality figure an *index*, one relating to airborne sound and another to impact sound.

It is intended that this procedure, which is simpler in practice than it sounds, and very similar to the existing "Schallschutzmass" in Germany, should be used only for estimating the insulating qualities of party walls or floors. For doors, windows or similar, the traditional average insulation airborne value in the frequency range of 100–3150 Hz will continue to be used.

Summary of sound insulation problems

As is known, good sound insulation is closely connected with good planning. One need only mention the importance of avoiding the placing of wash-rooms, W.C.'s, bathrooms, etc., next to the neighbours' bedrooms. The problem of noise in connection with sanitary installations has not yet been solved and freedom from disturbance cannot be guaranteed in bedrooms. For further details, reference should be made to textbooks on the subject. Planning does not, however, help us in regard to the vertical insulation of the flats, as usually the same types of room are placed above each other. Therefore great care must be taken in the insulation of the floors, while careful planning can abolish horizontal airborne disturbance even with relatively poor partitions.

Another main rule is that the partition constructions should be as heavy as possible. In building with concrete or solid brick in the traditional manner few insulation problems arise. With building members that weigh at least 400 kg/m^2 the insulation is usually good enough to satisfy the sound insulation requirements in most countries.

It should be pointed out as well that the insulation problem can be solved by the use of *light-weight* double or multiple constructions. Such partitions often, however, in practice cause a

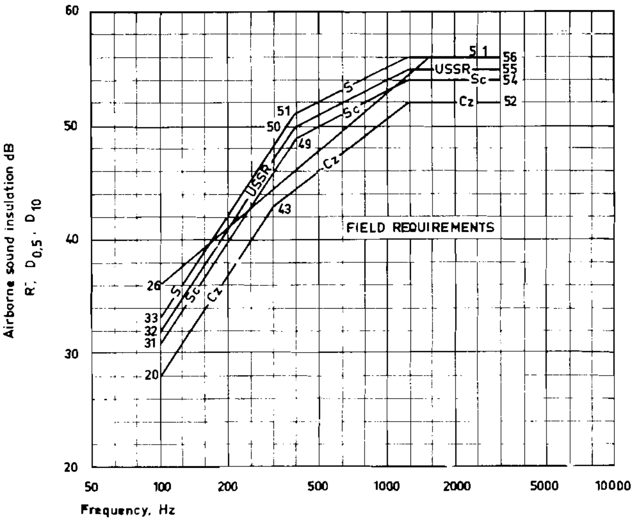


Fig. 1. Airborne sound insulation
Comparison between field requirements for flats.
I = United Kingdom, grade I ($D_{0\cdot5}$)
S = Germany, Sollkurve (R)
USSR = USSR, curve I (R',D_{10})
Sc = Scandinavian field requirement (D_{10} in Sweden, $D_{0\cdot5}$ in the rest of Scandinavia).
Cz = Czechoslovakian field requirement (D_{10})

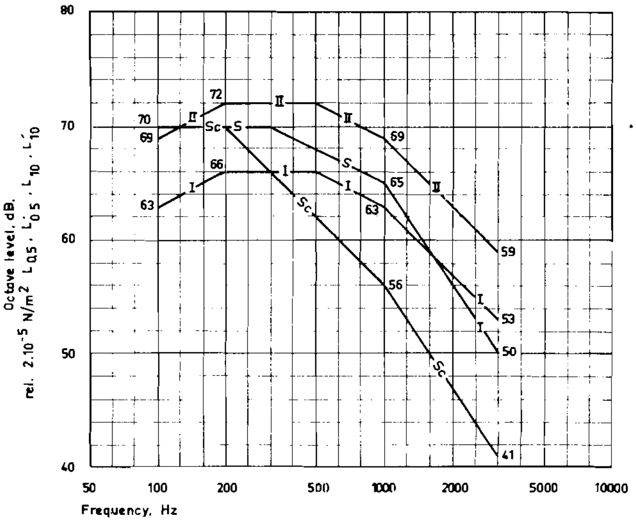


Fig. 2. Impact sound transmission
Comparison between requirements for flats.
I = United Kingdom, grade I ($L'_{0\cdot5}$)
II = United Kingdom, grade II ($L'_{0\cdot5}$)
S = Germany (Sollkurve) and USSR (curve IV) (L_{10}, L_{10}')
Sc = Scandinavia ($L_{0\cdot5}$ and $L_{0\cdot5}'$ except for Sweden where L_{10} and L_{10}' is used)

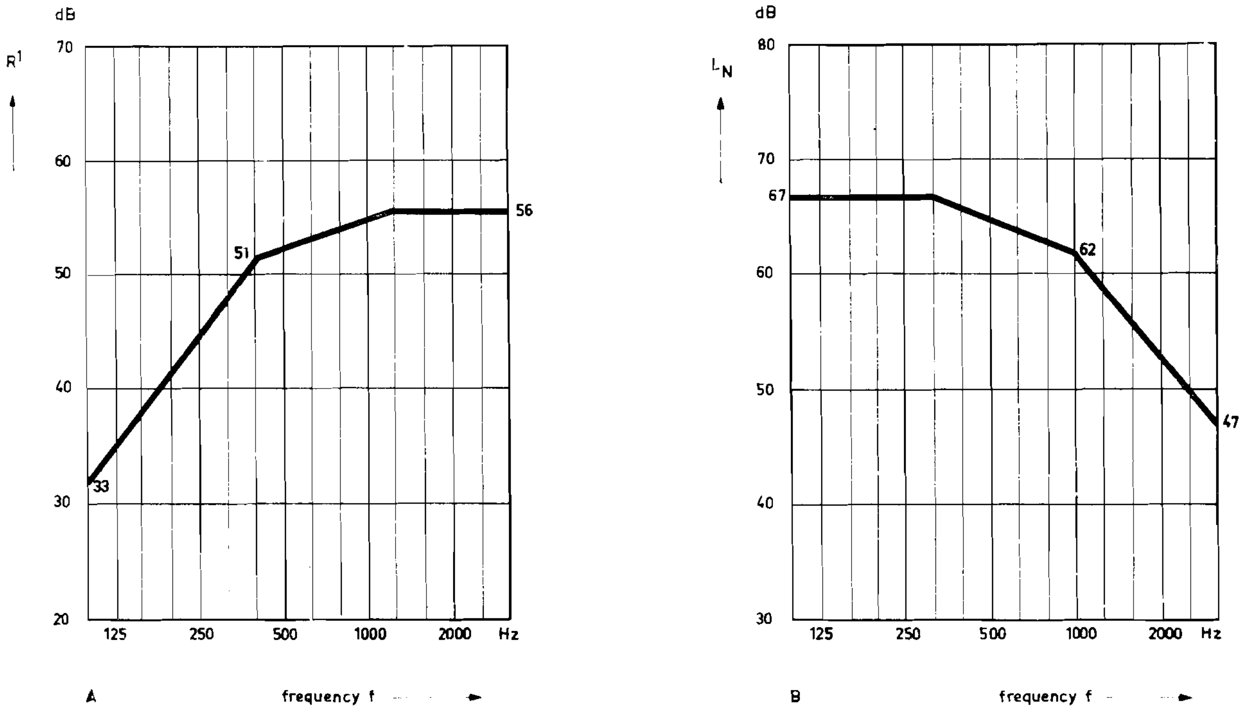


Fig. 3. Reference curves for airborne (A) and impact (B) insulation discussed by ISO/TC 43 WG 3.

number of practical difficulties: for example, it is difficult to avoid sound-bridges that destroy the insulation more or less.

Finally, it should be mentioned that good impact sound insulation can be obtained with the use of heavy, solid concrete floors and ceilings and the choice of a floor type that either in principle deadens the impact sound, e.g. a soft carpet covering the whole of the surface or plastic-faced jute fabric, or by insulating the floor from the framework of the house – so-called floating floors. The latter construction type is not used as widely as could be desired mainly on account of the fact that the insulation is very often spoilt by sound-bridges between the concrete slab and the building framework.

Special problems in blocks of flats built by prefab methods

The following observations are wholly based on investigations carried out in Sweden at the Institution of Building Acoustics of the Royal Institute of Technology.

The Institute started work in the later 1950's on sound insulation in blocks of flats built by prefab methods. It began by sample testing of airborne and impact sound insulation between a number of flats, completed between July 1959 and October 1960. The results are summarized in the following table.

The results are not particularly encouraging, but better results would hardly have been obtained if the investigation had concentrated on "modern" houses built according to traditional methods. An intensive investigation in the field of industrialized house-building was therefore started and the situation today can be summed up in the following points:

– a). The weight of the floors and ceilings between flats in buildings made of concrete elements has often been insufficient. The architects should have known that in cases where the weight is below 350–400 kg/cm^2 complementary structures are usually necessary.

– b). Lack of tightness showed itself in many forms. Joints are more often a source of leakage in thick concrete structures. The same is the case with cracks and leaks in floors, ceilings or at connections with side-walls when storey-high elements are used (see Fig. 4A and 4B).

– c). It appeared that the problems of flanking transmission sound were greater than had previously been the case in cast in situ concrete houses. Fig. 5 shows the sound insulation between two adjoining rooms where the outer walls were of in situ concrete with heat insulation material on the outside, and the sound insulation obtained in connection with a sandwich element used in assembly structure, where the construction has not been carried out correctly. With correct construction the sound insulation is very satisfactory.

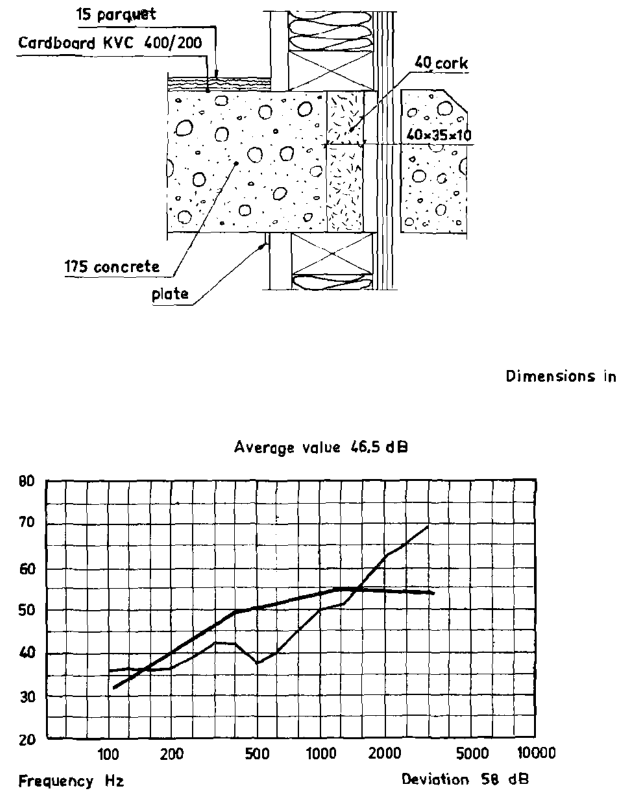
It also appeared that in light element building systems flanking transmission sound sometimes occurred due to some light weight walls between rooms in flats, thus vertically by way of the floor. Research is being carried out on how such walls can be mounted elastically against the floor and the ceiling.

– d). In the above mentioned sample investigation the impact

TABLE 1.

a. Airborne sound insulation in horizontal direction (partitions)

Theoretical maximum number of possible measurements	Number of investigations	Acceptable according to the building regulations of the National Board of Building and Planning (1950)		Acceptable according to the building regulations of the National Board of Building and Planning (1960)	
		No.	%	No.	%
1451	81	41	51	26	32
b. Airborne sound insulation in vertical direction (floors)					
3644	103	77	75	51	50
c. Impact sound insulation in floors					
3644	142	59	42	37	26



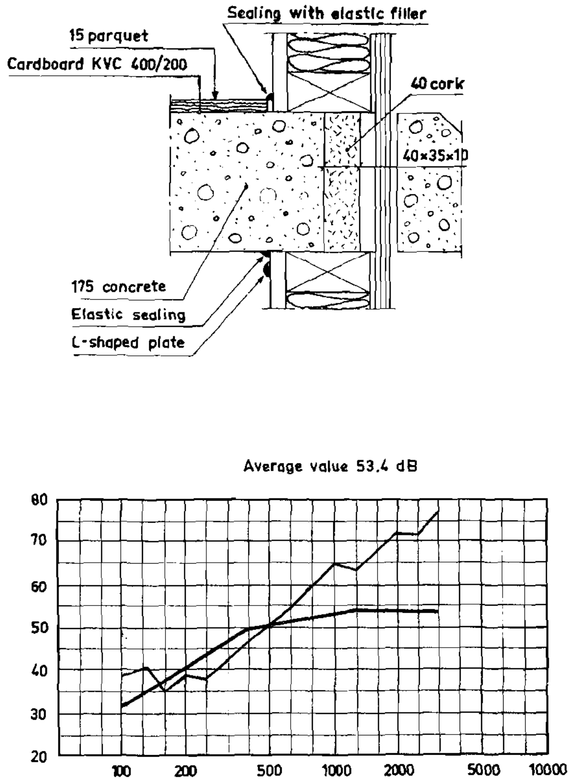


Fig. 4A. The airborne insulation for a massive 17.5 cm concrete floor may easily be destroyed, for instance due to leaks at a light outer wall. When such leaks are tightened the floor insulation is satisfactory.

Fig. 4B. The same as 4A but with scaled leaks. In both cases the Scandinavian and German grading curves are given for comparison.

sound insulation was surprisingly low. It was proved later that this was connected with the fact that the floor coverings were not sufficiently soft. Since then publications have appeared in Sweden on this subject describing suitable coverings, and the difficulties in getting good impact sound insulation have been largely overcome.

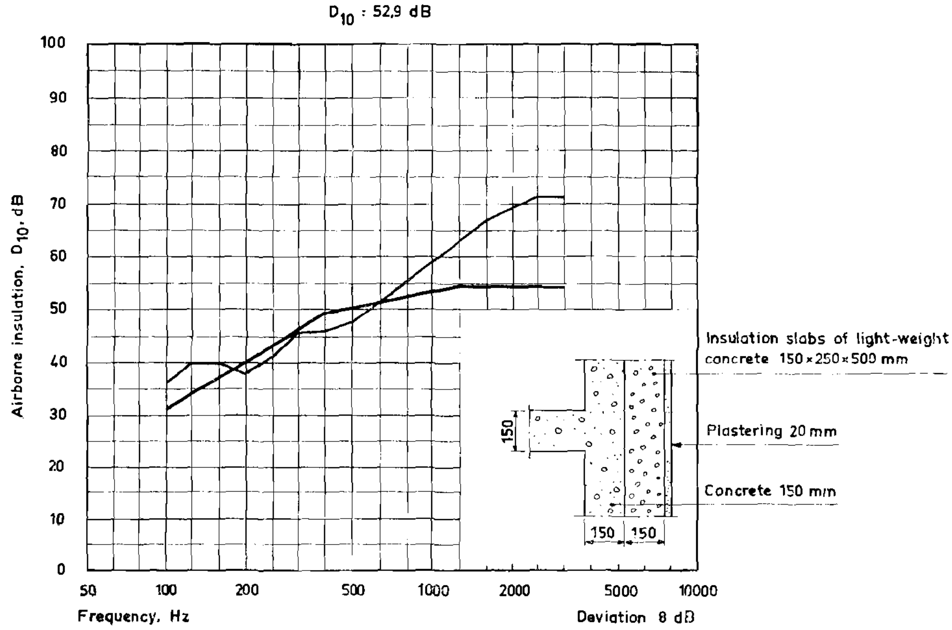


Fig. 5. Airborne insulation, D_{10}dB, between two adjoining rooms.

Fig. 5A. A concrete partition of 15 cm and a flanking outer wall of concrete (traditional design).

I have always been of the opinion that better sound insulation is obtainable in prefab concrete dwelling-houses than in those built in the traditional way. This view is based on the fact that planning a large number of units is easier than planning according to the old system. In addition, it should also be possible to abolish improvisation on the building site. So far perhaps this positive attitude has not been confirmed by the cases investigated in practice, but there is scarcely any doubt that in the long run element production will overcome these initial difficulties

Finally, Fig. 7 shows how the insulation in an element house can be considerably improved, if it is incorporated in the design from the start.

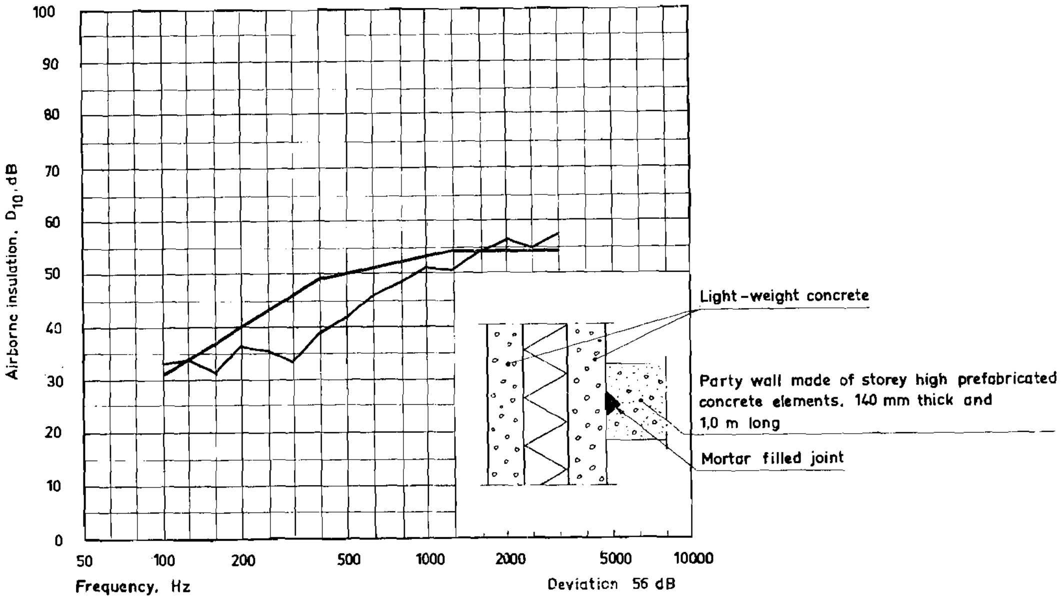


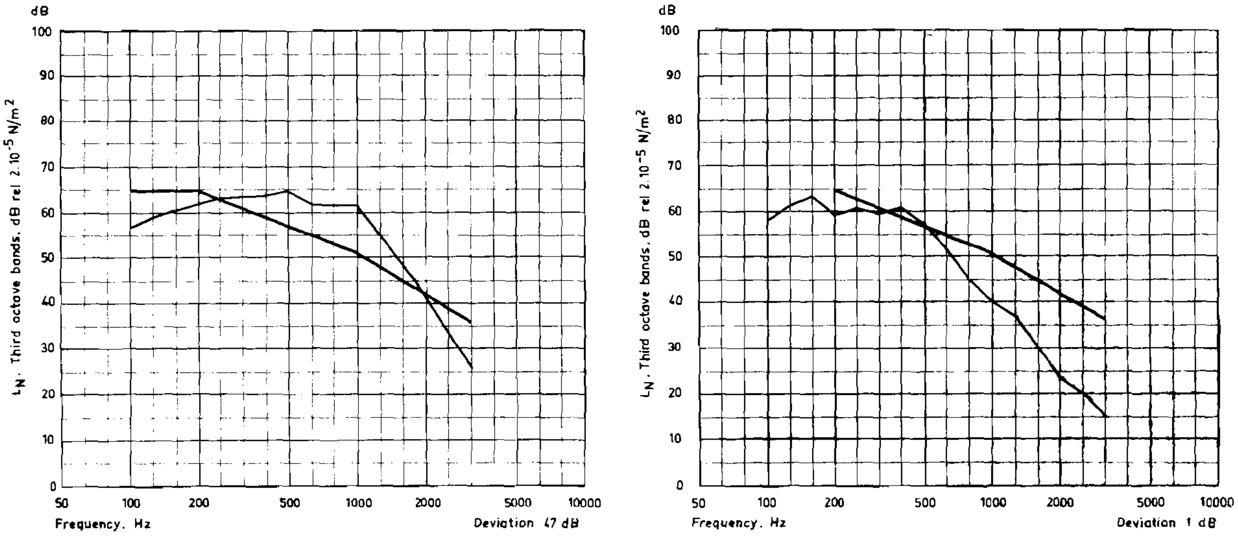
Fig. 5B. A concrete partition of 14 cm in prefab element and a sandwich outer wall of light-weight concrete.

Fig. 6. Impact insulation L_N for concrete slabs about 20 cm thick covered with two different flooring materials.

A. Linoleum, 2 mm and cardboard YL 400/600

Floor construction
Linoleum 2 mm
Cardboard YL 400/600
Screed 35 mm
Concrete 160 mm

B. Linoleum, 2 mm and granulated cork on asphalt paper (KYL 600/500).
Floor construction
Concrete element of room size 190 mm
Cardboard KYL 600/500
Linoleum 2 mm



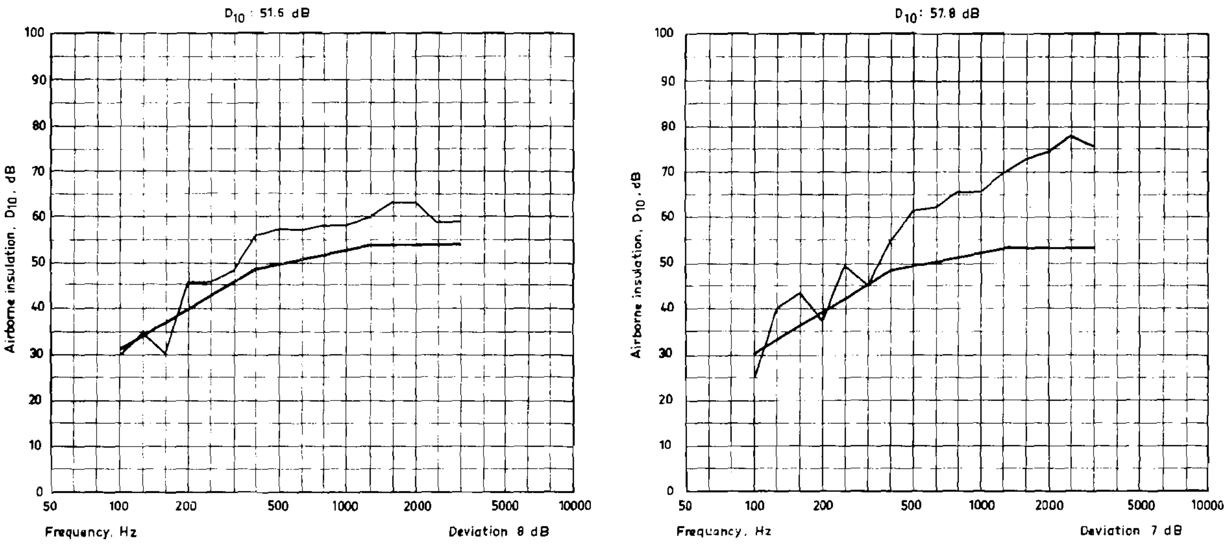


Fig. 7. Example of field measurement resultsfor light-weight prefab recently introduced in Sweden. All results are compared with the present Swedish requirement curve.

A. Horizontal airborne insulation D_{10}.
B. Vertical airborne insulation D_{10}.

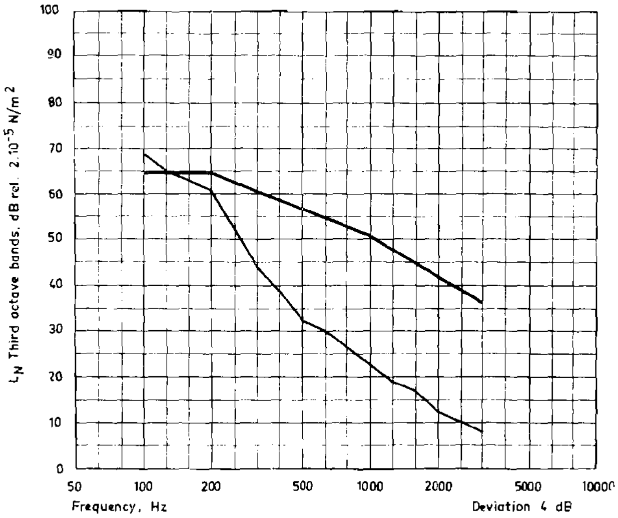


Fig. 7C. Example of field measurenemt results for light-weight prefab system recently introduced in Sweden. All results are compared with the present Swedish requirement curve.
Vertical impact level insulation L_{10}.

F. Bruckmayer

Evaluation of prefabricated dwellings with regard to building physics

By F. Bruckmayer (Austria)

Due to the rapidly increasing use of prefabricated elements in residential buildings great care must be taken to meet the requirements of building physics so as to obtain buildings with sufficient or, as far as possible, raised housing value.

A method is proposed for evaluating the properties relevant to building physics for prefabricated external wall elements in dwelling houses. The following viewpoints are considered:

the standardised specifications; the applicability for more accurate comparison of building elements of the same type, for sufficiently exact comparison of building elements of different types and comparison with traditional building methods; the climatological conditions by using the TBE-Climate Maps(1); simple application of the method; the possibility of partial judgements; the possibility of extension.

20 properties within the sector of building physics are deemed indispensable for the estimation:

1. meeting the requirements for each of the properties quoted relative to building physics is rated as 10 points;
2. any 10 per cent improvement or deterioration of the basic value gives 1 point plus or minus. The doubling or halving of the basic value consequently is reckoned as 20 or 5 points, (plus or minus);
3. if the standardised specification for one property, e.g. the minimum thermal insulation, is not complied with, the element is unsuitable for the country. Requirements not met as to one property may not be compensated for by excess in another. The minimum values according to standards, building regulations or similar requirements therefore must be plotted and attention paid to them;
4. in the event of assessment not being made of the 20 properties together the number of points achieved accordingly varies

Evaluation of prefabricated external walls

Group 1. Thermal protection

1. Thermal transmittance resistance of the compact opaque wall elements

The required thermal transmittance resistance (reciprocal thermal transmittance) depends on the climate which is taken as the average annual minimum of the temperature (DJM) and the heating degree-days (HGT)*.

The thermal transmittance resistance 1/k is evaluated by means of table 1

$$1/k = 1/\alpha_i + \Sigma\, d/\lambda + 1/\alpha_a = \Sigma\, d/\lambda + 0{,}193 \text{ m}^2\text{h °C/kcal}$$

... equation 1

As a rule it is obtained by measurement carried out on the external wall element. Cold bridges are included in the determination of 1/k.

The required thermal transmittance resistance is found out by means of the average annual minimum according to column 10 of table 1

$$1/k = \frac{1}{\alpha_i}\,\frac{t_i - t_a}{t_i - t_s} \text{ m}^2\text{h °C/kcal}$$

... equation 2

TABLE 1.

DJM °C	points																					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	30	40	50
−45 .	0,28	0.43	0,57	0,71	0,85	0,99	1,14	1,28	1,42	1,56	1,70	1,84	1,99	2,13	2,27	2,41	2,55	2,70	2,84	4,26	5,68	7,10
−42 .	0,27	0,41	0,54	0,68	0,81	0,95	1,08	1,21	1,35	1,48	1,62	1,75	1,89	2,02	2,16	2,29	2,43	2,56	2,70	4,05	5,40	6,75
−39 .	0,26	0,39	0,52	0,65	0,77	0,90	1,03	1,16	1,29	1,42	1,55	1,68	1,81	1,93	2,06	2,19	2,32	2,45	2,58	3,87	5,16	6,45
−36 .	0,24	0,37	0,49	0,61	0,73	0,85	0.98	1,10	1,22	1,34	1,46	1,59	1,71	1,83	1,95	2,07	2,20	2,32	2,44	3,66	4,88	6,10
−33 .	0,23	,035	0,46	0,58	0,70	0,81	0,93	1,04	1,16	1,28	1,39	1,51	1,62	1,74	1,86	1,97	2,08	2,28	2,32	3,48	4,64	5,80
−30 .	0,22	0,33	0,44	0,55	0,65	0,76	0,87	0,98	1,09	1,20	1,31	1,42	1,53	1,63	1,74	1,85	1,96	2,07	2,18	3,27	4,36	5,45
−27 .	0,21	0,31	0,41	0,52	0,62	0,72	0,82	0,93	1,03	1,13	1,24	1,34	1,44	1,54	1,65	1,75	1,85	1,95	2,06	3,09	4,12	5,15
−24	.	0,29	0,38	0,48	0,58	0,67	0,77	0,86	0,96	1,06	1,15	1,25	1,34	1,44	1,54	1,63	1,73	1,83	1,92	2,88	3,84	4,80
−21	.	0,27	0,36	0,45	0,53	0,62	0,71	0,80	0,89	0,98	1,07	1,16	1,25	1,33	1,42	1,51	1,60	1,69	1,78	2,67	3,56	4,45
18	.	0,25	0,33	,042	0,50	0,58	0,66	0,75	0,83	0,91	1,00	1,08	1,16	1,24	1,33	1,41	1,49	1,58	1,66	2,49	3,32	4,15
−15	.	0,23	0,30	0,38	0,46	0,53	0,61	0,68	0,76	0,84	0,91	0,99	1,06	1,14	1,21	1,29	1,37	1,44	1,52	2,28	3,04	3,80
−12	.	0,21	0,28	0,35	0,42	0,49	0,56	0,63	0,70	0,77	0,84	0,91	0,98	1,05	1,12	1,19	1,26	1,33	1,40	2,10	2,80	3,50
− 9		.	0,25	0,32	0,38	0,44	0,50	0,57	0,63	0,69	0,76	0,82	0,88	0,95	1,01	1,07	1,13	1,20	1,26	1,89	2,52	3,15
− 6		.	0,23	0,29	0,34	0,40	0,46	0,51	0,57	0,63	0,68	0,74	0,80	0,85	0,91	0,97	1,02	1,08	1,14	1,71	2,28	2,85
− 3		.	0,20	0,25	0,30	0,35	0,40	0,45	0,50	0,55	0,60	0,65	0,70	0,75	0,80	0,85	0.90	0,95	1,00	1,50	2,00	2,50

Thermal transmittance resistance 1/k m²h °C/kcal

to avoid condensation under the following conditions:

$\alpha_i = 5$ kcal/m²h °C, $t_i = 20°$,

$t_s = 10{,}8°$ (dewpoint for 20°, R = 55%), $t_a =$ DJM

In view of ascertaining the required thermal transmittance resistance for limiting the annual thermal requirements the heating degree-days total has to be taken into consideration. The characteristic temperature is calculated,

$$20 - \frac{HGT}{100}$$

... equation 3

and entered in column 1 of table 1, if it is lower than the average annual minimum of the place in question.

These thermal requirements are based on the heating degree-days total of 3500 with a thermal transmittance coefficient k = 1.20 kcal/m²h °C.

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* Climate Maps no. 2 "Average annual minimum of the temperature" and no. 3 "Annual number of heating degree-days" for Europe (scale 1: 1,600.000) issued by the Fédération Européenne des Fabricants de Tuiles et de Briques (TBE) and detail maps issued by the national organisations of brickmanufacturers, e.g. 1: 1,000.000 of the Verband Österreichischer Ziegel-Werke (VÖZ).

TABLE 2.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	points
thermal transmittance resistance 1/k			.	0,20	0,25	0,30	0,35	0,40	0,45	0,50	0,55	0,60	0,65	0,70	0,75	0,80	0,85	0,90	0,95	1,00	$\frac{m^2h\ ^\circ C}{kcal}$
thermal transmittance k				5,00	4,00	3,33	2,86	2,50	2,22	2,00	1,82	1,67	1,54	1,43	1,33	1,25	1,18	,110	1,05	1,00	$\frac{kcal}{m^2h\ ^\circ C}$
remarks				→|3|←					|← 1	|< 2											

1: field of compound windows
2: field of double windows
3: field of single windows

TABLE 3.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
wind ≦ 10 000	0,5	1	1,5	2	2,5	3	3,5	4	4,5	5	5,5	6	6,5	7	7,5	8	8,5	9	9,5	10	points
degree- ≦ 5 000	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
days ≦ 2 500	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	
air permeability resistance 1/a	0,2	0,4	0,6	0,8	1,0	1,2	1,4	1,6	1,8	2,0	2,2	2,4	2,6	2,8	3,0	3,2	3,4	3,6	3,8	4,0	$\frac{mh(mm\ WS)^{2/3}}{m^3}$
air permeability a	5,00	2,50	1,67	1,25	1,00	0,83	0,71	0,63	0,56	0,50	0,45	0,42	0,39	0,36	0,33	0,31	0,29	0,28	0,26	0,25	$\frac{m^3}{mh\ (mm\ WS)^{2/3}}$
remarks						|←1		|←2		3											

1: field of compound and single windows
2: field of double windows
3: sealed type

TABLE 4.

points	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
interior surface temperature t_i	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	°C
condensating quantity G about	110	100	90	80	70	60	50	40	30	20	10	none										$\frac{g}{m^2h}$
relative air humidity (20 °C) R_{zul} about	25		30		35		40			50		55	60		70		80		90		100	%
remarks											|←1	3					|←2					

1: field of regular humidity of the air in offices, living-rooms etc.
2: field of increased humidity of the air in sanitary rooms (kitchens, bath-rooms)
3: reference value for the establishment of minimal thermal insulation.

2. Mean thermal transmittance resistance of the wall including window

The mean thermal transmittance resistance (mean reciprocal thermal transmittance) $1/k_m$ is evaluated by means of table 1

$$1/k_m = \frac{F_W + F_F}{k_W F_W + k_F F_F}\ m^2h\ ^\circ C/kcal \qquad \text{... equation 4}$$

W ... wall, F ... window

It results from calculation of the measured thermal transmittance k_W, k_F and the share of surface F_W, F_F or by measurement made on the external wall element with window.

3. Thermal transmittance resistance of the windows without influence of the joints

The thermal transmittance resistance (reciprocal thermal transmittance) 1/k is evaluated as per equation 1 by means of table 2. It generally is obtained by measurement made on the fitted window (in the testing stand or the building) with puttied joints.

4. Air permeability resistance of window joints

The air permeability resistance 1/a mh (mm WS)$^{2/3}$/m^3 is evaluated by means of table 3 by considering the annual number

F. Bruckmayer

TABLE 5

DJM °C	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	points
−39	3,9	7,8	11,7	15,6	19,5	23,4	27,3	31,2	35,1	39,0	42,9	46,8	50,7	54,6	58,5	62,4	66,3	70,2	74,1	78,0	
−36	3.7	7,4	11,1	14,8	18,5	22,2	25,9	29.6	33,3	37,0	40,7	44,4	48,1	51.8	55,5	59,2	62,9	66,6	70,3	74,0	
−33	3,5	7,0	10,5	14,0	17,5	21,0	24,5	28.0	31,5	35,0	38,5	42,0	45,5	49,0	52,5	56,0	59,5	63,0	66,5	70,0	
−30	3,3	6,6	9,9	13,2	16,5	19,8	23,1	26,4	29,7	33,0	36,3	39,6	42,9	46,1	49,5	52,8	56.1	59,4	62,6	66.0	
−27	3,1	6,2	9,3	12,4	15,5	18,6	21,7	24,8	27,9	31,0	34,1	37.2	40,3	43,4	46,5	49,6	52,6	55,8	58,9	62,0	
−24	2,9	5,8	8,7	11,6	14,5	17.4	20,3	23,2	26,1	29,0	31,9	34,8	37,7	40,6	43,5	46,6	49,3	52,1	55,0	58,0	
−21	2,7	5,4	8,1	10,8	13,5	16.2	18,9	21,6	24,3	27,0	29,7	32,4	35,1	37,8	40,5	43,2	45,9	48,6	51,3	54,0	
−18	2,5	5,0	7,5	10,0	12,5	15,0	17,5	20,0	22,5	25,0	27,5	30,0	32,5	35,0	37,5	40,0	42,5	45,0	47,5	50,0	
−15	2,3	4,6	6,9	9,2	11,5	13,8	16,1	18,4	20,7	23,0	25,3	27,6	29,9	32,2	34,5	36,8	39,1	41,4	43,6	46,0	
−12	2,1	4,2	6,3	8,4	10,5	12,6	14,7	16,8	18,9	21,0	23,1	25,2	27,3	29,4	31,5	33,6	35,7	37,8	39,9	42,0	
− 9	1,9	2,8	5,7	7,6	9,5	11.4	13,3	15,2	17,1	19,0	20,9	22,8	24,7	26,6	28,5	30,4	32,3	34,2	36,1	38,0	
− 6	1,7	3,4	5,1	6,8	8,3	10.2	11,9	13,6	15,3	17,0	18,7	20,4	22,1	23,8	25,5	27,2	28,9	30,6	32,3	34,0	
− 3	1,5	3,0	4,5	6,0	7,5	9,0	10,5	12,0	13,5	15,0	16,5	18,0	19,5	21,0	22,5	24,0	25,5	27,0	28,5	30,0	

characteristic cooling time z h

of windy days with cold (TBE-Europe-Climate Table 5a), characterized by the "wind (speed) degree-days". As a rule it is obtained by measurement of the air permeability and carried out on the fitted window (in the testing stand or the building).

5. Cold bridges (temperature of the interior surface of the external wall)

The lowest temperature of the interior surface of the wall is evaluated by means of table 4 at 20 °C temperature of inside air and the annual average minimum (DJM) as temperature of outside air. For elements without cold bridges it is obtained by calculation. The temperature of the interior surface of the wall at the places of cold bridges is generally obtained by measurement made on the external wall element. If required electric model tests after F. Bruckmayer may be used as well.

6. Characteristic cooling time of the compact opaque wall elements.

The required characteristic cooling time (according to Austrian standard B 8110) is dependent on the climate of the place; the latter is taken as the average annual minimum of the temperature (DJM).

The characteristic cooling time z is evaluated by means of table 5

$$
\begin{aligned}
z = w/k = {} & d_1R_1c_1\,(1/\alpha_a + d_1/2\lambda_1) \\
& + d_2R_2c_2\,(1/\alpha_a + d_1/\lambda_1 + d_2/2\lambda_2) \\
& + d_nR_nc_n\,(1/\alpha_a + d_1/\lambda_1 + \ldots d_{n-1}/\lambda_{n-1} + d_n/2\lambda_n)\ [h]
\end{aligned}
$$

... equation 5

The counting of the layers starts from the outside. In general the characteristic cooling time is obtained from the calculated thermal storage w kcal/m² °C (ascertained for temperatures of 1° inside air and 0° outside air) and the measured thermal transmittance k kcal/m²h °C. The frame, the transoms etc. are included in the determination of w.

7. Characteristic cooling time of the wall including window

A mean characteristic cooling time z_m is evaluated by table 5

$$z_m = \frac{z_W F_W + z_F F_F}{F_W + F_F}\ h \qquad \text{... equation 6}$$

W ... wall, F ... window

It is obtained by calculation from the calculated characteristic cooling times z_W, z_F and the shares of the surface F_W, F_F. If there is no evidence about z_F, there may be inserted, as an approximation, $z_F = 1$ h.

8. Sunlight protection

The protection from radiation in % of the penetrating radiation (direct and diffuse radiation) is evaluated by table 6.(2)

9. Thermal expansion

The reciprocal value of the thermal expansion $1/\alpha t$ of the layers of building materials, particularly the external ones, and the amount of reflexion (of solar radiation) on the external surface is evaluated by means of table 7.

10. Thermal dissipation (hand warmth)

By touching the interior surface of the wall (leaning upon the wall also while asleep) there is felt, because of thermal conductivity, a sensation of "hand warmth" similar to that of "foot warmth" when walking with bare feet on floors with different conducting of the upper layers.

The reciprocal value $\frac{1}{W_{10}}$ of the heat quantity lost within 0–10 minutes* is evaluated by means of table 8. It is obtained by measurements carried out with the device serving for examination of thermal conductivity of floors ("foot warmth").

The further 10 properties relevant to building physics which have not been treated here because of the limited space available are:

Group 2. Protection from humidity and wind

11. Resistance to water-vapour flow (vapour barrier)
12. Water storage capacity of the inmost layers of the wall
13. Air permeability resistance of the compact opaque wall elements
14. Ventilation of the compact wall elements
15. Rain resistance of the compact wall elements
16. Resistance of the joints against rain, wind and water

Group 3. Fire resistance and durability

17. Fire resistance
18. Durability

Group 4. Sound insulation

19. Sound transmission loss (reduction index)
20. Flanking sound transmission insulation

References

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2 R. Schaal: Vorhangwände. (Curtain walls). Verlag G.D.W. Callwey, München 1961.

3 Ø. Birkeland: Curtain walls. Norwegian Building Research Institute, Oslo 1962.**

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* For short periods of contact it is necessary to find the thermal quantity lost within 0–1 minute. The relevant table has not been shown here.

** Particularly for groups 2 and 3.

TABLE 6.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	points
screened radiation	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	%
penetrating radiation	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0	%
remarks			1					2					3			4						

1: normal plate-glass
2: heat-absorbing glass, coating glass
3: plate-glass with heat-absorbing glass attached in front
4: plate-glass with light metal Venetian blinds in front

TABLE 7

dark	1	1,5	2	2,5	3	3,5	4	4,5	5	5,5	6	6,5	7	7,5	8	8,5	9	9,5	10	points
white or light	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
aluminium	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	36	40	
reciprocal thermal expansion $1/\alpha_t$	0,02	0,03	0,04	0,05	0,06	0,07	0,08	0,09	0,10	0,11	0,12	0,13	0,14	0,15	0,16	0,17	0,18	0,19	0,20	$\cdot 10^6 \frac{cm\ ^\circ C}{cm}$
coefficient of thermal expansion α_t	50,0	33,3	25,0	20,0	16,7	14,3	12,5	11,1	10,0	9,10	8,35	7,70	7,15	6,67	6,25	5,88	5,55	5,26	5,00	$\cdot 10^{-6} \frac{cm}{cm\ ^\circ C}$
remarks				1 2	3 4 5		6		7	8	9								10	

1: $\alpha_t = 23 \cdot 10^{-6}$ aluminium
2: $\alpha_t = 20 \cdot 10^{-6}$ phenoplaste
3: $\alpha_t = 18 \cdot 10^{-6}$ brass
4: $\alpha_t = 16{,}8 \cdot 10^{-6}$ copper
5: $\alpha_t = 16{,}5 \cdot 10^{-6}$ steel free from rust
6: $\alpha_t = 12 \cdot 10^{6}$ steel
7: $\alpha_t = 10 \cdot 10^{6}$ steel-concrete
8: $\alpha_t = 9{,}5 \cdot 10^{6}$ plate-glass
9: $\alpha_t = 8 \cdot 10^{6}$ stone
10: $\alpha_t = 5 \cdot 10^{6}$ wood, brick-work

TABLE 8.

	1	2	3	4	5	6	7	8	9	10	points
reciprocal value of heat dissipated within 10 min.	0,002	0,004	0,006	0,008	0,010	0,012	0,014	0,016	0,018	0,020	m²/kcal
heat dissipated within 10 min.	500	250	167	125	100	83,3	71,3	62,5	55,5	50,5	kcal/m²
remarks						2	1				

	11	12	13	14	15	16	17	18	19	20	points
reciprocal value of heat dissipated within 10 min.	0,022	0,024	0,026	0,028	0,030	0,032	0,034	0,036	0,038	0,040	m²/kcal
heat dissipated within 10 min.	45,5	41,7	38,5	35,7	33,3	31,2	29,4	27,8	26,4	25,0	kcal/m²

1: Heat dissipated within 10 minutes 70 kcal/m²: Maximum permissible value for living rooms according to Austrian standard B 8110 (foot warmth)
2: Heat dissipated within 10 minutes 90 kcal/m²: Maximum permissible value for factories according to Austrian standard B 8110 (foot warmth)

H 6

A. Dumez and R. Lauret

Thermal behaviour of materials and buildings related to the use of prefabricated components

By A. Dumez and R. Lauret (France)

The need for greater knowledge of thermal behaviour

Up to the present time it had been considered that the single concept of the thermal insulation of a wall was sufficient to define its thermal behaviour. Such reasoning was valid as long as one was dealing with heavy walls with comparable calorific capacities and whose thermal inertia permitted the assumption of steady heat transmission instead of that at the natural and varying rate.

The modern tendency to lighten walls and, especially, the development of front-walls with extremely small heat capacity have, following difficulties with heat control, led to the problem being re-examined. The short response time of lightweight walls to temperature variations has brought to the fore the little known factor of thermal inertia and it is now recognised that it is necessary to combine the damping effect of the thermal insulation (the K coefficient) with the dephasing due to the heat capacity of the wall.

Unfortunately, present knowledge is insufficient to estimate the accurate relations between these two factors and, under specified conditions, to determine the most suitable construction methods and to state the most economical heating and air conditioning systems. Not only is this knowledge insufficient but, since the requirement has only recently arisen, the methods of acquiring it are still at early development stage.

The mathematics of the transmission of heat under varying conditions are extremely tricky; graphic or graphic-analysis methods are lengthy and inflexible and it appears that these complex problems can only be solved by analogy. This resulted, in June 1961, at the Symposium organised by CIB at Delft on the thermal properties of curtain walls, in the proposal of a hydraulic analogy method of studying these phenomena.

The hydraulic analogy method

Since heat transmission follows the same laws as the flow of water (and also of electric current) it was natural to consider using the analogy to examine the problem and, over the past 30 years, many research workers have worked on this. The problem has been taken up again in recent years from the building research viewpoint, rather than only from the physical research angle. In the analogy model developed, a wall or set of walls, is represented by "slices" made up of vertical open ended tubes of section proportional to the heat capacity with their bases connected together by capillary tubes representing the thermal insulation between two slices. The levels of water in the vertical tubes are proportional to the temperatures of the slices and the quantities of water entering or leaving the assembly are proportional to the quantities of heat absorbed or given up. A device linked to a programme permits adjustment of the variations in either temperature or the internal or external flow and the whole system then functions as an analogue computer, whose results can be converted into curves (see references).

Although the principle of such an apparatus is well known, newly developed devices have given it flexibility and greater effectiveness. In the same field, mention should be made of the work of a Czecho-Slovak research worker, Dr. A. Polansky, with whom contacts, which will be referred to later, have been made.

A first series of studies has verified the validity of the analogy method by comparison with the conventional Binder-Schmidt method. The correlation obtained (a divergence of less than 2%) was satisfactory and this result was announced at the CIB 2nd Congress (Cambridge 1962).

The behaviours of various walls under varying conditions were then examined; this permitted comparisons between different materials, but it would have been presumptuous to extrapolate these results to a building or to a room, in which many other factors are involved. In many research institutes efforts have been made to solve this problem by the use of multidimensional models, which are unfortunately extremely complicated and which do not appear to have given easily exploitable results. The solution of this complex problem has been considerably simplified by the hydraulic transposition of thermal calculations (J. Jacq's auxiliary poles and A. Dumez's synchronous slices) which have enabled the desired result to be obtained (internal temperature or correcting flow) by contrasting two assemblies, one equivalent to the outside of a building (wall and roof) excluding the incoming flow from the sun, and the other the inside of the building (including its occupants). As the programmes are worked out from preparatory calculations based on factual data, the sole function of the apparatus is to act as a simple and effective analogical computer.

Results expected from this research

The possibility of being able to calculate accurately the positive or negative thermal loads to be applied to a building is obviously of great interest, in the first instance to planners and fitters of heating and air conditioning equipment, who until now have had to rely solely on empirical results to make allowance in their calculations for thermal inertia (or its absence). Knowledge of the rate of development of these thermal loads in a given cycle clearly affects the choice, output and flexibility of the correcting equipment which must be planned. There is a further result, however, just as important, to be expected of such research; in all countries it is said that it is better to prevent than to cure. The heating and air conditioning fitter intervenes after the event to correct – to the detriment of the cost of construction and of exploitation – the defective thermal behaviour of a building. The planner (engineer or architect) lacked the necessary physical data to assess the thermal behaviour of various methods and to make a wise choice from among them.

The value of such research is precisely to supply the architect with the necessary information to reach a decision. This is obviously only valid for fairly large buildings, in order to justify the cost of a special study. For many smaller buildings, which should certainly not be neglected, the solution is, by means of general purpose research, to decide on the recommendations to the planners as to what to do – and also what not to do – to provide, at lowest construction and exploitation costs, the best thermal comfort in the building they are planning, which, in fact, means selecting the building's materials and the optimal coupling of the building and its heating system.

In the long run, it may be foreseen that the architect will have available to him ranges of materials with different combinations of thermal insulation and inertia. All things considered, is it not surprising that the four walls of a building which, depending on the direction they face, are subject to very different thermal "assaults", are normally built of the same materials with the same thicknesses?

Although such use of different materials may be difficult to achieve with present day building methods, is it not, on the contrary perfectly feasible when using prefabrication techniques?

Such research of general interest to builders in all countries unfortunately involves the examination of a very large number of separate "cases" as a result of overlapping of the many parameters, such as:

- environment parameters: latitudes, winter and summer climatic conditions, orientation, local climatic variations,
- intrinsic parameters of the materials: composition, dimensions, thermal resistivity, heat capacity, external absorption factor,
- parameters of the building: internal thermal inertia, proportion of openings, protection of openings, correcting system methods and flexibility,
- parameters relating to the occupants and their activities: number of occupants, hours occupied (offices, schools, meeting

halls etc.), ventilation habits, internal arrangements (furniture and wall coverings), machines and equipment and their thermal flow rates, etc.

The need for an international research effort

The exploration of so vast a field would far exceed the capacity of even a large research centre within a reasonable time and the building industry is in urgent need of such data.

At the Prague Seminar (April 1964) on the development of the structure of the building industry, organised by the United Nations, one of us who was taking part took advantage of the occasion to propose cooperation with the very technically advanced Czecho-Slovak research team (the exchanges with them have developed since) and to make contact with various research institutes which might be able to take part in a coordinated programme. These proposals were favourably received and the President of CIB suggested that this work might be able to develop in a special working group, under the auspices of CIB.

We hope that, by the time of the Copenhagen Congress, these projects will be sufficiently far advanced for a report on them to be presented during the meeting.

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H 7

R. S. Ferguson

Aesthetic aspects of multi-unit housing

By R. S. Ferguson (Canada)

Industrialised building technique need not be an insurmountable handicap to the achievement of aesthetically acceptable design. The industrial technique is a tool which increases man's power many times. Because of the increased rate at which building is accomplished more intense thought and effort must be given to direction or design. Failure to make this effort has left the machine in charge. The trail it leaves is sometimes disturbingly chaotic (Figure 1) and at other times inhumanly monotonous (Figure 2). These effects can be avoided by proper consideration of industrial technique and aesthetics.

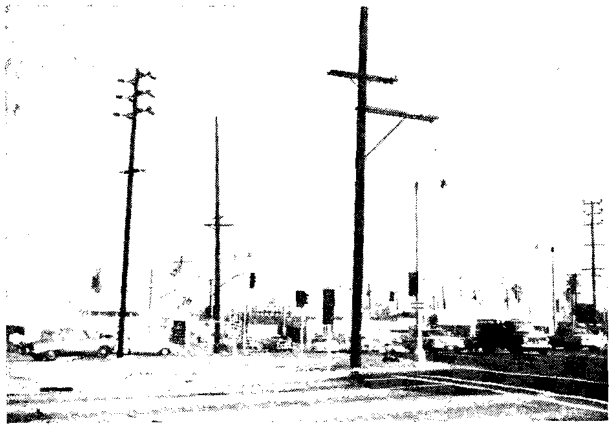

Fig. 1. "The trail is sometimes disturbingly chaotic..."

Fig. 2. "... and at other times monotonous."

Industrial technique

A suitable aesthetic for housing must express materials, technique and building use. The forms and expressions to which we have become accustomed are those developed for and suited to the craft technique. As building has changed from a craft to an industry, technological and organizational developments have made these old forms obsolescent, but the problem of creating suitable new forms has not been solved.

The developments which have caused this are of five kinds:

(1) Development of new materials

The processes of manufacture create new materials to supplement and often supplant natural ones. Man rather than nature determines the finish of these materials, but in so doing the harmony of one creator is lost.

(2) Mass production

Mass-produced articles are rarely of local origin. Most manufactured materials are designed by someone who does not know where or how they are going to be used. The architect and designer becomes a chooser and fitter of predesigned articles. His job is more essential but less appreciated by the layman. Although it does not require an expert to make a choice, it does require one to make a good choice. But what is good? Recently the artistic world has lost interest in an objective standard of aesthetics, of what is good and bad, and judgments must therefore be made on faith in some expert's word.

This attitude of artists and architects encourages the purchase and erection of building materials without expert artistic assistance. The buyer is often unable to appreciate the effect of the material in combination with others and manufacturers strive for finishes which are individually attractive and eyecatching. In so doing they complicate the aesthetic problem.

(3) Specialisation in design

The trend in industrialisation has been towards specialisation in design. When furnaces replaced fireplaces and structural frames replaced bearing walls mechanical and structural engineers replaced architects. With respect to design this is a disintegrative trend unless positive efforts to cooperate are made.

(4) Communal dependence

The pre-industrial agrarian or feudal manor was composed of socially dependent but functionally independent housing units. Each man was responsible to someone above him and for someone below him on the social scale, but he cut his own wood, drew his own water, taught his own children, and grew his own food. The post-industrial community is just the opposite. It is composed of socially independent but functionally dependent units. No man is responsible to or for any other man in the community, but he is completely dependent on the community for such services as water, sewer, roads, schools, and playgrounds. Whenever a service has become industrialised it has been taken out of the home.

(5) Automobile sprawl

The spread of cities depends on the means of transportation. The private automobile has succeeded the railway and the streetcar and has excelled these means in spreading cities into the countryside. The macro effect has been an urban explosion, but the micro effect is equally important. The scale of building and the standard of detailing and landscaping upon which the charm of the residential aesthetic is based is a pedestrian one. It cannot be appreciated by automobile and the presence of the automobile prevents its appreciation by foot. Pedestrians and automobiles both have their rightful place, but they do not mix. Notwithstanding this it is rare to find the two separated.

Two main influences in aesthetics

Two influences are fused in any work of art. The first is the influence of society, which guides the artist in attributing to the work some recognizable form. Society provides order and harmony and a common language of form, which enables an object to be identified, described and classed. The second influence is the intuition of the artist. He uses the common language and applies his talent to achieve some unique expression. Both contributions are necessary. If an art object is dull and monotonous, it is lacking in the liveliness and interest provided by the artist; if it is chaotic and incoherent, it is lacking in the order and the common language provided by society.

It will be appreciated that some social cooperation is necessary for art. This cooperation is not likely to come about under an industrial system without some determined positive effort. In a craft society such an effort was hardly necessary, and due to cultural lag it is probable that its need now is not yet generally recognized. It is fashionable at present to assume that art is purely intuitive and that there is no contribution that society can make. Through industrial technique building continues at an ever-increasing pace, yet because of its increasingly industrial nature and the trend to non-objectivity in art, the artistic influence in building is becoming more and more alienated.

A mediaeval form of individualistic craft design cannot be revived. Harmony and coherence can only be achieved now through cooperation by the many responsible for fashioning the various objects that form the residential environment. A new aesthetic language is needed so that the many designers involved can communicate and work together. Because of the difficulties of achieving this there is a tendency in technical circles to ignore aesthetics. While this may be excusable, it is hardly practicable under the circumstances. The public places appearance near the top of its list of requirements, and more often than not the form and the finish materials of a building are chosen for aesthetic reasons even though they might be rejected on technical grounds. To close the gap between aesthetics and technology science and industry must take a hand.

A language of form

The effect of the industrial technique on aesthetics can be illustrated. A language of form will evolve through the study of form in relation to industrial technique and the development of common understandings. It is then and only then that aesthetics can make the environment more interesting and meaningful. The following are a few selected examples chosen to illustrate the relation between form, function and language.

Fig. 3. Typical speculative housing development.

Figure 3 illustrates typical speculative housing development in Canada. The straight road is as much due to the straightness of the draftsmen's square as to anything else. Pavement and houses are positioned according to prescribed standards.

The form of composition used here is the 'vista'. It is successful when all variety is subdued to emphasize an object at the focal point. In this example the effect is weakened by distracting variations in the houses on either side, and the lack of any prominent object at the focal point. In its present form visual distractions and lack of interest in the proper place create dangers for pedestrians and the drivers of vehicles. It is an uneconomical, unsafe and dull compromise of pedestrian and vehicular needs.

Figure 4 illustrates the correct employment of the vista. The faults discussed in connection with the previous picture are missing. Even the greater density of building in this picture does not invalidate the comparison.

This composition (Figure 5) illustrates the group. Interest is focussed on the visual centre of gravity, in this case the tallest house. The group is distinct from other forms because it focusses attention on the buildings. In other forms such as the vista, the square, the crescent (Figure 6) or hillside development, the buildings are more often supporting elements of the composition.

The interest in this picture is created by subduing all variety in the pictorial elements to emphasize the curve. This form of composition resembles the vista because it leads the eye on, but it is unfinished and leaves in question what is around the bend. It is not a restful composition, but is suitable for driveways where it is seen from a fast-moving vehicle.

Fig. 4. Correct employment of the vista.

Fig. 5. In this group interest is focussed on the visual centre of gravity.

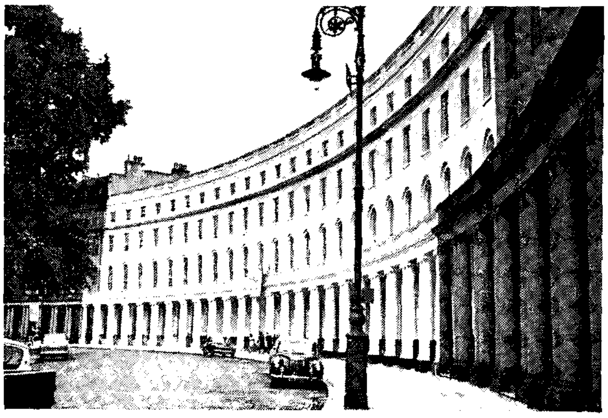

Fig. 6. All variety of form is subordinated to the curved horizontal lines of the building.

Conclusion. Positive measures to control development are necessary if both chaotic and monotonous landscapes are to be avoided. Interest and coherence can be achieved most satisfactorily when there is cooperation among those who contribute to the composition of a landscape—the draftsmen of zoning regulations and subdivision controls, surveyors, municipal utilities and roads departments, the builders, the manufacturers of materials, and last but not least the designers of the buildings themselves.

Under careful examination it is clear that the subject of the composition is rarely buildings. In the vista, the curved street and some other forms, it is appropriate to subdue basic differences in the buildings. The square focusses attention on the enclosed space by subduing variation in the facades. While variety is necessary, it is seldom that it must be provided by the housing units. There does not appear to be any basic conflict between aesthetics and the mass-production technique, but the evolution of a language of form and positive and deliberate steps toward cooperation among all those who make decisions affecting design of multi-unit housing are necessary for adequate aesthetic results.

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Required thermal characteristics of buildings in different types of hot climates

By B. Givoni (Israel)

Materials and design in un-conditioned buildings have great effect on indoor temperatures during day and night and, therefore, on the comfort and well-being of the occupants. For this reason, the choice of materials and principles of design in a given climatic region should be based on the physiological requirements for comfort in this region. The requirements, when expressed in terms of the desirable indoor temperature, depend on the characteristics of the local climate, because human response to a given level of temperature depends on the level of humidity and air motion.

Prefabrication magnifies the importance of proper choice of thermal properties of the building components, because a prefabrication plant, once erected, will continue, year after year, to produce many units, which can be transported only within limited distances.

A procedure is suggested in this paper for the determination of the required pattern of indoor temperature in different climatic zones and the thermal characteristics of building components and design principles required for the achievement of this pattern. Examples are given, based on climatic conditions in Israel.

Effect of climatic characteristics on design principles and required properties of materials

The main climatic characteristics of a given zone which determine the design principles and the requirements from the materials, are the level of humidity, preferably expressed in terms of vapour pressure and the daily range of temperature (maximum and minimum).

The level of local vapour pressure is the main factor in determining the possibility of keeping the windows closed during the day, which is the prerequisite for the control of indoor temperature through building materials. The daily temperature range determines the extent to which the indoor maximum temperature can actually be reduced in relation to the outdoor maximum. In most cases, these two factors are interrelated. Coastal regions are characterised by a high level of vapour-pressure and a small range of daily outdoor temperature. Inland regions are characterized by low level of vapour pressure and a large range of daily temperature.

In regions where the level of daytime temperature and prevailing winds enable thermal comfort when good ventilation is provided, the easiest way to achieve comfort would be to provide daytime ventilation. In this case, the main requirements of the building would be to prevent elevation of the internal temperature during the day above the external temperature, and to ensure rapid cooling of the interior during the evening. The required indoor temperatures at night are usually lower than those for daytime, because the wind velocity in many cases is lower at night, and therefore comfortable conditions can be maintained only at a low temperature.

In regions where thermal comfort cannot be maintained at a level near the outdoor temperature even with good ventilation, it might be necessary to reduce the indoor daytime temperatures appreciably below the outdoor temperatures. This can be obtained in regions with great differences between the maximum and minimum temperatures by proper design and choice of materials. But materials that attenuate the outdoor temperature fluctuations not only lower the daytime temperature, but also tend to elevate the night temperature. Therefore, special precautions are needed to obtain the desired reduction in daytime temperature without causing night temperatures above the limit of comfortable sleeping.

Physiological considerations related to the required pattern of indoor temperature

The required pattern in indoor temperature should be based on physiological considerations, e.g. on the upper temperature limit preventing thermal stress under the expected levels of indoor vapour pressure and air velocity. This can be done by the use of a thermal index which enables the estimation of the combined physiological effect of temperature, humidity, and air motion. The index suggested here for evaluating the thermal stress in warm countries is the "index of Thermal Stress" (I.T.S.)[1], which is based on the computation of the sweat rate required for the maintenance of thermal balance under different conditions of temperature, humidity, air velocity, and physical activity. The sweat rate is used as an indication of the overall physiological heat strain.

The basic formula of this index is: –

$$S = E\left(\frac{1}{f}\right)$$

where S is the required sweat rate, E is the overall heat stress, and f is the cooling efficiency of sweating, which is a function of the ratio (E/E_{max}), where E_{max} is the maximum evaporative capacity of the ambient air. Mathematically, these components are computed according to the following formula: –

$$E = M - W \pm (R + C)$$

$$\frac{1}{f} = 0.67\ e\ 0.02\ E/E_{max} \text{ where}$$

M = Metabolic Rate

W = Energy transformed into mechanical work, about 0.2 ($M - M_{rest}$).

(R + C) = heat exchange with the environment by radiation and convection, which is a function of the air velocity and Globe temperature.

E_{max} = Maximum evaporation capacity, is a function of air velocity and vapour pressure.

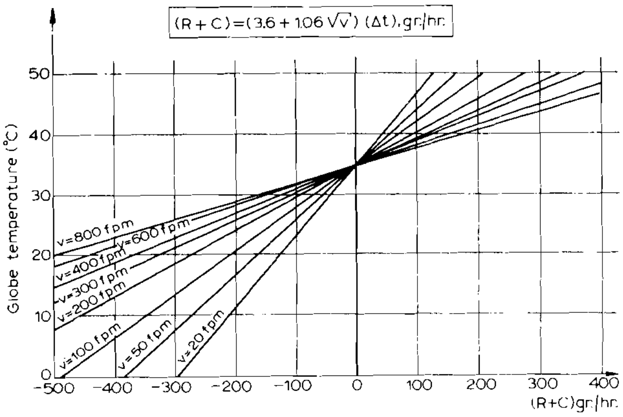

Fig. 1. Dry heat exchange (R + C) expressed in equivalent grams of sweat/hour as function of environmental temperature (global temperature) and air motion.

Fig. 1 enables graphical determination of (R + C) as a function of Globe temperature and air velocity, expressed in equivalent latent heat of sweat evaporation, grammes per hour.

Fig. 2 enables graphical determination of E_{max} as a function of dry and wet bulb temperatures and air velocity, also in equivalent grammes of sweat per hour.

Fig. 3 shows f and 1/f as function of the ratio E/E_{max}.

Fig. 4 shows the I.T.S. for people at sedentary activity and with summer clothing, and enables determination of it in conditions relevant to indoor climate research.

Fig. 5 shows measurements of sweat rate from various investigations, carried on in the U.S.A., England, Singapore and Israel, including a variety of environmental conditions and physical activities, expressed as a function of the value of the Index of Thermal Stress, computed for each experiment. It can be seen that good agreement and linear relationship exists between the measured and computed values.

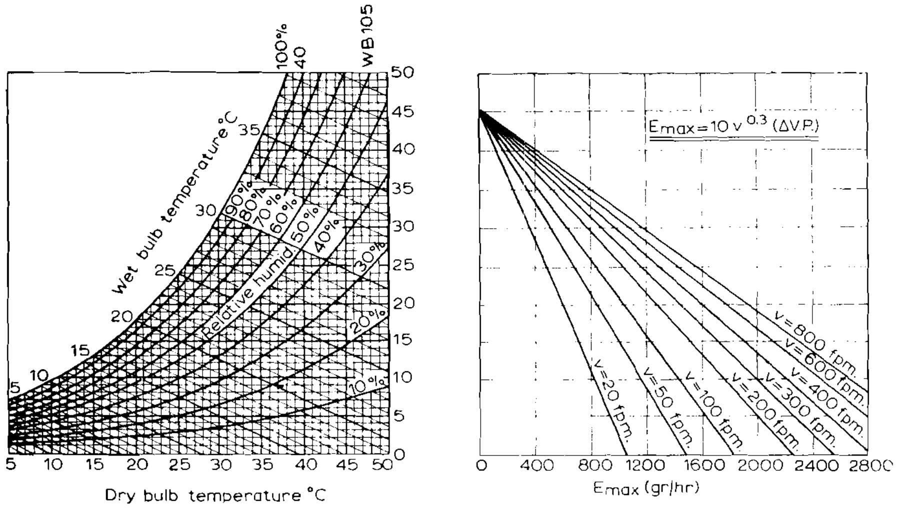

Fig. 2. Maximum evaporative capacity, E max. as function of air vapour—pressure (V.Pa) and air speed (V.).

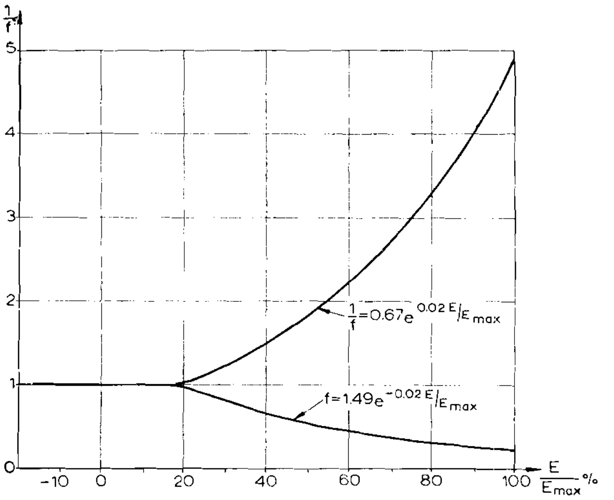

Fig. 3. Cooling effect of sweating (f) and its reciprocal (1/f) as a function of the ratio E/E max.

It has also been found that for people at sedentary activities, good correlation exists between subjective thermal sensations and sweat rate, and that a sweat rate of 100 gr/hr may be considered as the threshold of discomfort due to warmth[1].

But in humid regions there is another factor which determines the comfort conditions and that is the wetness of the skin (sensible perspiration). It has been found[1] that the skin wetness responds more sensitively to humidity and air motion, and less sensitively to temperature, than the sweat rate and the thermal sensation. Therefore, there might be situations where the sweat rate is below the stress level of 100 gr/hr, and a person will not feel the warmth of the air, but his skin will nevertheless be moist and as a result he will be uncomfortable. The wetness of the skin depends on the relative speed of evaporation, which is affected by the ratio of the heat stress to the evaporative capacity of the air, or the E/E_{max} ratio. The wetness of the skin can be scaled from grade 0 representing dry skin, grade 1 representing clammy skin when the moisture is still invisible, etc., till grade 6, representing soaked clothing and sweat dripping off. It was found[1] that the skin wetness thus scaled bears linear relationship to the ratio E/E_{max}, as can be seen in Fig. 6. The latter shows that in order to prevent discomfort caused by wet skin, (number 1 of the scale), the ratio E/E_{max} should be kept below 10%. Therefore, in humid regions, the skin wetness should be checked, in addition to the sweat rate, in the process of determination of the maximum desirable indoor temperature during different hours. The factors

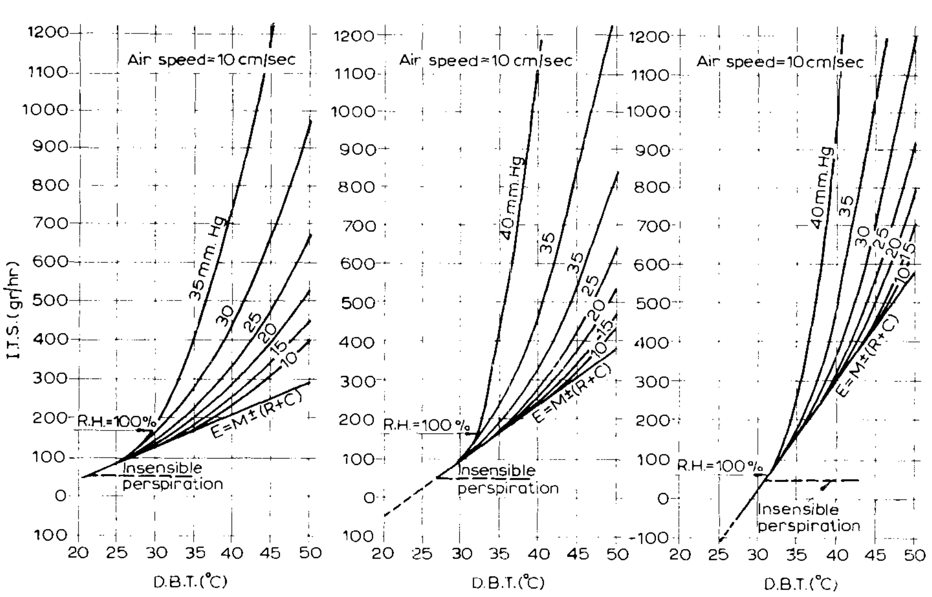

Fig. 4. Index of thermal stress for subjects at rest as function of air temperature at various humidities and air speeds.

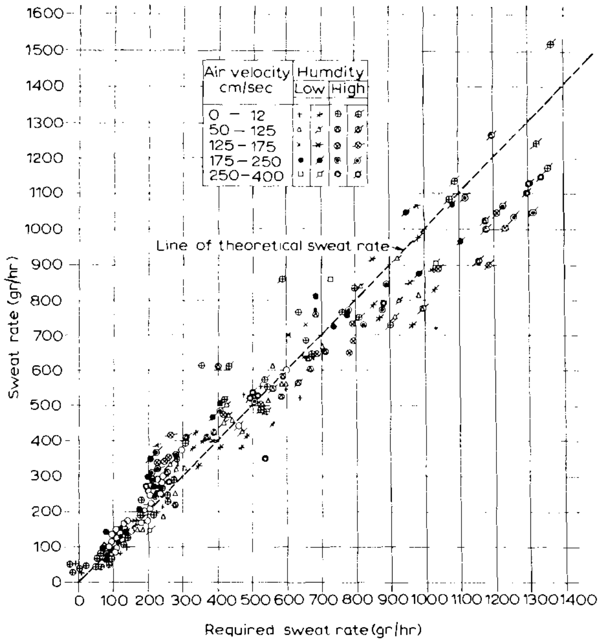

Fig. 5. Sweat rates from various experimental investigations as a function of the theoretical required sweat rate.

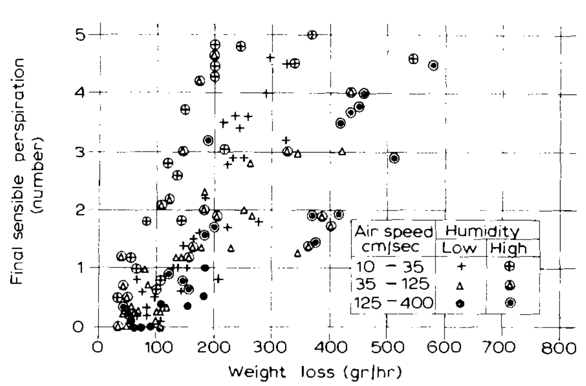

Fig. 6. Final sensible perspiration as function of measured weight loss.

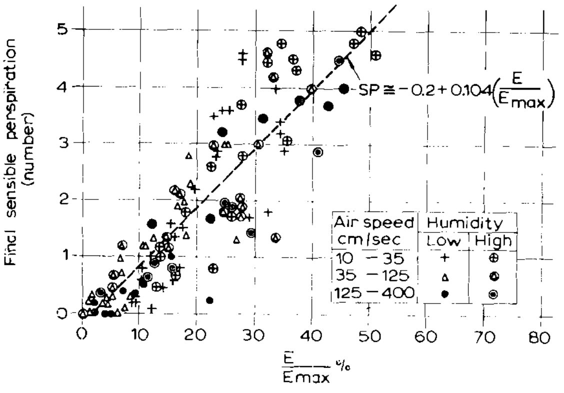

Fig. 7. Final sensible perspiration as function of E/E max ratio.

which should be taken into account are the expected levels of vapour pressure and air velocity inside the building, according to the outdoor pattern of temperature, humidity and wind velocity, the efficiency of the ventilation of the building, and the procedure of opening and closing the windows during day and night.

Determination of the desirable indoor temperatures in different types of hot climate

The procedure of determining the required indoor temperature in a given climate zone consists of estimation of the expected rate of indoor air motion, according to the design and location of the openings, and then the determination of the temperature which is apt to cause thermal stress or moist skin under the local conditions of vapour pressure and the expected air velocity.

Two climatic regions of Israel, the seashore and the Negev, will serve for illustration of the method.

General considerations. In built-up areas the wind velocity outside the buildings depends to a great extent on the planning of the town: the orientation of the main streets and large buildings towards the prevailing winds, the horizontal density and height of the buildings, etc. Very little is known as yet of the quantitative relation between the characteristics of town planning and the reduction in wind velocity inside the built-up area, and an estimate has to be made. In this case, the wind velocity outside the buildings was taken as 50% of the wind velocity given by the meteorological service and measured in the open.

The average indoor air motion depends to a very large extent upon the orientation and detailed design of the building, ranging from about 15% and less of the velocity outside the building, in ill-designed buildings, to about 50% and more in properly designed ones. (The maximum velocity in certain points in the room might be equal and even greater than the outside velocity)[2].

The sea-shore region. The sea-shore region in Israel is characterized in the summer by maximum air temperatures of about 30 °C, minimum air temperatures of about 21 °C, and vapour pressure of about 23 mmHg. The winds are moderate at noontime and in the afternoon, about 10 km/hr (meteorological data), and very slight in the morning and evening, with frequent calm hours during the night.

According to these data it is possible to determine the acceptable indoor maximum temperature. During hours with wind the anticipated air velocity in well-ventilated buildings might be estimated to be about 20% of the free outdoor velocity, i.e. about 60 cm/sec. The indoor vapour pressure is a little elevated above the outdoor-level, and may be assumed as 25 mmHg. Under these conditions, as can be seen from Fig. 4, a sweat rate of 100 gr/hr is reached at about 30 °C. In unventilated and poorly-ventilated buildings, with air velocity of 20 cm/sec, the maximum temperature should be about 27°–28 °C, from the viewpoint of sweat rate. However, since this is a humid zone, the main cause of discomfort might be the moisture of the skin. To estimate the maximum temperature from this viewpoint, it is necessary to determine the value E_{max} in buildings well-ventilated and badly-ventilated. From Fig. 2 it is possible to obtain at a vapour pressure level of 25 mmHg, a value of E_{max} 850 gr/hr approximately for air velocity of 60 cm/sec, and 550 gr/hr for air velocity of 20 cm/sec. This means that in order to keep the ratio E/E_{max} at 10%, the value of E should not be above 85 gr/hr in well-ventilated buildings and not above 55 gr/hr in poorly ventilated ones.

Metabolic heat production for people at sedentary activity is about 95 kcal/hr, or approximately equivalent to 160 gr. of sweat per hour.

Therefore, the heat loss by radiation and convection (R + C) expressed in equivalent gr/hr should be about 75 gr/hr in well-ventilated buildings and about 105 gr/hr in poorly ventilated buildings. From Fig. 1 it can be seen that air velocity of 60 cm/sec gives a value of (R + C) of 75 gr/hr at about 30 °C and air velocity of 20 cm/sec gives a value of (R + C) of 105 at about 25 °C.

Therefore, it can be concluded that the maximum permissible temperature during day-time should be about 30 °C in well-ventilated buildings and about 25 °C in poorly ventilated ones.

During the evening and night many calm hours should be expected, and therefore an indoor air motion of 10 cm/sec has to be taken into account. The maximum evaporative capacity under those conditions, determined from Fig. 2, is about 500 gr/hr and a sweat rate not above 50 gr/hr is required to prevent discomfort due to moist skin. If the metabolic rate at rest will be taken as 90 kcal/hr, or about 150 gr/hr, the required heat loss by radiation and convection would be equivalent to evaporation of 100 gr/hr. The temperature at which such rate is achieved is about 23 °C (Fig. 1).

Therefore the indoor temperature in this zone should not exceed 23 °C at night and 25° to 30 °C during the day, for ill-ventilated and well-ventilated buildings respectively.

Because of the small range of outdoor temperature in this zone, it is in fact impossible to obtain an indoor temperature of 25 °C when the outdoor temperature is 30 °C. Therefore good ventilation is the only way to ensure comfortable conditions in this region.

The Negev region. The Negev region in Israel is characterized in summer by maximum temperatures of about 35 °C and minimum temperatures of about 18 °C. The vapour pressure is about 15 mmHg. The winds at noon and in the afternoon are about 15 km/hr and in the evenings about 6 km/hr.

The indoor air velocity might be estimated during the day as about 1.5 m/sec in well-ventilated and as 0.30 m/sec in poorly ventilated buildings. The indoor vapour pressure may be assumed as 17 mmHg. Estimation of the sweat rate at 35 °C, vapour pressure of 17 mmHg, and air velocity of 1.5 m/sec. according to Fig. 4 yield the value of 170 gr/hr, e.g. above the acceptable level of 100 gr/hr. The level of air temperature that would yield a sweat rate of 100 gr/hr is about 32 °C under good ventilation conditions. Therefore, comfort cannot be maintained by ventilation, and a reduction in indoor temperature below outdoor temperature is required. This can be achieved only by closing of the windows during daytime, and therefore still air conditions (velocity of 10 cm/sec) must be assumed till the outdoor air temperature drops.

The air temperature which will yield a sweat rate of 100 gr/hr under still air and V.P. of 17 mmHg, is about 27 °C.

At night, the windows should be kept open, and with the expected rate of indoor velocity of about 0.5 m/sec the temperature should not be above 31 °C. With the prevailing low temperatures at night, it seems that any building that will not be heated above 27 °C with closed windows in the afternoon, will be satisfactory at night, when the windows are open, provided that their design ensures efficient ventilation.

The principles of design and choice of materials that are required in these two regions will be discussed further on.

Design principles and materials properties in different climatic zones

The procedure by which the design principles and materials properties could be chosen so that the indoor conditions will correspond to the physiological requirements will be illustrated for the two regions discussed above, the seashore and the semi-arid zones of Israel. Detailed discussion of the subject is presented in other papers and here only a summary will be given.

The sea-shore. In this zone, the design and materials should be such as to have the indoor temperature close to the outdoor temperature and to ensure the best attainable ventilation during day and night. Another consideration is that during the evening and night the indoor temperature should be lower than during the daytime. Because of the relatively warm nights, the night aspects are the more important in the design of the building. This calls for a building with small time lag, which responds quickly to the outdoor air.

From the materials viewpoint this means materials with low heat capacity. Lightweight insulated curtain walls may be suitable in this zone. But such materials are very sensitive to the effect of solar radiation, either absorbed in the external surfaces or penetrating through unshaded windows and heating the building from within. Therefore, the external surfaces should be of light colour, and effective shading is imperative.

From the design viewpoint, the main requirement is to provide effective ventilation. This requires care to ensure cross ventilation to every room, which in turn requires openings both on the windward and the leeward of the building. In the bedrooms it is very important to lower the window sill as near as possible to the level of the bed, since below the window sill there is an abrupt drop in the air velocity. As to the size of the windows, they could be as large as practical, provided that they are openable and effectively shaded.

The Negev zone. In the semi-arid and arid Negev zones, the design and materials should be chosen so that the indoor temperature in closed buildings will not rise above 27 °C till the late afternoon. As the outdoor temperature is about 35 °C, this calls for a reduction of about 8 °C in the maximum temperature. Two approaches are possible for the choice of the materials. The first is to choose heavyweight materials for the external walls, that would damp the fluctuations in the external surfaces' temperatures. The second approach is to use materials with moderate weight for the floors and internal partitions and to ensure adequate thermal insulation in the external walls, so as to minimize the heat flow into the building when the windows are closed.

From the design aspect, the main consideration is to minimize heat flow which by-passes the walls. This calls for small windows effectively shaded, but arranged so that in spite of their small area they would provide efficient ventilation when open in the evening.

Prefabrication methods that would be most suitable in such regions are those which have heavy load bearing cross walls of concrete. Lightweight insulation curtain walls with small windows can be used as external walls.

Conclusions. The method described above can be used in any type of hot climate to determine the most difficult hours, either day, evening or night, according to the meteorological local conditions, and to outline the best approach to the securing of thermal comfort in the buildings.

The actual choice of principles of design and materials that would yield the desirable pattern of indoor temperature, depends on the nature of the climate. Where the outdoor daytime temperatures are such that with good ventilation comfort can be achieved, then the main factor determining the comfort is the design of the building from the viewpoint of ventilation, and the materials are of secondary importance, although lightweight materials have the advantage of rapid cooling in the evening. Where the outdoor daytime temperatures are such that comfort cannot be achieved even with good ventilation, a reduction of the indoor maximum, in comparison with the outdoor maximum, is required and then the choice of materials becomes of primary importance.

The accepted method is to use in such regions constructions of high heat capacity, such as thick heavy-weight walls and roofs. In this case, there is, however, the risk of obtaining too high minimum temperatures at night, with the result of restless sleep which might be very detrimental to health and working efficiency. A better solution would be to have a building which heats slowly in the daytime and cools rapidly in the evening. Experiments which aim to obtain this end are now underway at the Building Research Station in Haifa.

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H 9

Miss W. V. Hole

Housing standards and social trends

By Miss W. V. Hole (U.K.)

In any society where housing standards vary from one group in the population to another, it is of interest to know the basis on which these differing standards are allocated and by what criteria, explicit or otherwise, such standards are defined. Is it an expanding economy, or marked advances in technology which occasions a break with traditional standards and the setting up of minimum standards for some sections of the population? Under what conditions, economic, technological and social does a high proportion of the population enjoy a 'good' standard of housing. Much could be learned from a systematic examination of housing standards in a range of different societies. The scope of the present paper is not so ambitious, but it is hoped that it might stimulate a more extensive study. It describes the conditions under which minimum housing standards were defined in England and raises some of the problems associated with mass housing.

The development of minimum housing standards in England

With the development of new processes of manufacture, known as the 'industrial revolution', the population of England expanded rapidly during the nineteenth century. Most of this expansion was concentrated in towns. Liverpool grew from 80,000 in 1801 to 264,000 in 1841; Manchester from 90,000 to 296,000 and Birmingham from 74,000 to 191,000 in the same period. There were few statutory controls of building and these were mainly concerned with precautions against fire. There was a strong demand for housing near the source of employment, such as factories. As many of the migrants to the cities were unskilled and therefore poorly paid, it was almost inevitable that the housing provided under these circumstances should be an inferior product. Moreover this mass housing was crowded together in narrow streets, so that daylighting and ventilation were severely restricted. Sanitation was rudimentary. These conditions, combined with poverty and lack of cleanly habits amongst the population, led to excessive mortality and severe epidemics such as cholera. In the 1840's the death rate in Liverpool was 36 per thousand, in Manchester 33 and in many large towns between 25 to 30 as against 22 per thousand in the country as a whole.

High mortality brought a heavy demand on funds to relieve poverty and this in turn precipitated a series of enquiries into its causes. The developing science of vital statistics helped to show the relationship between living conditions and ill health. From 1840, in a series of local and general statutes, some minimum standards for housing were gradually evolved. These were that each dwelling should have a continuous supply of pure water, that house drains should be connected to a main sewer, that there should be a w.c. or privy for every two houses and that there should be regular removal of house refuse and cleansing of streets. All inhabited rooms must have daylighting and ventilation by means of an openable window, a flue and so on. In addition, part of a cellar dwelling must be above ground level. As the century advanced and knowledge and experience grew, these standards were revised and extended. Daylighting and ventilation were improved by requirements regarding open space about a dwelling and, finally, by the prohibition of a design, known as 'back to back', which had no through ventilation. The trapping of pipes connected with sewers, the separation, by means of a passage, of a w.c. chamber and any room used for the preparation of food, and the ventilation of the w.c. chamber to the outside air were further refinements. Space standards were defined variously for hospital wards, army barracks, prisons, workhouses and common lodging houses (i.e. a type of hostel); these standards were calculated from the amount of oxygen consumed by an individual and the expected rate of air change in the room. The principle behind all these standards was the maintenance of public health and they were derived from existing knowledge of the cause and spread of disease.

However, the concern of the early housing reformers was not confined to questions of health. The overcrowding which was common in the slums where several families often occupied one room was held to endanger morals as well as health. Regulations governing the occupancy of common lodging houses required that persons of opposite sex over the age of ten, other than married couples, should sleep in separate rooms. For families, the ideal arrangement was thought to be three bedrooms, which allowed parents and children of opposite sex to sleep separately, and a further room for communal daytime use. A w.c. or privy and washing and cooking facilities for each family (i.e. a self-contained dwelling) were viewed as aids to the unity of the family and the proper upbringing of the children (Fig. 1 (a)). Self-contained dwellings were at that time generally available to middle-class families.

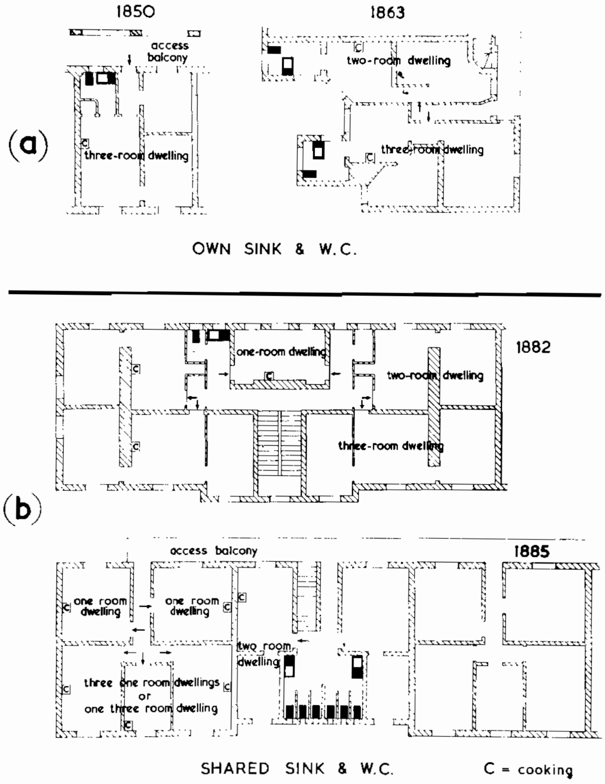

Fig. 1. Minimum family housing in England.

These standards for family dwellings were not embodied in any statute, but by the erection of 'model' dwellings, the housing reformers offered examples of their principles which it was hoped the private builder would copy. It was soon found, however, that the cost of such dwellings placed them beyond the means of all but the better-off skilled worker. Accommodation consisting of two, or even one room per family was provided in later 'model' dwellings and for poorer families, the self-contained principle had to be sacrificed (Fig. 1 (b)).

City improvements and expanding commercial interests destroyed a great deal of housing which was occupied by persons of the working class. In 1875, an Act which was designed to effect slum clearance also required that alternative accommodation should be provided for persons displaced from their homes. This and another housing act of 1866 listed certain criteria concerned with the structural condition of the dwelling, daylighting and ventilation by which it was judged habitable. This legislation implicitly recognised the individual's right to a dwelling which was at the same time sound and in a healthy environment. An Act making elementary education compulsory for all children coincided in time with the housing acts. These acts reflected an ideological trend which was at a later date to accord the individual the right to certain minima of employment, subsistence and medical care.

Slum clearance proved costly and the sites, which were usually in the central areas of cities, brought a higher price for commercial purpose than for housing. The building of railways and tramways made it possible to live in the suburbs and travel daily to work in the city. Housing reformers saw this as a better solution to housing for the working classes, since suburban land was cheaper and the atmosphere was thought to be healthier. Towards the end of the century the Garden City movement brought a new approach to town planning, which included residential areas developed at a low density. By 1918, a minimum density of twelve houses to the acre was recommended for minimum housing. The two-storey house, with garden attached dominated the provision made for the working classes in the interwar years. More recently, shortage of land for housing has gained official support for higher densities; between twenty to thirty dwellings per acre, or in inner areas of large cities up to fifty odd dwellings per acre. The strong opposition amongst administrators to densities higher than this is no longer on grounds of health but to preserve amenity.

None of the attempts by housing reformers to bridge the gap between a desirable minimum standard in housing and one which the worker could afford was wholly successful. In 1919, a state subsidy was introduced for minimum housing. Since then an increasing proportion of families from the lower economic strata have been housed in self-contained dwellings with three bedrooms. The accommodation is designed for the typical two generation family. A fixed bath was added to the list of necessary equipment in 1918 and after the second world war a continuous supply of hot water. The state is now prepared to subsidise a house containing two w.c.'s when it is designed for more than three persons (Fig. 2).

Now that public health has improved and overcrowding has been virtually eliminated, the earlier emphasis in housing standards on health and morals has been submerged; criteria for modern standards are convenience and amenity. The newer standards take account of anthropometric measurements and data from social surveys; current pre-occupations are with matters such as external noise and traffic nuisance in the vicinity of the dwelling, thermal comfort and privacy.

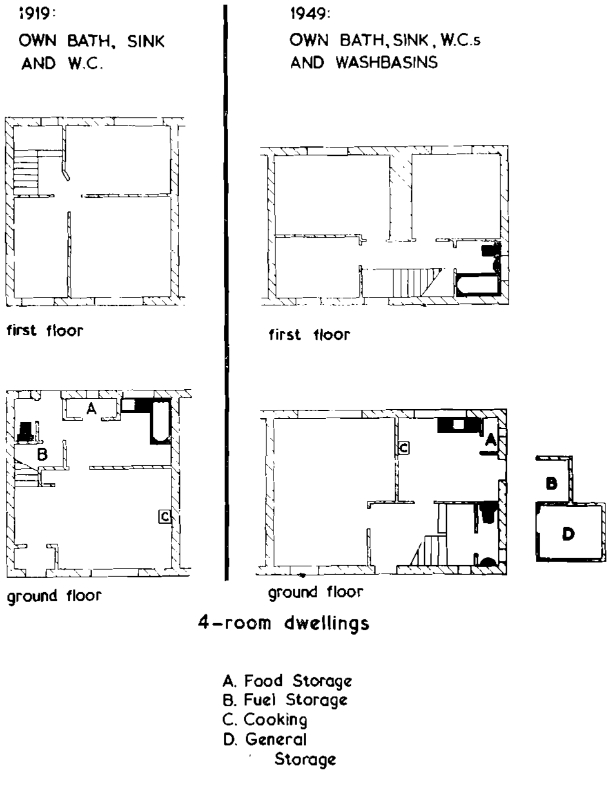

Fig. 2. Minimum family housing in England.

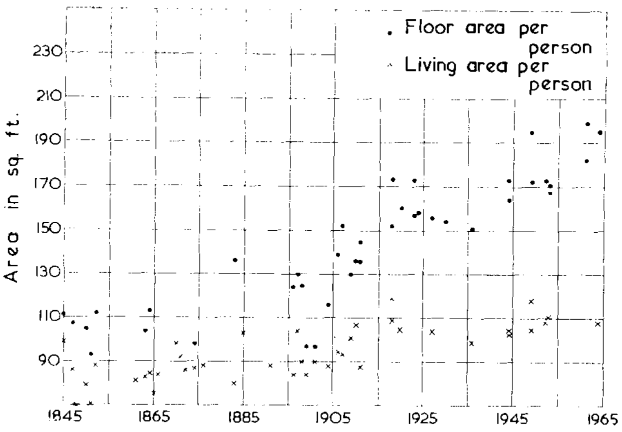

Fig. 3. Recommended space standards for minimum family houses.

The advances in methods of building construction, such as the development of reinforced concrete or the use of steel had little effect on the design of dwellings until, during the last ten years, blocks of high flats have formed part of the mass housing programme. The chief impact of technological developments has been on the equipment of the dwelling. For example, the discovery of a process for making salt-glaze stoneware offered a cheaper and more efficient means of providing sewers and so improved house drainage. Mass production made water closets and cast iron cookers widely available in minimum housing in the nineteenth century; more recently the introduction of the fixed bath and gas or electric cookers, have led to certain modifications to the house plan.

It is clear that standards in minimum housing have undergone a marked change in the last hundred years. At least with regard to space standards, it is possible to measure this change more precisely. Fig. 3 shows the changes in recommended space standards. The data for the earlier years is from 'model' dwellings built in London and after 1918, from official handbooks[4]. Floor space refers to the total area of the dwelling, living space is the sum of areas of living room and bedrooms. The overall floor space per person has increased at the rate of about one sq. ft. (929 cm^2) every two years. The relatively greater increase in floor space is due to the introduction of a separate bathroom, more space for storage and for circulation. Removal of cooking from the living room came when gas and electric cookers replaced the solid fuel range, and the small space used for food preparation and washing up expanded into the modern kitchen. It is interesting to speculate on the direction which further improvements might take: more amenities and equipment, such as full scale central heating and more space to accommodate leisure pursuits.

The trend in Fig. 3 is clearly related to a general improvement in living standards, although there is insufficient data to permit a detailed analysis of building costs, wages and rents for the whole period. It is of interest that, at the present time in a number of European countries and the United States, all of which have different standards of living, the relationship between average cost of minimum housing and the average annual earnings of adult male industrial workers, expressed as man years per dwelling[5], is remarkably similar.

It must be emphasised that the data presented in Fig. 3 represents an ideal minimum standard which was not achieved by any substantial number of the population. Further, superimposed on the long-term increase in size of dwellings there are fluctuations in suggested standards. Fig. 4 shows the average overall area of three bedroom houses built under state subsidy and thus represents the space standards that have been achieved in minimum housing[6] for the period 1920 to 1960. There has been a tendency to reduce space standards from a peak immediately following the two major wars, so that the overall gain in forty years has been under ten sq. ft. (9.29 m^2) per person. It is known that short-term reductions in space standards have been made, in order to speed up the rate at which families obtained houses. The number of man years per dwelling follows a broadly similar pattern, with an average for the whole period of around three man years per dwelling[7].

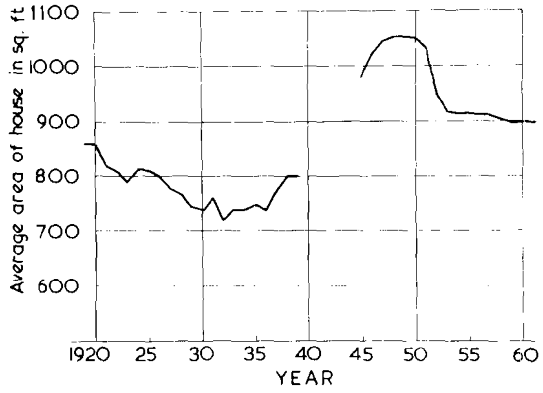

Fig. 4. Average floor areas of 3-bedroom houses built under subsidy in England.

Discussion and conclusion

The paper has suggested some of the relationships between economic, technological and social factors in housing, a commodity which may be regarded as one of man's universal needs. At least in some simple societies, the house is related to the way of life and, moreover, housing of an acceptable standard is available to everyone. When house building passes into the hands of specialists, the needs of particular groups, or needs arising from changes in patterns of living may not be adequately met. It is a matter for debate whether the housing standards of the English working class deteriorated at the beginning of the last century from what they had been earlier, but it is certain that there was a wide gap between the standards of space and comfort available to the urban worker and that which the middle-class enjoyed. Industrial and urban expansion created the need for minimum housing standards in England and the paper has shown how these standards were in turn shaped by some of the processes of urban growth. Similar housing problems to those of nineteenth century England may be found in the slums of Hong Kong and Calcutta to-day. The growth of industries and towns, together with the existence of large numbers of poor unskilled workers who are badly housed, are conditions found in many under-developed countries. Systematic study of both the causes and the attempted solutions to housing problems is thus of more than academic interest.

Attempts to improve mass housing in England underline one of the chief dilemmas of the housing reformer. If the standard is raised only slightly and the houses, as in England, have an expected life of sixty years or more, they may become obsolete long before their useful life is over. If the new standard is set too high, it will remain beyond the reach of those who need it most, if such houses are only available on the open market. The extent of this problem can be better appreciated from a calculation based on household income and current arrangements in Britain for obtaining a mortgage to buy a house[8]. Even in a comparatively wealthy country such as this, it can be demonstrated that a substantial number of the households have insufficient income to buy a new house which incorporates the most recent recommendations[9] concerning standards of space and equipment. The need for some kind of mass housing programme extends beyond the short-term effects of war or economic recessions. The standard of mass housing in any country is a measure of its economic and social achievement. The question of how much of the national product can be allocated to housing without losing ground in other fields such as education, is a point for debate. There may be no single answer to this question, but its consideration is as pertinent to schemes for under-developed countries as for those which, like Britain, have moved, at least empirically, some way towards a solution.

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Evaluation of building products and services

By P. Keys (Australia)

In the last 20 years the demand for building has led to the introduction of new design concepts, the development of new materials and products and techniques of construction. Such advances have emphasised the need to rapidly assemble and assess the growing volume of technical information.

A designer working in any part of the building industry is continually faced with the problem of making decisions concerning the use of these techniques and products. With the advent of industrialised building and systems for building, these decisions become crucial, since every component will be reproduced many times and its proper choice is becoming vital.

This paper is concerned with setting out a general method for acquisition and processing of information to enable proper and adequate decisions to be made.

The analytical approach adopted in this method is developed through a number of progressive stages until ideally a solution is reached. At specific stages in the development it will become apparent that certain products or services will not satisfy the need and are thus eliminated.

The solution should then satisfy the many criteria such as quality, cost service, durability as set out in the statement of the problem.

The most important operation in the analysis is the acquisition of comprehensive, reliable information about the products or services under consideration. In Australia, this information is seldom provided in the manner in which it is required for use. There are three groups involved:—

User	(architect, planner, engineer, quantity surveyor, builder, etc.)
Manufacturer/ Servicer	(suppliers, fixers, suppliers and fixers)
Information/ distributor	(Commercial organisations engaged in the distribution of trade and technical literature in Australia include the Buildings Materials Data Service, Suppliers Index Bureau, Ramsays Catalogue, Building Information Centre)

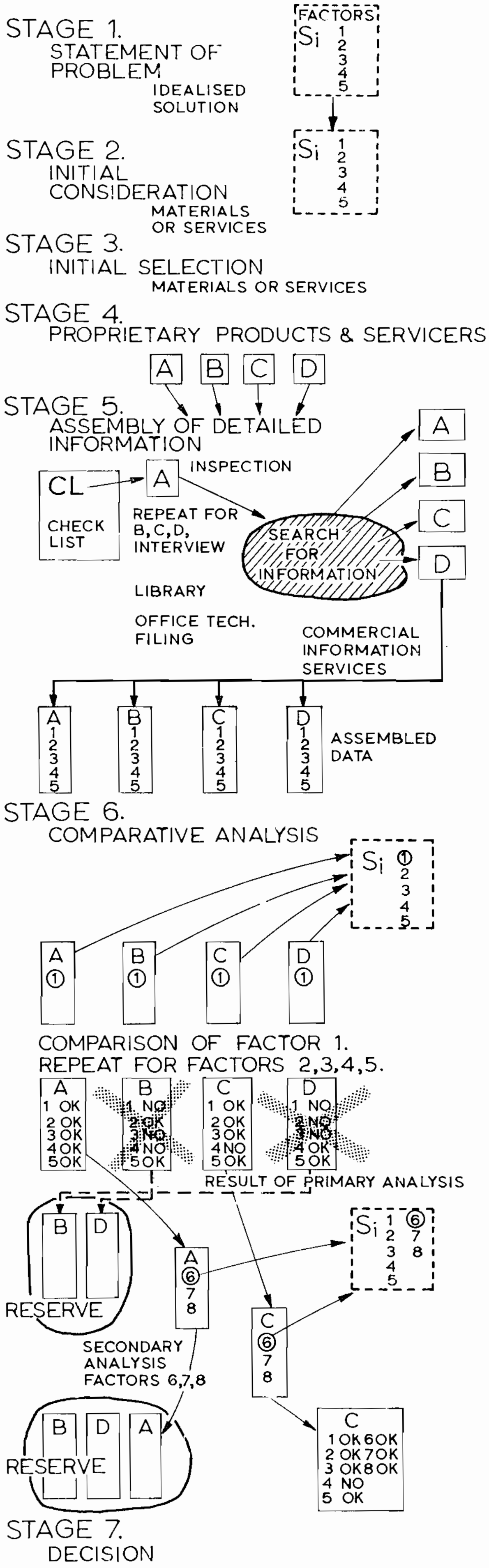
The Technical Sub-Committee of the Building Science Forum of Australia has studied the technique and has so far prepared two draft check lists, one covering Product Information, and the other Service Information. These check lists form only part of the analytical method and are the only part of the method which has been studied in detail, (see figures 2 and 3). The check lists have been partly tested in use by a selected group of architects, builders and manufacturers and comments have been incorporated in the final forms shown.

Whilst the Committee has been preparing the present paper, it came to its notice that the CIB Working Commission W31 has recently published 'A Master List of Properties for Building Materials and Products' being CIB Report No. 3. It is realised that this master list covers somewhat similar ground to the check lists. It should be pointed out however that both these check lists and the CIB master list are part only, (although an important part) of the overall philosophy of the process of evaluation and selection elaborated in the present paper. The paper has been envisaged as an integral whole which serves to develop a functional approach to the problem of evaluation and the check lists where developed to fit into this comprehensive scheme. Therefore, the check lists are regarded as unique and part and parcel of the paper.

So that the user may finally select the most suitable building material, product, or service for a particular use, a process in seven stages, is set out below in a much simplified and idealised form, so that the procedure is made clear.

Stage One—Statement of Problem

A clear concise statement of the problem in written form, with



due consideration of the principles involved—(what function a particular product must perform, the exact type and extent of work required to be carried out by a servicer, etc.)

However simple or complicated a problem, no solution is possible until the problem has been stated. From this wiritten statement of the problem, some kind of 'idealised solution' (S_i) can be derived, indicating the factors that require to be considered and their order of importance or priority. The diagram shows the S_i with an arbitrary five factors: in reality there may be more or less factors depending on the type and complexity of the particular problem.

Stage Two—Initial Consideration of Materials or Services

An initial consideration of possible materials or services is carried out in the light of the 'idealised solution'. This consideration should be a comprehensive one embracing concepts which do not at first sight seem to be entirely opposite; that is to say, the consideration should be spread across and on either side of the area in which the solution might be thought to lie.

Stage Three—Initial Selection of Materials or Services

From Stage 2, a selection is made of the most likely lines of solution. This process is predominately a subjective one, being primarily based on the knowledge and experience of the User. It is, of course, possible and indeed advisable, to get other User opinion at this early stage so that the analysis can proceed in a way which is most likely to point to a satisfactory solution.

Stage Four—Consideration of Proprietary Products and Services

This stage takes the results of Stage 3 and translates the most likely materials or services into terms of proprietary products, or servicer organisations. These are then listed so that the detailed information required for proper analysis can be obtained. In the diagram it is assumed that the products or servicers are nominated as A, B, C, D. Again there may be more or less alternatives depending on the problem under consideration.

Stage Five—Assembly of Detailed Information

This is the most important stage in the whole analysis. The successful solution of the problem depends largely on the adequate assembly of detailed information about the products or servicers under review. The two detailed check lists are for Products and Services and have been prepared to assist this stage. Bearing in mind the implications of the factors, and their order of priority, set out in the 'idealised solution', the appropriate sections of the appropriate check list are marked up. The search to gather the information can then be started, covering such sources as libraries, office technical information files commercial information services, interviews and inspections. This process is repeated (in the case of the diagram for A, B, C and D) until all the relevant information is gathered; it then can be tabulated, in order of priority, as indicated.

Stage Six—Comparative Analysis

A comparative analysis is then carried out, checking progressively the Factor I's of the Products against Factor I on the 'idealised solution'. It is possible that at this stage one Product or Service may fail to meet the requirements of the 'idealised solution'. If this is so then this particular Product or Service (B in the diagram) is relegated to a "reserve" at the end of this Stage. When a comparison of all the Factors of all the Products or Services have been carried out, comparing them with the 'idealised solution', the analysis for this Stage is completed.

The diagram shows a simple and ideal state of events—at the end of Stage 6, Products A and C are still in for consideration, Products B and D have been eliminated. In actuality the situation may be less clear. It may in fact range anywhere from total rejection of all Products or Services to total acceptance—or anywhere between as previously stated. If all the Products have been rejected then either the 'idealised solution' (Stage 1) is faulty in the selection or priority of Factors, or the consideration of possible alternatives (Stage 2) has not been adequate. This situation requires a return to the start, a reconsideration, and a further run through.

If however all the products are equally acceptable at the end of Stage 6, then a further set of Factors must be evolved to sort them out. Again it might be advisable to start at the beginning to make sure that the 'idealised solution' is adequate for the purpose. The diagram shows a further selection of Factors, 6, 7, 8 for the secondary analysis of Products A and C. When this has been carried out the situation at the end of Stage 6 shows C as the most likely product with B, D and A being held in reserve, having been previously rejected. A quick check should be made between Product C and those in reserve to make certain that all is in order to proceed to the next stage.

Stage Seven—Decision

Having gone through the other stages in the process, the final decision should be comparatively simple. There are however, various intagible, subjective factors (which cannot be satisfactorily stated) which have to be taken into account here, and weighed against the objective and factual results of the analysis. Even, if at this stage the final basis of the decision is a subjective one, at least the User in making this subjective decision has a clear objective back ground. Finally the results of the analysis should be fedback into the User's technical filing system for future reference.

The success of the method depends on its acceptance by all sections of the building industry. Unfortunately, in Australia, at least, people are still apt to specify and purchase materials according to loose descriptions, inadequate knowledge of properties or sometimes merely because of a whim. There is no doubt that increased industrialisation of building and a greater awareness of the importance of rational selection will help to reverse this trend and it is hoped that a systematic method like the one presented here will generally be adopted.

If architects, for instance, were convinced that this is in the best interests of building efficiency and economics, and would insist on the submission of properly evaluated check lists, this could then form the basis of such a re-assessment of methods of selection. This would compel manufacturers and servicers to look more closely at what they are offering and by research and testing improve quality and restore consumers' confidence in the building products' market.

In present day design considerations, even when data is available, it is mostly scattered, and valuable time is spent in collecting it into a form where comparisons can be properly made.

The final outcome will be that comprehensive information is readily available on all aspects of any material, product or service likely to be required in building. This will possibly lead to large libraries in architects' offices being filled with volumes of information; the architect will then have to spend a considerable amount of time in research with this material. However his time will be well spent since it will ensure a proper foundation for any choice made and it will eliminate much of the present headaches due to uninformed decisions. So let us have these volumes and spend the time initially rather than later when the damage has already been done.

All decision making processes can nowadays be formulated for programming and computer techniques, such as can be seen in the CBC techniques of Bjorn and Knud Bindslev. It is believed that the outlined method lends itself readily to such techniques.

A final word about international co-operation in this work: much of the data required is common to most countries, and the method of analysis proposed may be used in an identical fashion. Therefore, much benefit could be derived from an exchange of information between countries in this field.

In conclusion, it is hoped that the evaluation technique described in the paper will assist the building industry towards industrialisation and towards better and more efficient building.

H 10

P. Keys

Service
Information
Date of Issue:

THE FACTS REQUIRED

It is assumed that the Company to be studied functions by offering to the Building Industry what is primarily a SERVICE, related to "supplying and fixing" their own or others' Products, or "fixing and applying only" others' Products, not only normal "after sales"

SfB
UDC
Ref

IDENTIFICATION (briefly)	TRADE NAME/ MARK	
	SERVICER	name – phone number head office address registered office address representative(s) name(s)
NATURE OF SERVICE	GENERAL STATEMENT	what does the SERVICER do? e.g. fixes windows, lays roof finishes cleans stonework, etc.
EXTENT OF SERVICE	DETAILED DESCRIPTION	what is done what is not done supply and fix fix or apply only
	EXISTING WORK	will SERVICER repair or demolish/replace existingwork even if in another product, or by another Servicer?
	AREA OF OPERATION	location(s) limitations
	ON BEHALF OF	whom
	DESIGN SERVICE	what is provided, if any; if so, then state what information is required from Architect, and whether any charges will be made.
	TECHNICAL ADVICE	if any is available, then state its extent and list names and addresses of the technical representatives.
PRODUCTS MATERIALS COMPONENTS	LIST OF ITEMS USED	if any product, material or component is supplied by other manufacturers, give 1. source – local/imported 2. names and addresses
	WHAT ITEMS NOT USED	provide list and give reasons, if necessary
	CROSS REFERENCE (S) TO WORK METHOD AND PRODUCT INFORMATION	quote numbers of catalogues technical leaflets, if any
DESIGN CONSIDERATIONS	SUB-BASE CONDITIONS	specify requirements
	TOLERANCES	manufacturing fixing
	APPEARANCES	description of finishes
	STATUTORY REQUIREMENTS	Bye-laws, Ordinances, etc.
	OTHER TECHNICAL CONSIDERATIONS	wind loading roof traffic abrasion loading
	QUALITY/GUIDE COST RELATIONSHIPS	give basic data for comparative Cost Planning/Analysis
SPECIFICATION	STANDARD SPECIFICATIONS	A.S. B.S., A.S.T.M. etc.
	CODES OF PRACTICE	A.S., B.S., C.A. No.
	RECOMMENDED CLAUSES	include also references to statutory requirements – e.g. fees – who pays?
	TEST REPORTS	quote source(s) and result(s)
	OPERATION DEFINITIONS	list tasks for operatives and materials to be used.
PERFORMANCE	MAINTENANCE SPECIFICATIONS	clauses and requirements.
	MAINTENANCE SERVICES PROVIDED	describe how, in detail & schedule charges involved. when is it to be provided?
	GUARANTEES	describe exact nature, then indicate what and whose responsibility is involved, whenever guarantee invoked.
TENDER	the date from SERVICER to ARCHITECT &/OR QUANTITY SURVEYOR &/OR CONTRACTOR, to give a BASIS for the SELECTION OF TENDERER should contain these items:	
	CONSIDERATION	approximate quotation, or firm tender sum
	DRAWINGS	list, if any provided
	PRICE ANALYSIS	where decision needs it
	SITE WORK SCHEDULE	outline description time allowed – comments
	BILLING INFORMATION	clauses, methods, units

TENDERING DATA from ARCHITECT & CONTRACTOR to SERVICER		
	DATA SERVICER NEEDS	for an Approximate Quote for a Formal Offer
ESTIMATE AND MEASUREMENT ON	TENDER "SERVICE INFORMATION FORM"	should contain these items:
	DRAWINGS REQUIRED	what and when needed
	DIMENSIONS	actual and tolerances
	DESCRIPTIVE OR EXPLANATORY NOTES	e.g. eaves heights etc.
	NAMES, ADDRESSES AND TELEPHONE NUMBERS OF	Job Architect Quantity Surveyor Consultants – as applicable Main Contractor, when known other Specialists involved
	CONTRACT: FORM	R.A.I.A. Edition 4 Public Works Authority Civil Engineering, etc.
	CONTRACT: TYPE	Lump Sum – with Quantities – without Quantities Schedule of Rates, etc.
	TERMS OF PAYMENT	method of certification discounts, period, etc.
	PRELIMINARIES	e.g. time schedule work sequence damages – liquidated or ascertained
	GENERAL DATA	description of the job location of site means of access approximate delivery data scope of this subcontract tender form to be used
INFORMATION	to be supplied by SERVICER to ARCHITECT, etc. when tendering, for use in CONTRACT ADMINISTRATION	
	ORDERING PROCEDURE	clear explanation
	PROGRAMME	sequence of own work relations to other trades drying out or curing times
	DELIVERY	time method unloading and checking
	SITE STORAGE	requirements who will provide
	BUILDER'S WORK	required in connection with
	PROTECTION	requirements who will provide
	ATTENDANCES DEFINED	with respect to: – lighting hoisting scaffolding electricity, water, gas amenities (? statutory) workshop facilities
	PACKAGING AND CONTAINERS	arrangements re form, types, sizes, protection
COMPANY	SAMPLES OF USE	time – e.g. when done durability or life
	COMPANY STATUS	public or private top management financial (status, references, credit rating) state if operating as LICENSEE, AGENT, IMPORTER for Overseas Manufacturer
	CAPACITY FOR WORK	Capabilities present commitments
	RESEARCH AND DEVELOPMENT	describe programme, if any, and list the staff engaged
	OTHER PRODUCTS AND SERVICES	schedule descriptions, if any
	BRANCH OFFICES	schedule – addresses telephone numbers representatives' names etc.
REFERENCES	LITERATURE	general data technical instructions published articles

H 10

P. Keys

Product
Information
Date of Issue:

THE FACTS REQUIRED

It is assumed that the Company to be studied functions by offering to the Building Industry what is primarily a PRODUCT, not a SERVICE. In this case the word "Service" is taken to mean services which are not normal product, sales or supporting services.

SfB
UDC
Ref

IDENTIFICATION (briefly)	TRADE NAME	
	DESCRIPTION	what is it? what is it made of? how is it made up for use?
	PURPOSE	what does it do, or is it for?
	MANUFACTURER	name – phone number head office address registered office address representative(s) name(s)
CLASSIFICATION		building material unit section assembly function element service systems equipment and accessories
PROPERTIES AND CHARACTERISTICS (detailed)	PROPERTIES	Quote Standard Tests for items:
	COMPOSITION	chemical
	DENSITY	
	STRENGTH	tensile compression/crushing torsion bending shear modulus of elasticity modulus of rupture impact adhesion abrasion hardness fatigue
	pH FACTOR	
	THERMAL	coefficient of expansion conductivity (k) resistivity (u) specific heat transmission radiation reflection (%age)
	FIRE RESISTANCE	combustibility classification flame spread classification early fire hazard rating explosion hazard temperature – softening – yield – operating distortion at °F
	MOISTURE	vapour permeability coefficient of absorption moisture content (%age) moisture mobility potential drying shrinkage hygro-expansivity
	BIOLOGICAL RESISTANCE	insects pests fungi
	SOUND	coefficient of absorption reflectivity (%age) transmission
	LIGHT	diffusion (%age) absorption reflectivity
	ELECTRICAL	resistance insulation conductivity dialectric electrostatic
	CORROSION RESISTANCE	oil acid etc. alkali salt in atmosphere sulphur dioxide
	ODOUR	
	CHARACTERISTICS: TYPES PURPOSES DIMENSIONS	height width length thickness manufacturing tolerance accuracy classification
	COLOUR	fading
	TEXTURE	internal or cross section surface
	WEIGHT	
	CONSISTENCY	batches – sizes colour weight

PERFORMANCE	USES	normal other limitations
	FIXING APPLICATION ASSEMBLY	position fixed protection storage protection sub-base requirements
	CHARACTERISTICS	span/loading capacity output limitations
	WEATHERING	air water wind sun (ultra violet) (infra red)
	COMPATABILITY	in association with other materials – specify them
	LIFE	durability expectation when – installed – on shelf – in package
	GUARANTEES &/OR WARRANTY	what & whose responsibility?
	MAINTENANCE	how? requirements? (now or future)
	REINSTATEMENT REPAIR	methods facilities required timing
SPECIFICATIONS	STANDARD	A.S.
	SPECIFICATIONS	B.S., A.S.T.M., etc.
	STANDARD CODES	A.S., B.S., etc. C.A. No.
	CLAUSES	recommended
	STATUTORY REQUIREMENTS	Bye-laws, Ordinances etc.
ESTIMATE AND MEASUREMENT	METHOD	standards billing information ordering pricing
	GUIDE COST	supply only fix only supply and fix primage sales tax depreciation for income tax import duty delivery
SUPPLY	SOURCE	country of origin area offices works/depots agents/licences
	METHOD OF DELIVERY	road or rail sea or air
	TIME OF DELIVERY	from ordering to supply
	SUPPORTING SERVICES	technical advice design/layout erection fixing maintenance future extensions
	PACKAGING CONTAINERS	form types sizes protection
	CONDITIONS OF SALE	cost – ex works cost – delivered to site terms of payment – discount time quantity
COMPANY	EXAMPLES OF USE	building architect builder engineer
	COMPANY STATUS	public private directors financial (status, references credit rating) production
	CAPACITY	capabilities and commitments
REFERENCES	LITERATURE	general data technical instructions

Concrete element constructions in areas liable to earthquakes

By M. Lourenço Antunes (Portugal)

Features of construction

It is a fact that nowadays the development of all constructional schemes depend mainly on team work: program-handwork. The situation of such teamwork controls the appearance and improvement of the industrialised systems, either concerning previously manufactured items or standard reinforced concrete works.

Considering that there is no lack of construction plans both long and short term, even in all those countries in full development, the appearance of previously manufactured items is being delayed by the lack of labour. However, the lack of qualified people as well as the following increase of wages and social charges will contribute, no doubt, to fully mechanize building sites and to look for new building and construction proceedings. In some countries, the industry has kept its traditional features, failing to follow the technical advances developed in other industries.

Recently it has been discovered in the field of construction and building, that the use of standardised plans and solutions does help to increase the rhythm of execution and the quality of the job, thus reducing charges and the time necessary for plans and schemes and encouraging productivity and industrialisation while making use of the most advanced technology.

Certainly all investigation and research institutes should give their attention to standardisation of structures and to constructive solutions by means of previously manufactured elements.

Construction in seismic zones

It goes without saying that there are special problems concerning previously manufactured concrete elements in seismic zones. The connection of single parts which are of outstanding importance in regard to the structures in such zones should assure the simplicity of construction of such connections, a minimum of steel employed, the direct transmission of the strength of one part to the other and the precise geometric accuracy besides the suitable stiffness and the monolithic feature of the connected bodies.

The most outstanding features of industrial development and transformation are standardised methods and increased productivity, characterised by an increasing technological approach.

Considering countries in full development the manufacture of precast elements in earthquake zones must start or continue simultaneously on two fronts: in the urban zones showing a strong density of population, the way must be the manufacture of middle and large sized precast concrete elements; in the rural zones; generally in the poorer districts, it should be started in such a way as to interest the population itself. For example, it is a fact that the Chilean experience after the 1960 earthquake brought very interesting results. On the other hand, the experience made with large-sized panels mainly in east Europe shows the practicability of the manufacture of precast elements in the zones where earthquakes are experienced. Such experience, as well as tests made in laboratories on small-sized models, prove to be the most suitable as they permit checking between the efficiency of the different systems and stability of each one when submitted to horizontal stresses.

Besides these tests one should not forget that constructive details are also of the utmost importance. Thus the connection of pile reinforcements in beams and distributing reinforcement in reliefed floors with precast girders, may be decisive as to seismic safety details.

Further, the use of partition walls turns out to be rather efficient, in fact, considering that partition walls even when split, help to absorb energy. During a very strong earthquake, horizontal stresses are always sufficient to produce wall cracking. The resistance of the construction is practically nil after cracking occurs, and whenever there is no vertical stiffening at all.

All constructions containing reinforced concrete structures and panels may be used without limits as long as framework is dimensioned, calculated and executed in order to resist horizontal stresses corresponding to seismic actions. In case of precast panels, its connection to the framework must be guaranteed.

Thus we conclude that certain constructive standards should be followed together with all different applicable regulations. Among such standards, we would like to point out the following ones:

- Pile reinforcements and other vertical parts must not be discontinued when connected to floor levels, this being only possible half way up.
- Concerning beam-pile connections, the operating of the framework requires the production of plastic joints at pile ends. The moments that can be absorbed by such joints are strongly influenced by the care in the design and execution of the connections.
- Whenever possible, vertical elements must be used as stiffening parts and therefore conveniently reinforced.
- On standard sized piles, reinforcements must be concentrated close to corners in order to increase its resistances in both directions.
- Precast elements must be duly connected to concrete elements made on site, thus involving a careful study and execution of all details.
- Rather strong precast walls must be used to resist traction and to avoid damaging walls.

The seismic technique has sufficient means to study all very important and outstanding concrete problems, and further it can proceed to general studies of wide application. However, it should be pointed out that the construction works in seismic zones should profit always by the correct assembly and good quality of materials. Any suitable project to resist horizontal stresses will not be sufficient to obtain the highest safety against earthquakes, whenever connecting elements are of poor quality or deficiently executed. Items of different modulus of elasticity should not be used.

The basic idea of the constructive solution is to try to obtain from independent precast elements one final constructive scheme operating in the same way as any similar construction made from monolithic reinforced concrete. All experiments carried out show that it is quite possible to obtain a framework similar to a monolithic item when all precasting is connected in the right way.

However, it should not be forgotten that the connection between, or among, precast elements produces some weak points in the construction. It will be quite necessary to ensure perfect fixing and a good connection to foundations, considering that cracks, even without breakage, do reduce firmness. Reinforcement eccentricities produce local strains, so that connections may not be made under satisfying conditions in such cases.

Conclusions. Connection of different elements is one of the most delicate points of pre-manufacture in seismic zones. The experience of some countries where heavy pre-manufacture has practically been solved, should be widely advertised.

Together with the conditions contained in the different regulations against earthquakes, certain constructive standards should be followed in order to increase the stability of constructions under horizontal stresses.

Seismic engineering has means to study all specific problems in regard to the application of concrete elements in zones where earthquakes occur. Thus the efforts of all such countries should be concentrated in order to obtain the best possible improvements.

The different national organizations should encourage pre-manufacturing industries in research concerning stability against earthquakes which might help its utilization in other countries, with evident benefits.

Studies of environment within workplaces

By P. Manning (U.K.)

The architect's major task in the design of workplaces is to ensure that the requirements of the work are reconciled with the environmental needs of the people who will perform the work, in the most pleasing and economic manner possible. Most architects are aware that their buildings can influence both work and people, but it is not so certain that they know the ways in which this happens nor can they predict the results with any accuracy. This is because design is still a largely intuitive process.

The problem is essentially one of knowledge: there is a lack, at present, of a properly established basis for design. The output of building research has been diffuse and much of the literature relevant to a particular design problem is scattered. Where objective methods of design have been established they are often so time-consuming that many designers still work by rule-of-thumb because they believe that it would be completely uneconomic for them to do otherwise. There is, however, no need for the design process to continue as a matter of solving 'one-off' problems. It can be placed upon a more rational basis by the preparation of 'standard' solutions for recurring 'standard' problems. It is unlikely that unique, universally applicable answers will ever be found but it should be possible to determine a range of optimum solutions for a given range of conditions.

There are two main ways in which building design problems can be studied: by design aspect or by building type. In the first case a subject (e.g., lighting) is studied intensively and its application to a range of building types considered. In the second case the design problems of a particular building type (e.g., factories) are considered in the context of all the variables—constructional, environmental, human, economic, etc.—which influence the making of design decisions. Both types of study are necessary but the immediate advantage of building-type investigations is that their results can be presented in a form suited to speedy and effective application to practice: the special needs of an individual building owner need only be added to or subtracted from the basic solution. Speed in the application of building research findings is of great importance today, especially in respect of buildings in which work is to be performed, for it is common experience that many such buildings are out-of-date by the time that they are completed.

Any building-type study of workplaces necessarily involves consideration of many matters including user requirements, production planning, physical working conditions, people's subjective attitudes and needs, the climate, building costs and building design. It is clear that no one individual or profession can possess all the necessary skills and experience to appraise such a range of considerations: they can only be given the professional attention they need by multi-disciplinary research teams.

This paper reports research investigations made in Great Britain into the design of three different types of workplace: farm buildings, factories and offices, each of which involved a multi-disciplinary approach. The purpose and methods of each of the investigations were different, and each was conducted by a different combination of professional research workers. Nevertheless, there has been a continuity of experience; one project has been built upon another and all three form the basis for further studies now being planned.

Farm buildings

Investment in farm buildings is an important consideration to an agricultural industry—for in Europe annual building costs may represent something of the order of 15 percent of total production costs, or about five times the comparable figure for manufacturing industry. In addition, the economic consequences of building design decisions are more apparent in this building type than in others. It can be expected, for example, that in a good environment animals will grow more readily while consuming less food than they will in a bad one. Careful planning can increase efficiency by reducing labour requirements and increasing opportunities for mechanisation.

A technical and economic study of farm buildings was undertaken at the University of Nottingham Department of Agricultural Economics during the period 1958–1959. The main objective was to evaluate post-war farm buildings from the standpoint of their contribution to increased farm efficiency and profitability and the adequacy of their design and workmanship.

The work was concentrated upon housing for dairy cattle, for this was found to be the farm building type which, since the war, had been constructed in greatest numbers. Surveys were undertaken by an agricultural economist and an architect, and took two main forms. First, the siting and layout of a new building was examined in relation to the effort involved in the daily routine of moving materials (e.g., feedingstuffs, milk, manure) in and out of the buildings. Second, the building cost implications of design decisions affecting the building layout and environment were calculated on a 'Standard Cost' basis.

Although the buildings surveyed were constructed from modern materials (e.g., concrete block walls, corrugated asbestos cement sheet roofs) they were of mainly traditional design and so offered relatively few opportunities for better environmental control than older buildings of the same sort. Indeed, in one important respect, the incidence of condensation, they often provided much worse conditions because the old forms were followed without an understanding of the different thermal properties of the new materials.

The principal findings of the study were in the sphere of management decision and its consequences. Farm owners, it was found, rarely make use of existing design knowledge, nor are they aware of the most efficient and economic procedures for buying buildings. And they often site their buildings and relate one to another so inefficiently that they create unnecessary transport effort. There can be wide variations (of the order of 10 to 1) in the costs of similar accommodation serving substantially similar purposes on different farms. Approximately 80 percent of this variation was attributed to differences in building design and construction, the remainder to market factors. The annual rates of gross return which were estimated for the surveyed buildings were, on average, sufficiently high to suggest that the buildings were earning their keep but the returns varied very greatly (from 30 to 500 percent), the causes being wide variations in production, building utilisation and building costs.

Factory buildings

An investigation into the design of factory buildings was undertaken in the University of Liverpool Department of Building Science to provide an answer to a specific question—what was the likelihood of the American pattern of 'windowless' factory (which relies upon electric light for the whole of its working illumination) becoming more firmly established in Britain? Such a problem necessarily requires evaluation in many different terms: in this study it was examined from the technical, environmental and economic viewpoints. The medical and psychological implications of a decision to create a 'windowless' workplace are profound—indeed they may be crucial—but there has been little work done in this field, and it was not possible to initiate studies of such a nature during the course of the project.

The work, which had three main lines, was undertaken by an architect, who was later assisted by a geographer and professional engineering and quantity surveyor consultants. First, a survey was made of the main characteristics of existing British factories, and any special influences (such as legislation) which determine their design. Second, the actual environmental performance of existing post-war factories was studied and enquiries instituted about the costs of operating them. Third, typical production spaces and their environment were designed by the architect and his engineer consultants and their construction costed by the quantity surveyor. Alternative designs which would provide equivalent standards of environment were then compared on the basis of their 'Annual Costs'.

In a study of this sort two difficulties present themselves. One is that although much work has been done on such isolated aspects of factory environment as working illumination and the thermal environment, there is a continual rise in standards of acceptability and many criteria have not yet been revised for today's conditions. The second difficulty is that, having constructed 'models' of alternative designs, the comparison of their annual costs has to be done on the basis of approximations because there is little or no 'feed back' from completed buildings of performance and operating costs. In part, this is due to the fact that factory managements normally group the costs of their buildings (e.g., lighting, heating, maintenance) with other production costs so that they are not readily separable.

The quality of the physical environment in single-storey factories depends very largely on roof design, the most important determinant being provision for daylighting.

To obtain an effective working illumination from daylight it is advisable to design to achieve not less than 5 and probably as much as 10 percent daylight factor on the working plane (equivalent to 25 to 50 lm/sq. ft. with a '500 lumen sky'); this is likely to be the maximum practicable value that can be accomplished. In the typical factory illuminated via patent glazing in the roof, the combined effects of obstruction (from structure, overhead services and equipment) and obscuration of the glazing (by atmospheric pollution) were found to reduce the actual daylight factor on the working plane to between one-third and one-half of the value of sky factor calculated with protractors designed by the British Building Research Station.

A serious problem to the users of factories, and one largely unrecognised by designers, is a possible build-up of heat during hot weather, mostly as a result of penetration of the roof glazing by solar radiation. Natural ventilation is usually relied upon to dissipate this heat but its effects are uncertain and unreliable. The problem can best be minimised by the use of correctly-orientated sawtooth roofs, or by limiting the area of glazing which could be penetrated by sunshine and maximising thermal capacity and insulation elsewhere in the roof.

Theoretical comparisons of the annual costs of a flat roofed building without rooflights and three daylight buildings designed to a daylight factor of 10 percent showed that (over a life of 60 years at 5 percent interest) the annual costs of the windowless flat roof were about 11 percent greater than the cheapest (shed) daylight form. The sawtooth is perhaps the best daylight form because it is least susceptible to solar heat gains; its annual costs are only 4 percent greater than those of the shed. With annual costs 8 percent higher than those of the flat roof, the monitor was the most expensive of the four roof shapes and it is difficult to see what justification there can be for its use.

Similar economic comparisons of windowless and daylit shed-type roofs revealed that although the construction costs of the windowless buildings were the least, their annual costs were greater than those of the daylit buildings.

Office buildings

Until recently, studies have largely consisted of separate and unrelated investigations of single subjects, for example, lighting, heating or acoustics. While this has been helpful to the growth of understanding of these parameters individually, it has not been very helpful to the development of knowledge of environment, because these and other parameters inter-act to create a 'total' environment which has properties greater than the sum of its individual components.

The environment within a building is dependent upon many factors. The building fabric itself modifies the effects of the external surroundings, circumstances and climate, whilst the mechanical and electrical services create working conditions which are largely artifical. People experience an environment through their physical comfort, their aesthetic awareness and as a result of the social relationships in which they are placed by the way the building forces them to use it.

Developing out of the factory study described above, a series of investigations has been initiated at Liverpool which has as its aim an increased understanding of this total environment. An enquiry into the design of offices has permitted many aspects of environment to be studied in the context of a building type which, in recent years, does not appear to have been the subject of much critical thought.

The research team for this investigation consisted of an architect, a geographer, a physicist and a psychologist. There were three main lines to the study. It was necessary, first, to determine the main characteristics of recent office building in Britain – their location and such characteristics as size, ownership and type of use. Second, physical measurements of the visual, thermal and aural environments were made within offices and compared with established standards. Third, extensive studies of the subjective response of office workers to their environment were made in one large office building of advanced design which accommodates more than 2,500 staff.

Over 80 percent of Britain's post-war office construction has been built in the London region, and a majority of office buildings throughout the country are sited where environmental conditions are at their worst, i.e., in town centres. The typical office building has a linear plan-form consisting of a central corridor with shallow offices on either side. It is rarely practicable to achieve from daylight alone the high levels of illumination (30 lm/sq. ft. and upwards) now considered necessary for clerical work, yet this appears to be the main reason for the general adoption of the narrow plan. A subsidiary reason might be a general preference for small sized office spaces.

It is probable that the size of an office space has an important effect upon the character of the working group it houses. Sociometric studies have shown that small office areas tend to produce very cohesive small work groups and isolated individuals, whereas large areas containing many people tend to create a more integrated whole. The consequences, in terms of competition and collaboration, and of output, need further investigation but the finding has obvious and potentially very important consequences for management.

A belief in the importance of daylight is widespread but it has been shown that, in conditions where electric lighting is used constantly and where there is an unobstructed view of windows, people working mainly in artificial light cannot properly distinguish between the two forms of illumination. It is probable that windows are really valued for their view to the exterior and that this is now their important function.

The most widespread environmental problem in offices located in city centres is noise. There is little that can be done to mitigate traffic noise, apart from using heavy cladding and double glazing, fixed windows and air conditioning. It is often believed that large offices present special difficulties of noise control, but surveys in general clerical offices have shown that, properly designed, they need be no more noisy than small ones.

Taken together, the increasing needs for adaptability of layout, use of mechanised procedures and better communication within the office, with the finding that the visual requirements of clerical workers can be adequately met by well-designed electric lighting installations, suggest that openplanned, artificially-lit office spaces of comparatively great depth may be suitable for more widespread use. A general trend to such a plan form would have important consequences for town planning.

Conclusion. Traditionally, the creation of 'total environment' has been the province of the architect. It is now such a difficult task that multi-disciplinary design teams are found necessary. But the design of workplaces continues to be mainly arbitrary and intuitive, for little positive design guidance based upon research findings is available.

This paper has shown that a useful contribution can be made to the knowledge required for the design of efficient, pleasant and economic workplaces. Research needs to be undertaken by teams which are multi-disciplinary in composition, for only thus can an investigation take into account the many aspects of a building-design problem. At the same time, the number in a team should be small for it is necessary that the members pool their individual skills and work together upon a common problem.

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Meteorology and planning; from theory to commercial practice

By W. Neuzil (Austria)

Recommendations given by climatologists are realised only when they are economic and of trading value. Climatology gives much information and many recommendations to improve the quality of buildings. But not all recommendations are put into practice. How is this fact to be explained? Experience has shown plainly that such recommendations must have two qualities: first they must be economic, i.e. need little energy, and second they must be of trading value, i.e. the customer must be ready to pay the price. It would e.g. be useless to attempt to silence the noise of an airport by moving it to another area. But in house-building, plumbing and the swimming-pool have high value not least because of the psychological facts which guide the customer, i.e. prestige and civilisation. And those psychological moments are well known to industry and user through clever propaganda.

Sun is of great importance to hygiene, but not a market article; shortage of building land and housing are working against it. There is no doubt that supply of sunshine (insolation) is an urgent demand of hygiene, especially social hygiene. All those interested in building are fully aware of this demand. Yet insolation is neither an article which is of economic interest to industry nor a commercial value for which the customer is ready to pay.

One way to make use of sun energy would be to store sun heat, but up to now these attempts have not passed the experimental stage. A second possibility lies in screening off unwanted sunshine, which becomes most necessary in tropical climates. Of course—and this is characteristic—modern industry has already developed efficient constructions to put on the market. Specialists of insolation of houses, among them Mr. Tonne, an architect from Stuttgart, have contributed considerably by their research work.

A third possibility would be the rationalisation of insolation of dwellings. Tough house-hunters are greatly interested that this demand be met with restraint by all those who are interested in making intense use of land property, by high rents and a great number of dwellings—i.e. mainly building cooperations, contractors and also those offices of public authorities which, pressed by the housing shortage, pay more attention to quantity than to quality. For there is a correlation between insolation and the residential density. The higher the density, the less it is possible to insolate the flats. The better insolation, the smaller the number of flats, and the higher the rents. Though people love sunshine they are not ready to pay higher rents for it, the more so as today the rent is a great burden because of high expenses for building land and construction. Thus the demand for sufficient insolation does not offer any attraction to contractors, especially as it might make it impossible to use sites with insufficient insolation for the building of flats. The customers, on the other hand, are also not ready to pay for insolation as much as they would pay for many other technical comforts.

Building as investment

Though flats are not yet complete industrial products, this is becoming the tendency. Therefore dwellings can be looked upon from similar points of view as other industrial products. There are short-lived ones, produced for quick consumption, like electric bulbs, or bicycles, which are not planned for a long working life but for quick turnover. They are produced as well, or as badly, as the customer is ready to accept. But there are also long-lived industrial products such as powerplants, bridges etc.—and here the situation is reversed. Best and most modern construction is wanted in order to amortise the high investment costs.

A block of flats belongs to the latter group, especially if constructed industrially. In this case dispensing with modern equipment and quality would mean investing at short term, immediate decrease of value, and need for redevelopment.

We must face the fact, that our blocks of flats will certainly last for three generations, i.e. at least for ninety years, while the building trade need not be afraid of not getting enough orders, as there will be enough to do in redevelopment of old buildings after the most urgent housing-shortage has been removed.

Demands for better comfort

Another factor is the fast rising demand for high quality flats, created by the many new products of the technical age which are offered to the public by well-aimed advertising. Advertising is applying most modern methods, making use of psychology in order to wake the purchasing readiness and to convince the customer that he owes his prestige a car, a swimming-pool etc. This dynamic movement spreads comparatively fast over the widest groups of society and proves that "the utopias of today are the realities of tomorrow". If already today everyone, who can afford it, plans his own new house to get a fair amount of sun, then it will not be long before the inhabitant of a flat will demand his right to sufficient insolation,—while now perhaps leaving these demands unexpressed under the pressure of housing shortage.

Decrease of market value

Thus, there is a double necessity to prevent a decrease of value of flats within the near future and to guarantee a certain minimum of insolation for every flat. Every political programme puts social welfare as its foremost aim. In the long run one cannot prevent drawing conclusions from it concerning demands for insolation.

Today houses with better insolation are being built. It is characteristic that the building trade as well as building associations have already understood this tendency of development and put it into practice. Numerous new housing projects show sufficient insolation. Though the share of sun may not always be well balanced, i.e. some flats get too much while others get too little sunshine, in general insolation is better than modern specialists dare hope today.

A measuring unit and methods of measuring

In order to agree on a minimum of insolation it is necessary to have a measure that is universally acknowledged. Up to now this is unknown to building authorities in their practical work. The building regulations of most cities—among others of Vienna—do not guarantee in the least, any sufficient insolation but generally only a minimum of daylight, without regard to the point of the compass. But these regulations are authoritative for the houses which are being built today and will stand for at least 90 years. Thus it is lawful to erect a house that completely robs a neighbour of all insolation.

Since the nineteen-twenties a handy measure and a practical method of measuring has been looked for, but constantly changing position of the sun and varying intensity formed an obstacle that seemed not to be overcome.

Development of a method for measuring

The first problem was, to find a practical and handy way of judging the insolation of a flat and, by applying it, agreeing on a minimum. This way of measuring must allow its application to plans of towns or houses which, naturally, have to be judged before being built. Developing such a way of measuring has taken about 35 years, but today the development is nearly completed, after much consideration, in a way suitable for similar climatologic research.

What has to be measured? Up to this day specialists do not agree on one point: whether the insolation has to be characterised by measuring the duration of sunshine, or by intensity. As it is well known, meteorology follows both methods. From the point of view of physics, only the question of intensity is exact, while the sunshine per hour is only of optical and psychological importance, as "one hour's sunshine" does not tell more about the sun energy than the statement: "one hour's rain" can inform us about the quantity of water that has fallen. Measuring per hours has but one advantage: it is more simple; yet this simplified

W. Neuzil

way of measuring cannot very well be used as the basis of commercial or juridical decisions, for one hour's sunshine at noon has a hundred times more energy than one hour's late evening sun which reaches the window from a low angle. Therefore, though it is somewhat more complicated, the system of measuring the intensity of insolation has to be preferred because it is the more exact.

Where has it to be measured? The planner has the duty to plan in such way that every window will get sufficient sunshine. Then the architect has to draw a layout in such a way, that it allows the sunshine to enter the flats. Therefore it is the first problem to measure the amount of sunshine that reaches one special window during the course of one day.

The method of measuring. The obstacle with which the sun meets a system of measuring—changing position and intensity—had been overcome in the year 1938 by the fundamental idea to choose not the sun but the centre of the window that has to be examined for the central point of a graphic projection. From this point the skyline of houses (keeping the sun from reaching this window) as well as the sun's orbit have to be projected on one and the same plan. Thus, by turning from a heliocentric system to the geocentric one the complicated way of measuring becomes simplified. There are several ways of projection.

Perspective projection. The first projection was a perspective projection on a perpendicular plane e.g. the window plane showing the skyline of neighbouring houses and the sun's orbit. On the projection of the sun's orbit the hours have to be indicated by marks. Where the line representing the sun's orbit crosses the skyline of surrounding houses, there is the point of sunrise or respectively sunset for the window to be examined. The hours of sunshine can be seen on the scale. By adding another scale also the intensity of sunshine reaching this window can be measured.

Spherical projection. The plane on which the skyline of surrounding buildings and the sun's orbit are projected can also be spherical. Thus projections are created which remind one of maps of the polar regions. This system of stereographic projection was developed by the meritorious deceased Swedish scientist Mr. Pleijel and the German pioneer of insolation, Mr. Tonne from Stuttgart. It is characterised by being multipurposed, as only one plane of projection—the spherical one—is needed for all points of the compass.

Method of contour-lines (projection of orographical maps). Already as early as 1944 a third way of projection was published which has proved very efficient in practical planning. It is based on the same principle as orographical maps, where the altitude is indicated by way of figures and contour-lines. In the same way, sunrays entering a window in the course of one day can be projected by contour-lines on the layout, showing location direction and angle of elevation. (The contour-lines are contour-lines on the surface of a cone the point of which is formed by the centre of the window.) It is sufficient to place such a sheet with contour-lines on a site-plan also containing indications of altitude, and for every point of the plan it becomes evident which is higher, the neighbouring building or the sun.

For practical work in a planner's office the latter system is distinguished by the great advantage of giving a clear picture of the insolation of any window in the site-plan, without the necessity of drawing a single line! If measuring the hours of sunshine, a single sheet with the lines mentioned above will be sufficient. In case of the intensity of insolation reaching a point during the course of one day having to be measured, then a separate sheet is needed for every point of the compass, i.e. usually 10, at the most 12 sheets. The technician is used to working with contour-lines and the layman, even if not versed in reading maps, can, with the help of a diagram of contour-lines understand how the situation and height of surrounding buildings can effect the insolation of a house.

When it became necessary to find out the insolation of the race courses for skiers at the Winter Olympic Games 1964 in a mountain region with highly uneven surface, it was sufficient to put the contour-lines of the sunrays and the contour-lines of the map showing the area in order to find the exact time of sunrise and sunset for every point of the area. By practical experience I have come to the conclusion that I am obliged to give the following statement: The method of measuring insolation by the help of contour-lines has to be recommended as the most efficient for practical planning, especially for industrialised buildings.

Method of measuring insolation by help of a model. Another method might be also mentioned which shows insolation by help of a model. Such apparatus proves useful for special cases.

Which key-date has to be chosen? One question has to be answered: When has the insolation of a flat to be measured so that a characteristic value can be found? Is it useful to measure the amount of a years's insolation or to decide to measure the insolation on a given key-date? Specialists have agreed on a key-date which has to be chosen from the point of view that windows which do not get a certain minimum of insolation on that day have to be declared as insufficiently insolated.

This key-day was found by logical thinking. December 21st would be desirable for hygienic considerations, but it cannot be realised. March 21st on the other hand, cannot be justified, as it would mean dispensing with 6 months' sunshine—and whoever is ready to do without any insolation for 6 whole months can save himself the trouble of regulations. Therefore February 7th was chosen as a justifiable key-date and recommended unanimously by 4 specialists. A minimum of insolation being proved on February 7th, then there is only a three months' lack of sunshine in the worst case.

The minimum of insolation

What minimum amount of insolation has to be demanded for the key-day? One or two hours? Or about 200 or 300 kcal per square meter? At first such figures seemed to be chosen arbitrarily. But thorough consideration reveals that there is not much choice left. Therefore specialists have suggested to demand simply one hour's sunshine on February 7th as the minimum of sufficient insolation, well aware of the fact that this unit is not an exact measure. Moreover this minimum is so small that any architect or private builder would object to building his own house so poorly insolated.

The quality of a flat

Judging the insolation of a window does not yet mean judging the quality of insolation of the flat. Here too an arbitrary limit has to be erected. A flat can only be looked upon as sufficiently insolated, if at least the windows of one living room are sufficiently insolated; in case the flat has three or more living rooms at least two of them must have the minimum amount of insolation. This demand, too, is the absolute minimum of insolation that can be demanded for a flat.

Report on residential density based on the demands for insolation

In which way does insolation influence the residential density? Is it technically and economically possible to supply all flats with the minimum amount of insolation? Practical experience has proved that blocks of flats planned in order to fulfil this condition of a minimum amount of insolation already have a density which is greater than any density admissable for other reason. The need for open sites, parking areas and space for traffic between the buildings, generally forbids a great density. This fact, and the moderate minimum amount of insolation, might help to dispel many of the apprehensions which are still uttered against classifying a flat according to the quality of insolation, and against laws and regulations demanding a minimum of insolation.

Standardisation of flats according the quality of insolation

All that has been said up to now has been directed to classifying the quality of the insolation of a flat and to standardise this. In industrialised building such standardisation is indispensable. A technical journal has recently reported that such classification of insolation of a flat according to several degrees of quality is already practised in Sweden, undoubtedly owing to the most valuable research work done by Mr. Pleijel. As soon as the house market and the building industry will have realised the advantage of such standardisation,—i.e. the possibility to rationalise the sunshine—the way is free for enforcing by law (building regulation) a minimum of insolation.

Regulation by law

During the last years a team of specialists of the "Österr. Forschungsgesellschaft für den Wohnungsbau", in Vienna has prepared a draft of a model building regulation which already contains a separate paragraph demanding a minimum of insolation for a flat. The conferences lasted for more than three years as this very question caused great difficulties. On the one hand a research team basically has to prevent the planning, approbating and building of flats destined to be inhabitated successively by three generations, but not possessing those qualities which today are demanded by the majority of customers, i.e. flats which for these reasons will soon be looked upon as low quality products of our time that have to be renovated. On the other hand all persons and authorities responsible for planning, building and administration of flats are deeply impressed by the shortage of developed and developable building land and housing. Therefore they are anxiously opposed to adding a further difficulty to the already existing and very pressing ones, by accepting a law concerning insolation.

Public relations

This is a conflict between the foresight for the future ninety years, and the need of the present day. It is a conflict fought within a man's own heart, and its result depends on our ability and readiness to overcome the need of the day.

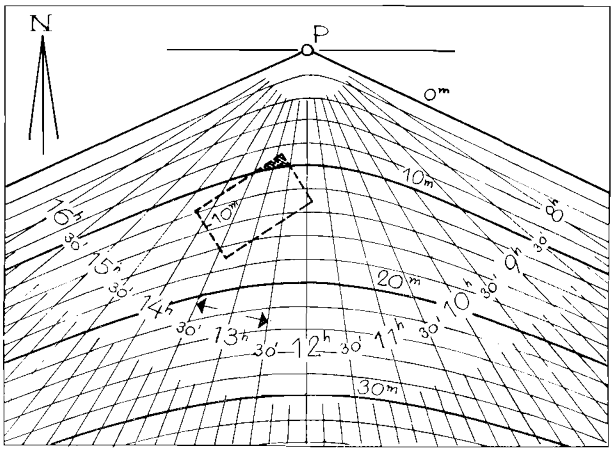

Fig 1. Contour—lines for measuring insolation. Layout of the sunrays reaching point "P" (ground plan of a certain window) on February 7 th in scale 1:1000. The inclination of the sunrays is given by contour—lines (10, 20, 30 m).

Place this diagram, directed to the north point on the layout of the building (scale 1:1000) in such way, that the point "P" of the diagram is placed on the ground plan of the window chosen for examination.

Then see which is higher: the neighbouring houses or the sunrays.

All parts of houses which are higher, cast shadow to "P". In our example, the neighbouring house is 10 meters high and casts shadow on P from 12.30 to 1.30 p.m. (12.30 - 13.30).

There are peoples able to provide storage for the future, and others that do not care. Their attitude is their fate. There are men caring for profit and there are pioneers. In order to plan for the future it is necessary to make the public realise this obligation. All latest methods of public relations have to be used to get the public interested in setting up and enforcing standards of quality of insolation and their regulation by law.

As mentioned before, a draft for such regulation has been worked out in Austria, and it is but a question of time before the opposition against it will be silenced.

Notes on the law

Exceptional and transitional regulations

First object of any regulation by law has to be new buildings in order to prevent for the future the construction of new flats which do not get a minimum of insolation. Laws have to help to given an account of the quality of insolation of any flat and to set up standards concerning insolation. At the same time it makes it possible to classify the quality of old flats regarding their need for renovation. Of course there might be cases, where it is impossible to fulfil the conditions of a minimum of insolation, owing to a peculiar shape of the land or other circumstances of the site or perhaps reasons of protection of historical monuments. In such cases well-aimed regulations for exception are inevitable.

The aim: measuring of intensity

If we aim at industrialised building, we shall not be content with measuring the hours of insolation as proposed by many experts and also used by "Österreichische Forschungsgesellschaft für den Wohnungsbau" for the model building regulation, mentioned above. But the only real measure of the value is given by measuring the intensity. In this way the architect has to decide at what time of the day he wishes to have the sun in the flat. It seems more reasonable to regulate by law the physical energy and to lay the psychological ones in the hands of the architect—i.e. the question of morning or evening sun,—than to demand a measure for the time of insolation and leave to the architect's ability, whether he makes good use of sun energy or not. As soon as people estimate the energetic and caloric value of insolation, the additional trouble, caused by measuring will not be thought unbearable. In this case—when applying the method of contour-lines—several diagrams are needed instead of only one. But what does this small demand mean to the technician in comparison to the amount of work needed for calculating statics, heating and for many other branches of engineering! It is well known to all of us that people are ready to put up with even the most complicated research work if the value of their results is acknowledged.

Conclusions. All demands of climatology have to pay attention to the economy and the physical disposition and therefore to keep an eye on commercial methods on the one hand and to use the methods of public relations on the other.

Measuring of insolation of buildings has to be internationally standardised according to one single method or to several methods.

International standards of the quality of a flat concerning its insolation are to be agreed upon.

A recommendation to the lawmaker is necessary in order to regulate the insolation of a flat.

Dwelling value appraisal

By C. Noel (France)

In general, the term "value" as applied to any product covers two distinct notions, one of them relating to the price of the product and the other relating to its utilization. This applies also to housing; any method of estimating the value of a housing unit must enable us to judge whether the price is too high or not, and the extent to which it possesses the characteristics demanded of a housing unit in order that it may fulfil its purpose. The French "Centre Scientifique et Technique du Bâtiment" (C.S.T.B.) has developed a method which meets this double objective. A succinct explanation is given below of the aims of this method, its principles, its applications, the information that can be drawn from it, and the reasons for its adoption.

The existence of a problem of quality

In France, as we know, the construction of State and Municipal housing (known as H.L.M.) conforms to three imperatives:

– *a maximum price*, varying according to the number of habitable rooms;

– *a minimum quantitative and qualitative consistency* of the materials and components employed, laid down by the "Cahier des Prescriptions Techniques et Fonctionnelles Minimales Unifiées" (C.P.T.F.M.U.).

– *a scale of surface areas*, depending on the number of rooms.

The application of these three conditions leads to the construction of housing units of very different characters, depending on the way in which the clients, architects and builders take advantage of the latitude allowed to them.

In point of fact, the application of the first of these conditions – maximum price – almost always results in prices very near, or equal to, the ceiling price.

On the other hand, the relative proportioning of the two other conditions varies considerably according to the preferences and requirements of users; some clients place greater importance on large surface area than on the quality of certain materials, or vice versa. Understandably, it is difficult for anyone not conversant with the subject to judge the equivalence of the finished products, covered by the same terminology.

The C.S.T.B. method aims to remove these difficulties by providing those concerned, especially the public authorities subsidising the work and clients, with a quick and convenient way of knowing the value of what they are getting. This value is expressed in Francs whenever possible, and in terms of degree of quality in respect of other aspects which are difficult to express in terms of figures, notably because of their totally or partially subjective character.

The method

The method involves a number of dispositions which are briefly explained below.

Nature of housing units to which the method applies

The method is applicable to all categories of housing units, collective or individual, which are in habitable condition; it does not involve any corrective measures relating to their conditions of building (volume of operations, date of completion, geographical location), their design (layout of accommodation unit, height of buildings, means of access, etc.) or the techniques used in building them. But these various factors are taken into account when the results are classified, as will be explained later under the heading "information derived".

Limitation to certain aspects of price and quality

The quality of a housing unit is a general term covering many aspects of the same problem. It would be more logical to speak of "qualities" in the plural, since each human demand presupposes a distinct quality. Thus we may make a distinction between the qualities of heat insulation, acoustics, lighting, ambience, design, durability, ease of maintenance, suitability for family life, and so on.

The present state of our knowledge in certain fields (such as ambience and durability) on the one hand, and the subjective nature of certain aspects of quality (e.g. design) on the other hand, prevent us making an exhaustive examination of the problem. For this reason the C.S.T.B. has confined itself, for the time being, to four main aspects:

1) *The value (expressed in Francs) of non-structural components, finishes and fittings*, by which are meant all objects and surfaces which an occupier can "see, touch or manoeuver", in a finished housing unit. Such objects and surfaces altogether account for 55% of the price of a collective housing unit. It may be noted that we are concerned here only with the value of these items, and not with the quality of their manufacture or execution.

2) *The value (expressed in Francs) of floor areas.* A housing unit may be subdivided into:

– the main premises (main rooms and services);

– accessory premises (loggias, balconies, annexes).

More accurately, we take into account only the areas in excess of the area of a standard housing unit (defined below), in accordance with a scale worked out by the C.S.T.B. on the basis of the price per square metre additional to a standard reference area S_0, in the light of constructional value.

The price per additional square metre includes all the materials and services necessary for the additional area, and amounts to about 18,000 Francs (January 1st. 1959).

The qualities themselves have been reduced to two:

3) *The acoustic quality* of certain structural elements such as floors, party walls and floor coverings. This aspect of quality is expressed with reference to minimum standards of quality laid down by C.P.T.F.M.U. regulations.

4) *The thermal quality* of the housing unit as a whole, which involves the overall volumetric heat loss coefficient of certain structural elements such as façades, bearing walls, gable ends, roofs, loggia walls, exposed floors, etc. There is a special notation for protection against sunshine in summer, and other hot-weather precautions.

It will be noted that in reality the price level often coincides with the level of quality, at least for certain aspects such as durability and design. This applies particularly to non-structural components, finishes and fittings, whose price-level fairly accurately reflects the main qualities demanded of these items.

Determination of a reference housing unit

Each housing unit tested (or the average unit in the case of an operation comprising several units) is compared, in all the respects listed above, with a reference unit whose characteristics are defined once and for all as follows:

– *the number of rooms* is fixed at 4, this being the average to which homes are tending in France.

– *the habitable area* is 61 square metres, the minimum area permissible for a 4-room housing unit without balconies or loggias.

– *the qualitative consistency* of non-structural components, finishes and fittings is fixed on a basis slightly higher than the minimum permitted by the C.P.T.F.M.U. for fittings, and on specially worked out flat-rate bases for partition wall surfaces.

– *the quality of elements relating to acoustic and thermal characteristics* is based on minima laid down by building regulations in France.

– *unit prices of reference* are selected from the price scale (see below) on a basis of quality slightly higher than the minimum permitted by the C.P.T.F.M.U.

Determination of the representative housing unit of the operation to be tested

We shall consider that the operation is fairly characterized by a housing unit possessing the following features:

Number of rooms: 4 (same as reference unit).

Area: the area of the reference unit, plus:

– the excess area, broken down pro rata by the number and amounts of excess areas in each category;

– the area of loggias, balconies and annexes.

Quantitative consistency of non-structural components, finishes and fittings:

- fittings: real consistency.
- partition walls: consistency identical to that of the reference unit.

Qualitative consistency of non-structural components, finishes and fittings: real consistency.

Unit prices: on price-scale corresponding to the real nature of the work.

Application of a fixed price-scale

This scale of prices was established once and for all on January 1st. 1959. It includes a number of prices which differ according to their nature. These prices are laid down in the light of average conditions, intermediate between highly industrialized methods and hand craftsmanship. The scale is added to, as and when necessary, by inserting the items lacking.

The scale does not include very expensive work; should such work be carried out, the maximum prices on the scale will be applied.

Method of application

The method consists of comparing the price of the reference housing unit with the price of the typical 4-room unit of the operation being tested. This comparison reveals a difference, plus or minus, which characterizes the value of the areas, non-structural components, finishes and fittings. The acoustic and thermal qualities are expressed in notes, the appreciation of which is left to the judgement of those concerned.

Field of application

Since its introduction 3 years ago the method has been applied to various State and Municipal housing projects, whose breakdown is as follows:

a posteriori	140 H.L.M. projects (collective)
(in the past 3 years)	25 H.L.M. projects (collective) 3-year plan 25 individual housing projects.
a priori (in the past 2 years)	all projects (total 130) in the H.L.M. 3-year plan.

Moreover, the method is to be applied on a wider scale to the construction of individual houses subject to approval by the "Commission Nationale des Plans-Types". For H.L.M. projects alone, the sample covered represents about one seventh of all housing units built in France.

Information derived from the application of the method

As stated above, the method comprises no corrective measures making it possible to take account of certain parameters such as:

- conditions of building (dates, locations, volume of operations, nature of contracts, etc.);
- the design of the project (plans, depth and height of buildings, means of access);
- the techniques employed (prefabrication, mechanisation, rationalisation, etc.).

But the classing of results in accordance with these various parameters gives valuable indications as to their influence; for example, we may in particular follow, relatively easily, the evolution of the situation in a given region or on the national level.

On the international level, this method -or a method derived from it—can prove extremely valuable in comparing costs equitably, taking into account the fact that disparities in surface areas and descriptive methods are much greater than they are within one country. In particular, we may use our method to bring out differences in price and quality in relation to a suitably chosen reference housing unit valid for all countries.

Conclusion. The method described above does not claim to be perfect, notably because of the many qualitative aspects it neglects. But, as it stands, it has provided valuable information which even at this stage makes it possible to detect good and mediocre building work; without it, the latter might well have merged into the general picture and remained undetected.

Used a priori, it enables modifications to be made to projects that reveal inadequacies, particularly in respect of insulation, and such modifications have considerably improved conditions of habitability.

The method would seem to lend itself to interesting developments on the international level at a time when the equitable comparison of building costs in different countries is a matter of increasing concern.

H 15

C. Rambert

Man and the large machined unit

The architect's position

By C. Rambert (France)

War-time destruction, lack of maintenance of buildings during and immediately after the war, growth of population over the last five years, budgetary difficulties have been the cause of the critical housing situation we are now facing in Europe. A solution has been proposed: industrialised building for quicker and cheaper construction, and for housing a maximum of people in a minimum of time.

How will man react to a machined housing unit? What exactly will the architect's part be in the industrialisation which will have made feasible the building of such a unit?

The best introduction to this discussion I can think of is to quote the well-known British art critic and sociologist, Ruskin: "We expect buildings, like maids, to display two qualities: first they should do their job and, secondly, they should, in so doing, be pleasing and graceful, which is a form of beauty".

Modern man's new attitude and expectations

Quick building, mechanical means

Those who were born during the war are now twenty five. They set up a home. It is the people of their generation who are the most interested in modern town planning, architecture and housing.

The man born during the 1940–1945 war is attracted by the speed with which work is completed and, therefore, takes an interest in mechanical means of achieving this speed. As a child he admired the war material that gave us victory. This material has been changed into building site material.

Look at a site where earthwork is going on, using powerful excavators, and see the number of saunterers gaping at the machines at work. Building site and public works material impress and satisfy people just as war material did. So the coming generation will begin to require more powerful material.

The housing problem

Housing demand is enormous. In France, annual requirements have risen from 250,000 dwellings in 1955 to 400,000 in 1965. This figure should be taken as a minimum. If the building rate to be kept up till 1985 is not maintained, the housing shortage will ever get worse.

People born during the war, who have now reached the age to set up a home, wish to find a dwelling and are therefore in a hurry to have one. But it is not proving possible to cope even with all priorities. What then can be done about it?

Town planning to-day

Those who aspire to find a home can be but impressed by new building designs achieved as a result of the development of town planning. These have done away with dark courtyards, with houses crammed against each other and their hateful subserviencies. A modern building stands on its own ground, in a green area. In other words, it provides a decent view. There are no more inner courtyards because the higher a building, the more nonsensical the courtyard. Street traffic is at a distance from the location of the building. The site provides playground facilities for children. The housing unit has come into being.

If people looking for a home have to compare the nineteenth century living quarters with the housing unit, they will inevitably prefer the latter.

Smaller dwelling area

Whereas the surrounding area, the so-called "green area" has been adequately developed, on the other hand the habitable area has, since the turn of the century, registered considerable reduction. However, in France, from strict minima the cheap dwelling habitable area has been increased for turning to better account and to make for more rational living conditions.

Man to-day will accept a relatively small habitable area, that is without unnecessary corridors, as long as he can have well-balanced, properly ventilated, sun-exposed, reasonably comfortable rooms, as long as he enjoys the necessary privacy vis à vis annoying neighbours, and has his share of green and his parking space. As a matter of fact, modern furniture, rational as it is, has been partly instrumental in the evolution of the size of flats nowadays; the old family furniture, which was so cumbersome, has almost entirely disappeared. The war took care of that or its unattractive appearance has driven it into sale-rooms or the stores of dealers in old furniture.

Outside walls with large glass windows

As buildings stand detached in a green area, and are mostly high, flats enjoy a view they were deprived of in nineteenth century urban mansions; whence the panoramic-view idea. Moreover, since their shape has evolved from a vertical to a horizontal rectangle, glass windows have become a very important feature in façade design.

People to-day therefore accept that rooms have large glass windows, because they need no longer shrink into their flats away from the sight of the ugly surrounding district. On the contrary, people wish to enjoy the open view and have their share of nature.

The co-owner or tenant's disappointment

The growing population

As a set-of to the enthusiasm of the would-be flat occupant or successful flat-hunter, one should consider the disappointed family man and, particularly, the disappointed mother of an already large family. Indeed, what seemed big for the new occupant with expectations, quickly proves too small. As a matter of fact, the family grows rapidly and the size of the flat is no longer adequate. Whereas plans may have been made for extensions to individual houses, this is out of the question for housing units.

Changes in buildings are then difficult because, if there is a majority of three- to four-roomed flats, those with five rooms are quite uncommon. So the search for a larger flat becomes quite a problem.

Finishing

Heavy industrialisation makes for the speedy production of simple structures but it comes up against the finishing problem. Here we have buildings without plastering; partition-walls and floors are particularly thin, and there is a minimum of decoration. On the other hand, there is the necessity to build quickly, very quickly, and this precludes all lengthy and carefully done finishing work. There is no question of fiddling over the job. The incoming occupant of a new place, which has a good exposure, a nice view, and sanitary comfort not found in old houses, does not pay much attention to finishing. But, having settled down, the occupant will inevitably examine closely any cracks, or want of paint or looseness in woodwork.

Thickness of floors and partitions, pipework: We have already mentioned thin partition-walls. Floors are necessarily thin in accordance with the minimum requirements of building regulations. The idea is to reduce structural weight (industrialised component parts have to come on lorries). The bulk of building components having thus been reduced, there is always the risk that such reduction may be detrimental to sound and heat insulation.

The minimum value for the K factor in heat insulation according to French law governing building is now supplemented with the requirement that builders abide by definite sound insulation standards.

Obviously there can be no question of having walls so thin that there is a risk of heat transmission, or floors and dividing walls between flats so thin that this results in sound transmission, which is harmful to occupants' moral and physical health.

Consequently, industrialisation is only acceptable inasmuch as it takes care of these two requirements.

Industrialisation leads to centralising pipework; this has a bearing on design. Too much concentration, particularly in large flats, may result in functional defects. There are now a lot of industrialised buildings and we are aware of the blame usually attending to most of these structures. Such blame refers to:

Inadequate quality of materials: Builders tend to make use of materials of inferior quality on a plea of saving, i.e. maximum prices, speedy completion of building work, relative lasting qualities of buildings since French law provides that dwellings shall be designed to last at least 50 years.

Building regulations require ordinary walls to be at least 20 cm thick. In other words a hollow brick or a cement parpen of this thickness will do with, on each side, a very thin coating. Now, it is well known that a cement parpen is not worth a baked-clay brick and that workmen do not care much about bricks and parpens; many are laid that are broken. The same applies to rough floor masonry, whence unavoidable heat exchanges.

Besides, it is my opinion that a coat of cement painted over is not sufficient as an exterior facing. One need only see the present state of buildings in the Paris area that were given this treatment 10 years ago.

As for carpentry, this is quite unsatisfactory and we should acknowledge our admiration for Danish standards in this respect. Wood sections are too small, oak is of inferior quality and wood is usually not dry enough.

Very many other examples could thus be given, relative both to main walls and foundations, and to equipment and plumbing for instance.

Inadequate sound insulation: This inadequacy is so notorious that recent regulations require minimum insulation. It is well known that acoustic and thermal insulation in a building accounts for only 2 to 4% of total structural cost (4% if the building is equipped with double glass-panes). I feel that human comfort is worth this additional expense, quickly written off.

But it is a fact that in quite a number of recent building projects dividing walls (15 cm only in thickness) between flats were nominal, that partitions between rooms were not strong enough. Some buildings had 4 cm thick partitions. If ever one of the occupants drove nails into this 4 cm thick partition, the result spoke for itself. The way they were built, stairs were often but a sound-box, that is to say, reinforced concrete sections, steps made of granite or stoneware with no application of absorbant materials such as Heraklite, for instance, which is popular in Scandinavian countries.

Working of garbage shoots: This refers to gravitation garbage shoots; the noise made by tins or oyster shells can be heard on every floor. If it is possible to insulate water and heating pipes, there is no reason why it should not be possible to insulate this other kind of piping too. The sum of all these factors making for sound transmission and amplification can but prove irritating for modern human beings, whose nerves are particularly sensitive.

Inadequate thickness of external walls: This is mostly a matter of aspect. As a matter of fact, too thin a wall means a high K factor or heat transmission at the joints. We have all seen inside rooms, mostly in the case of gable walls, with the outline of masonry showing through the coating and paint as a result of condensation produced by such deficient walls.

As a remedy, curtain walls are recommended. Their thinness is made up for by a high degree of insulation, provided however that panel joints are carefully designed to prevent heat transmission. But there are as yet few instances only of this building technique, and these are in fact linked with cost price.

Fixing problems: There are not often available to the Frenchman fully equipped constructions like those first-rate buildings in the suburbs of Stockholm. A Frenchman likes to handle a hammer and a screw-driver. He enjoys fitting things up himself in his home. It is not long before a feeling of disappointment overtakes him when he finds himself facing reinforced concrete surfaces and solid floor slabs, with inherent difficulties in installing household appliances, fixing furniture, curtain-rods, lights. And this is liable to cause a bit of domestic trouble...

Man before large built-up centres

Erecting high buildings: A recent census of opinion revealed that over 70% of the French population preferred individual houses to collective housing units. Industrialised solutions for constructing individual houses could then be considered, but this idea is in conflict with the inclination of every family to personification. Each family wishes to distinguish itself from and to do better than its neighbour, whereas the occupant of a flat will only want to give his own home a personality, as he will not be in a position to do anything about the front walls and common parts of the building. In France high buildings are considered as inhuman and as not being a family proposition. By high buildings are meant those more than ten-storey high. On the other hand, a medium solution, 4 to 5 stories above ground floor meets with much favour (especially five floors as then the building will by law be equipped with a lift).

Structural fragility: Modern man is concerned about structural fragility just as he is not happy about the extreme reduction of car-bodies. There have been cases of light roofs being blown off, false ceilings of school buildings falling in; a large building, in course of construction, collapsed in Paris.

Such fragility seems still worse in school buildings, where urgency was the foremost consideration in planning to accommodate all the children. If there is a housing problem, there is practically no school building problem. Of course, class-rooms are too full (there is also an important shortage of teachers) but the children are not left out in the street.

It has been necessary to build many temporary school premises which generally were factory-produced.

Human concentration: Man to-day is afraid of human concentration with its implications (supplies, school age, occupations for youngsters). It is possible and advisable to build new housing estates, provided suitable density is kept to. Examples come to us from Northern Europe (Tapiola, Farsta). Piling up buildings on ridiculously narrow land just outside capital cities should be avoided.

The urban estate: This involves building integrated housing estates, that are complete with an adequate shopping centre, primary and even secondary and technical schools, a social centre, restaurants etc. There again I would like to give Farsta as a very good example; despite the proximity of the Swedish capital, the estate is an active unit as care has been taken to provide local employment. The 1965 man will not have dormitory-estates.

Cars and the housing estate: Man to-day also demands that motor traffic be avoided in the commercial centre and in the green area which dwellings share in common. There are quite a number of cases where the separation of pedestrians from cars is effective, but most cases are isolated ones. There is need for generalisation that would spare mothers trembling with fear when children are sent to school.

In Venice one is surprised at being able to walk about without meeting a car. Back in the country, in Verona's streets without pavements, one then perceives that a car is a trespasser.

The architect before large built-up centres

The bulk design: A large built-up centre involves a bulk design. Such bulk design, the work of an architect, presents a suitable balance of structures and their approaches, since the design is *composite*.

Composition of bulk-design elements: Such being the case, it is a matter of course that all the elements of the bulk design are themselves composite, that is to say, each building, its façades and architectural detail are all planned.

Standardisation: As this is a repetitive scheme, that is the repetition of similar buildings, dwelling units, windows, it is essential that all components are standardised. It is indeed amazing how builders and manufacturers have scattered their efforts. There is a countless number of window models and sizes with builder's merchants. Obviously we must aim at Europeanising door, window and frame measurements.

In a recent visit to window manufacturers in Trevisa and Casteggio in N. Italy we found that it was perfectly possible to produce quickly and efficiently good-quality fully-equipped windows including solar protective devices. Feeling the pulse of a buyer's market the Italian firms have consequently considerably increased their manufacturing capacity.

Reduced standard surface measurements: It is also possible to have a satisfactory standardisation of building components. But this attempt at simplification and efficiency should not give rise to too strict standards. It is a good thing to try for economy in manufacture by mass production that will allow to write off quickly the investment cost of material, but it is not a wise thing to try and save on surfaces.

The architect is opposed to too strict surface measurement standards that no longer allow the design of a functional, and just simply decent, dwelling. It is, for instance a mistake to save on an entrance-door to a flat, thus inviting intrusion into family life in the home.

Furthermore, too narrow rooms (2.40 m and even less) are unsatisfactory as they are practically impossible to live in. It is not possible to go below the limits set hitherto. On the contrary, one should aim at a more human size of rooms, starting from which all manner of prefabrication will be permissible. Thus Citroën designed its "deux chevaux" as a car with the lowest running cost. Nevertheless, from year to year, Citroën introduces improvements which do not impede chain production.

Closed prefabrication

This refers to industrialised dwellings or schools where the architect will not come in at the designing stage. This has led to talking of "open prefabrication" and "closed prefabrication".

The former system consists in organising industrial chain prefabrication of components, the application of which will then just be provided for in designing (façades and floor panels, distribution system component parts etc.).

The latter system consists in prefabricating all that goes into an integrated building unit. Such components are then available to builders —say in the form of price-lists— and they are delivered to the building site for assembling.

It is a matter of course that the latter procedure cuts out the architect. The "Conseil Supérieur de l'Ordre des Architectes Français", in favour of open prefabrication, has flatly rejected the closed-prefabrication method, stating, (in a widely-published memorandum) its reasons as follows;

– because closed prefabrication will no doubt force builders to make a selection from an architectural catalogue among a restricted number of methods;

– because each such method, among a restricted number, will have required the service of one architect only;

– because this one and only architect would to some degree practically be involved in building work worth millions, that would, consequently, be lost to his colleagues, particularly the country ones;

– because the architect would become a mere blue-print producer.

Conclusion. Industrialisation is advisable provided:

– that due consideration is given to human needs by keeping to a reasonable building density, by a decent balance between high and low structures, by providing large space for a natural environment (provision for plant-decorated terraces and flowered balconies);

– that comfort developes at the same time as improvement in social conditions; this demands flexibility in—too strict—standards;

– that standards and regulations are adhered to in order to avoid chaos in building; these should however be complied with by following out the spirit of their requirements rather than as border-line minimum specifications;

– that the services of an architect are provided for irrespective of the selected building solution. A large built-up centre requires composition. It should therefore be planned by a designer who has had an academic education and has thus acquired a creative sense, both in regard to ground-plan and to façade;

– that such a man preserves his creative ability by adjusting industrial production to his own views, within the framework of dimensional standardisation;

– that excessive saving is presented so that materials remain presentable and sufficiently strong, particularly floor and wall covering, interior coating and equipment, because homes, like schools, should remain architectural productions.

Indeed William Kickling Prescott made this quite clear: "The best yard-stick for estimating a country's civilisation in respect of mechanical accomplishments is architecture. This allows a very noble expression of grandeur and beauty, while being closely related to essential living comfort".

Weather data for the building trade

By R. Reidat (West Germany)

It is the task of the building industry to create spaces that enable man to live and work comfortably, in good health and under the ever changing weather conditions. To achieve this goal, all positive atmospheric influences should be used to full advantage and all negative factors barred as far as possible. A thorough knowledge of local climatic conditions is therefore indispensable for the proper utilization of the technical means where planning, execution and general care of the building are concerned.

Measurements taken jointly by architects, engineers and meteorologists have resulted in a better insight into the influence of atmospheric conditions on the climate inside a house. With this in mind, the meteorological services have the task of presenting the meteorological data which have been collected over the years in such a manner that architects and constructional engineers may derive benefit from them. In this connection the following facts should be borne in mind:

Average and extreme values may be used to characterize different climates but they are no physical constants which can be used as a sound basis in building construction calculations.

The weather is a complex entity. The various factors making up the weather are closely intertwined and hard to separate. If the windows and doors are opened to benefit from one particular weather factor and its positive effect on the indoor climate, undesirable weather elements will also get into the house.

The house is exposed on all sides to the weather from which it is supposed to offer protection.

The individual weather factors show, in their attack on the house, a more or less pronounced directional preference which makes it necessary to take different measures for protecting the walls.

The location may highly influence the action of individual weather factors. Therefore, in addition to the intertwining of the various factors and their directional effect, the "micro-climatic conditions" must also be considered. This realization led to the compilation—for use by architects and engineers—of a report on the climatic conditions in Hamburg ("Hamburger Wetterdaten für das Bauwesen" Einzelveröffentlichungen des Seewetteramtes Nos. 23 and 24). These publications show average and extreme values and spread of various weather factors in the form of graphs and figures, together with the directional effect and sun exposure graphs which show the extent to which the individual walls are exposed to the sun in winter and summer. The temperature diagrams show the heat load on the walls. The wind diagrams show how often winds of 3 Beaufort or more and 6 Beaufort or more hit the walls at right angles or at another angle. The rainfall diagram shows the frequency of light and heavy rain (heavy rain = rain with wind velocity 5 Baeufort or more) which may be expected from different directions. A simplified diagram shows the combined effect of these four weather factors.

These data give only a rough and general impression of the climate of a given location. Often this is not sufficient to meet the requirements of the modern building industry. Exhaustive discussions between engineers and meteorologists have led to attempts being made to reconcile the wishes of the former and possibilities of the latter category so as to arrive at a suitable basis for further investigations.

Briefly, some of these results are:

Special problems require a more detailed study of the frequency distribution of the meteorological elements. The data may be given in the form of tables or in the form of graphs as shown in Fig. 1 for temperature. These frequency values may then be used for compiling data on the climatic conditions inside a building, see Fig. 2.

From the temperature frequencies and the heat transfer values (K-values) of various building materials we can derive frequencies of the surface temperatures of outer walls, normal and storm windows at inside temperature of 20 °C (= 68 °F).

When the room air is heated, or cooled, the absolute humidity remains unchanged as long as the temperature does not fall below the dew point. Knowing the distribution of the vapour pressure present in Hamburg in winter, it is simple to draw the diagram shown in Fig. 3. It illustrates how often in Hamburg during the six winter months water vapour must be added to, or removed, from the air in different air-conditioned living rooms, working and storage areas in order not to exceed, or fall below, certain limits of relative humidity (e.g. 35%–75% for comfort).

Taking into account the diurnal variation of the meteorological elements, the availability of the frequency distribution for 3 or 4 periods enables us to draw the frequency distribution curve for the whole day. Fig 4 shows a diagram of equivalent temperatures obtained in this manner. In contrast to the saturation temperature (= the temperature of saturated air having the same heat content as the moist air), the equivalent temperature (= the temperature of dry air having the same heat content as the moist air) can be easily calculated from the temperature and dew point.

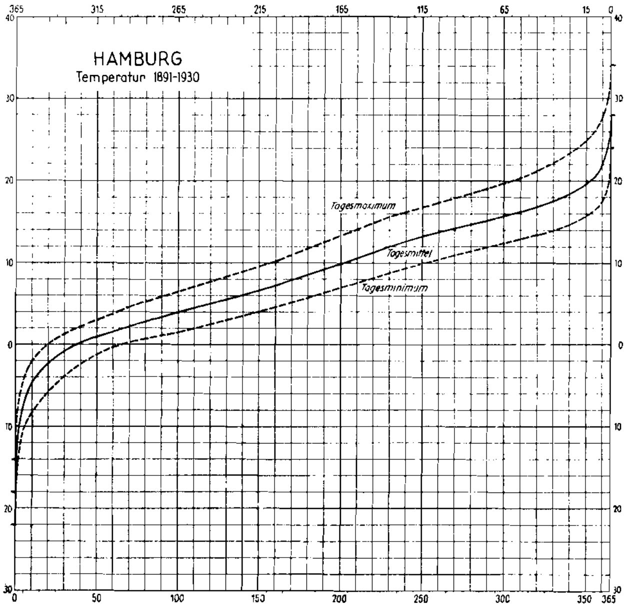

Fig. 1. Cumulative frequency curve of the air temperature in Hamburg.

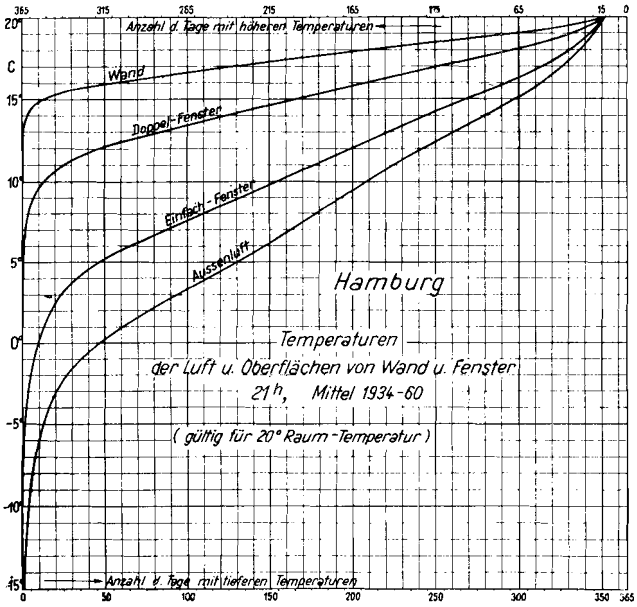

Fig. 2. Cumulative frequence curve of the surface temperatures of walls and windows at an ambient temperature of 20 °C (= 68 °F).

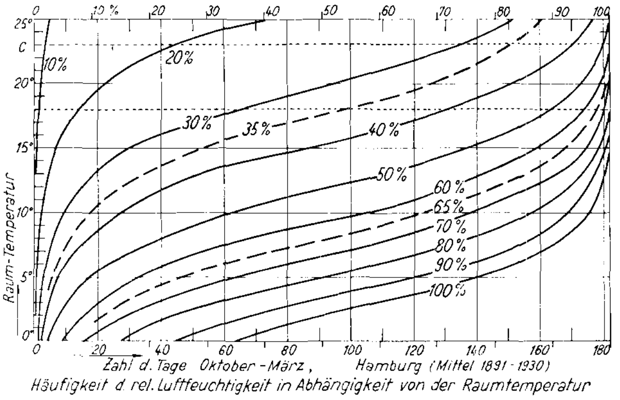

Fig. 3. Frequency distribution of the relative atmospheric humidity during the six winter months when heating and cooling the relevant area without changing the absolute humidity.

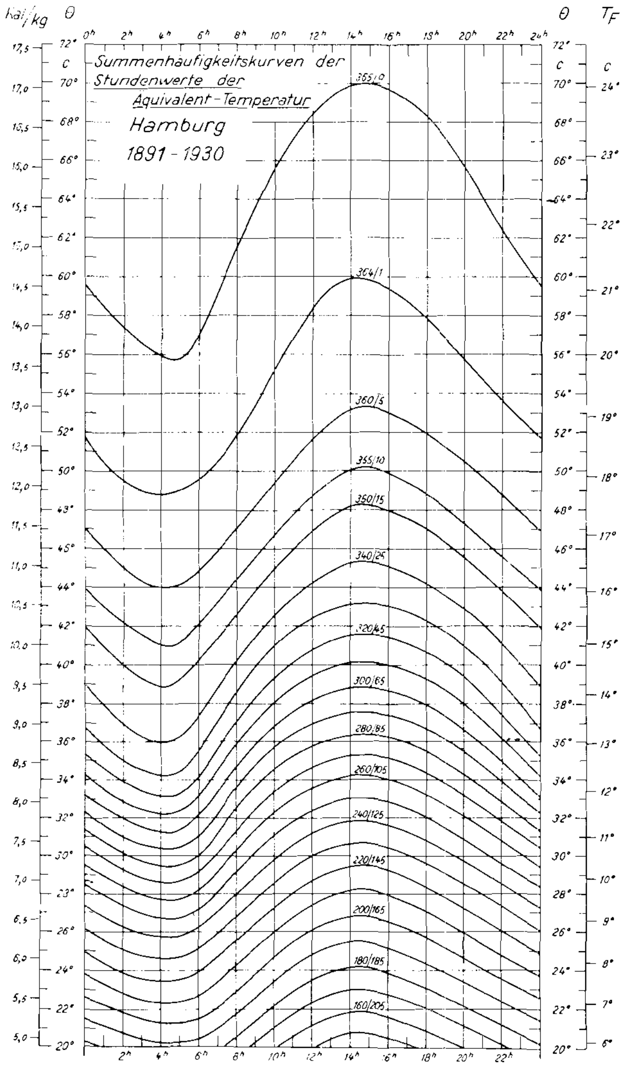

Fig. 4. Cumulative frequence curve of the hourly values of the equivalent temperature, the humidity temperature and the enthalpy.

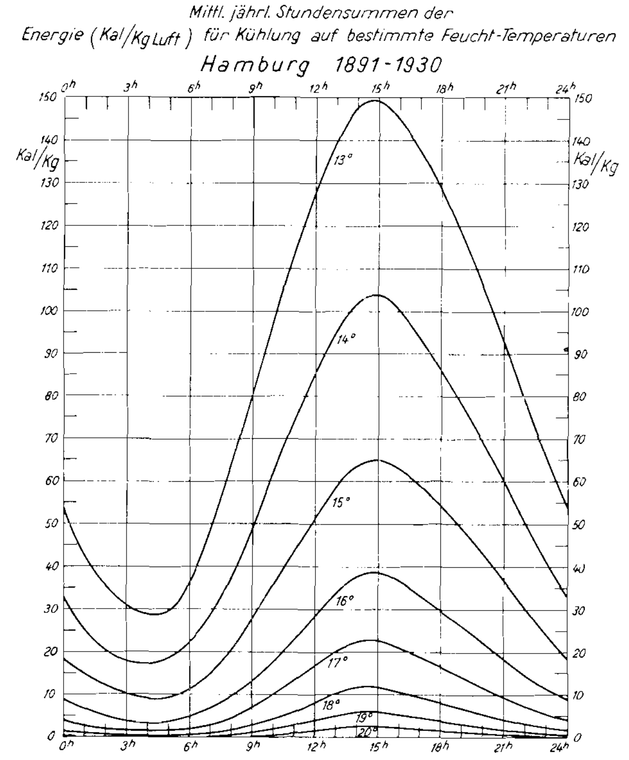

Fig. 5. Daily curve of the cooling load (cal/kg of air) in Hamburg.

Multiplied by $c_p = 0.24$, the equivalent temperature yields the enthalpy. Two additional scales, one for saturation temperature and one for enthalpy, also allow the frequency distributions for these quantities to be read-off from the chart. Using the hour frequencies of the equivalent temperature, it was possible to calculate the average cooling loads for the various hours of the day independent of the saturation temperature – see Fig. 5.

From the above it will be clear how the abundant meteorological data available anywhere can be utilized to the advantage of architects and engineers in close cooperation with meteorologists.

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An appraisal of the environmental design of post-war primary schools in Britain

By Mrs. J. A. Marsh and Miss S. M. Taylor (U.K.)

The Pilkington Research Unit was established in 1959 to undertake an investigation into the design of roofs of single-storey factories with special emphasis on the economics of daylighting. After the completion of this project, which was carried out by an architect with the assistance of a geographer and various professional consultants, the unit received additional financial support in order to engage upon further environmental studies. To broaden the unit's scope, a physicist and psychologist joined it in 1962. The unit's long-term aim is to establish the interaction and interdependence of the many factors which together comprise the "total environment" within buildings. The research, so far, has been based on building types—factories, offices and, most recently, schools. The advantages of this method of approach have been discussed in a paper delivered at this Congress by Mr. P. Manning[1].

Schools were chosen as the basis for further environmental studies for several reasons, but mainly because this building type has constituted a considerable part of Britain's post-war building programme and earned a high reputation for its standards of architecture and economy of design. There have been, however, no independent and impartial assessments of these buildings. It was originally assumed that, in an investigation of school buildings, the research would be concentrated upon the most typical space, the classroom. After discussion with members of the Architects and Building Branch of the Department of Education and Science, it was decided to attempt the assessment of the environment of complete schools rather than their individual classrooms. Because of the problem involved in such an approach, the study has been based on primary schools, which is the smallest type of school.

The preliminary stage of the schools project was to learn something of the building type, of any limits which constrain design and of any problems which may influence environment; then to determine the whole available sample of buildings and its principal characteristics in order to choose representative buildings for the study.

A sample of twenty post-war primary schools was drawn from one local authority to give a picture of the different types of schools and representation of the following variables: ownership (county primary or church); size (one, two or three form entry); architect (local authority or private); date of construction (between 1948 and 1960); district (city centre, inner suburb, outer suburb); age group (infants, 5 to 7 years; juniors, 8 to 11 years; or juniors and infants, 5 to 11 years).

Qualitatively, most of these schools were very different from those described in the architectural press and in official publications, in spite of the fact that all primary schools are designed and built within the same framework—i.e., they are intended for the education of children between the ages of five and eleven, have to conform to the national school building regulations, and are built within the same cost limits. Many seemed relatively undistinguished, lacked colour, sparkle and vitality and there was little evidence of their design developing and improving with time.

One of the reasons for the lack of progress in the design of these schools was thought to be the absence of contact between the teachers and architects, and it was considered that an enquiry into user requirements and the way in which these were communicated to designers would be useful.

Because the unit's resources were insufficient to undertake a survey of a large number of schools and also because the useful information which could be obtained from a large number of mediocre schools might be small, it was decided to restrict future work to a sample of nineteen schools selected by the Department of Education and Science for inclusion in one of its Building Bulletins (2), and thirteen other schools which had also been recommended. The possibility of confining this study, like the factory project, to the north-western area of Britain, was rejected on the grounds that the ranges of building techniques and design approach might be limited.

User requirements and channels of communication to the architect

The unit has made contacts with primary school teachers in the north-western area of Britain. In addition to informal discussions with teachers during the initial stages of the study, more formal meetings have been held with a branch of the National Union of Teachers, diploma students in a University Institute of Education, and student teachers at two Training Colleges. Each group was introduced to the unit's work by a short illustrated lecture on environmental aspects of the design of primary schools, which provided a basis for general discussion. About a dozen teachers from a branch of the National Union of Teachers have attended a continuing series of evening meetings. The teachers were asked to indicate the relative priorities of their requirements for a primary school building, and to outline the activities that take place in primary schools.

Top priority was given to the need for larger floor areas in classrooms and ample provision for storage and display. Opinions differed on the optimum shape of the classroom, whether, for educational reasons, a rectangle would be preferred to a room with alcoves, but it was finally agreed that the amount of floor space was more important than the actual shape. There was some controversy about the provision of "special" rooms for art and science in primary schools, but the majority opinion was that at the primary stage of children's education such specialised spaces were not essential and the classroom should be designed as a "workshop", suitable for a wide range of activities. However, the need was felt for some smaller spaces for special remedial or advanced classes. Other items (such as sinks, power and radio points, adequate pinboard and storage in each room) are not provided in all post-war schools in spite of their being basic essentials which have been officially recommended ever since the war. The teachers in the group expressed a dislike of plans that have either long corridors or circulation through the hall; they also deplored the use of the hall for dining. Similar points of view were expressed by the groups of experienced teachers studying for a University Diploma in Education.

Further seminars have been held with two groups of students at Teacher Training Colleges. The first seminars were held shortly before the students commenced their teaching practice. They were asked to provide certain information about the age, design and environmental characteristics of the school at which their teaching practice was done; to write a short essay on the influence of the school environment on their teaching; and to draw a rough plan of their "ideal" classroom. The students were met shortly after their teaching practice to discuss their essays and their general reactions to the schools in which they had been teaching.

Most of the students who had done their teaching practice in post-war primary schools found them pleasant to teach in and the facilities adequate for the needs of teaching. However, a number of features which they thought could have a detrimental effect on the morale of both teachers and children were pointed out: these included poor staff accommodation, insufficient toilets and cloakroom space. Many requirements for school design were mentioned which had previously been stated by the other groups of teachers.

A few of the students had taught in pre-war schools and found that happy, purposeful atmospheres prevailed in them despite cramped, badly lit and inhibiting buildings. They believed that this was due solely to the tremendous expenditure of energy by the teachers who were trying to teach their children in modern creative ways under almost impossible conditions.

The willingness of teachers to accept bad conditions and adapt themselves and their teaching methods to their buildings is, in many respects, an admirable characteristic. However, it may prevent their local education authorities from fully realising the problems that exist. There are many difficulties involved in making known the user requirements for school buildings. The only official channel of communication for most teachers is via the local education authority's subject specialists or Inspectors. The Department of Education and Science rely very largely on their Inspectors for the collection and transmission of new educational ideas. These are developed and interpreted in building terms by the Development Group of the Department's Architects and Building Branch. The results of this work are then published by the Department in the form of Building Bulletins. The main objections advanced by local authority architects and educationalists to consulting teachers are that, firstly, since there are many different approaches to teaching, teachers are rarely agreed on their requirements, and, secondly, that teachers are not familiar with architects' methods of working; they cannot, for example, visualise how a set of plans will "work out" in practice.

Some local authorities have realised the value of providing a channel of communication for teachers' ideas and suggestions. One County Council, whose schools have a particularly high reputation, had, as long ago as 1949, devised a system whereby monthly meetings were attended by architects, administrators and teachers, at which matters of design and policy were thrashed out. From the outset the educationalists had carefully thought out what sort of schools they wanted and what kind of environment the children needed; from this they were able to give the architects a detailed brief of their requirements. Their procedure was flexible enough to allow new educational and design ideas to be incorporated in school plans, while ensuring that mistakes were reported by the teachers and rectified in future designs. Similar procedures have been devised by some other authorities but their number is still small. There are some authorities whose brief consists only of the minimum Ministry regulations concerning accommodation and cost limits. They sometimes repeat earlier school plans with all their mistakes without consulting the teachers for their views on any major faults that could be rectified.

Subjective assessments of the internal environment of primary schools

Although quantitative features of a school environment—areas, illumination levels, temperatures, etc.—influence its success, they do not provide a complete solution to the problem of why one school may seem inadequate while another appears better. It was, therefore, decided that the unit should endeavour to develop an understanding of the important subjective aspects of school environment. All the members of the unit have had some experience of making critical appraisals of environment and between them some of the most important fields of environmental design—building design, climate, environmental physics and social psychology—are covered. One important specialism, that of the educationalist was lacking, so an attempt has been made to partly fill this gap by meeting teachers and encouraging research into aspects of school design by teachers preparing theses for higher degrees.

So far only the pilot surveys of the project have been completed. Five schools were drawn from the sample provided by the Department of Education and Science and have been visited by the unit for one day. The procedure adopted on these visits commenced with the members of the unit, working independently, making a quick tour of the building both inside and out and then recording their first impressions of the building as a whole. This was followed by more prolonged inspections of the building when each of the following factors was assessed in turn—the visual, aural, thermal and spatial environments and the educational and social aspects of the environment. In addition, each member of the unit completed a check list of the factual characteristics of the building appropriate to his particular skill (e.g. building construction by the architect, landscape and site by the geographer).

The members of the unit held discussions about the school buildings with the schools' staffs at some time during each visit. Finally, just before their departure, the members of the unit reappraised the whole school to see whether their detailed examinations had caused any modifications of their original impressions.

For the initial, detailed and final appraisals of the schools check-lists of the many factors to be considered were used so that the surveys could be made in an ordered manner. In the first survey, items were assessed on a 6-point scale, but following the "post-mortem" on this visit, it was decided to adopt a 7-point scale. In addition, some items on the "subjective" check-lists were rephrased in order to avoid ambiguities arising in their interpretation; the modified check-lists were used for subsequent school surveys.

At the outset of the pilot surveys no attempt was made to define criteria, the intention being that the members of the unit should evolve their own and after the completion of the pilot surveys the way in which these had been developed would be discussed. In spite of there being no common criteria and the fact that each member of the team made independent assessments, there was considerable agreement in the ratings of the schools. There was, however, a slight tendency for each team member to be more critical of the aspects of environment which involved his particular discipline than those aspects in which his experience was less. At this stage of the study it is not possible to draw firm conclusions but the surveys completed so far indicate that subjective appraisals should help in the development of a better understanding of the environment in primary schools.

Conclusions. The emphases of the present building programme in Britain are mainly quantity, speed of construction and costs. Whether the buildings being constructed now will fulfil their users' immediate and future requirements is only rarely a subject for research. Post-war schools have earned a reputation for the high quality of their design but wide variations in quality can be seen. Apart from practical examples (3) there is little guidance on the *educational* function of school buildings; even if there were more, there are no means of gauging a designer's success in achieving a satisfactory environment for education. The studies reported in this paper (which are still in progress) are directed at the environment within primary schools and form part of a long-term programme whose aim is a greater understanding of the total environment created by buildings.

An impression resulting from visits to many schools, combined with discussion with education authorities, architects, teachers and others is that, in general, schools are being built only for the practice of the present day. There seems to be no awareness on the part of either architects, or the local education authorities who commission them (as evidenced by their buildings) that, in twenty or thirty years' time, teaching techniques and the staff situation might be radically different from those of today. The authors believe that such an awareness must be developed since too many primary schools are being built in which there is no provision for adaptability and easy extension.

Much can be learnt for the benefit of future school design from greater consultation with teachers; at present it seems that they are not sufficiently consulted. However, although most of them have opinions and information of interest and value to designers, they tend to be more concerned with detail than with overall concepts. Following experience in small, informal groups with structured discussions they become better able to project themselves into future situations and more ready to discuss building requirements in terms of teaching practice rather than physical restraints. In order that new schools should not restrict future teaching practice, there is great need for joint studies by educationalists and building research workers into educational trends and their expression in terms of environment and buildings design. Studies currently in progress suggest the potential value of simple and speedy rating methods which can be applied by small multidisciplinary teams using carefully prepared checklists and rating scales.

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The problem of choosing a building solution

By Z. Wasiutynski (Poland)

The *subject* of this paper is the choice of building solutions in various sizes of constructional work: detached buildings, blocks of buildings, quarters, towns, urban centres, regions. Its *purpose* is to state facts established through an examination of the usual approaches to the choice of a solution in this matter. The *need* to consider the problem of choice in a broader manner than is the usual practice is supported by the following discussion.

The building business covers several groups of operations such as: investments, fulfilment, utilisation. As a rule such groups are not overlooked, but they are usually more or less dissociated; the investor's, the executor's and the occupant's view-points are examined separately and a succession of part-decisions are arrived at. Furthermore, such decisions are made following quite different methods: economic computation, technical design, types, standards. If adequately grounded on experience the methods may lead to satisfactory results. In other cases, the solutions are not the best ones. Major errors ensue from consideration of outlay while neglecting that of results, or from ignoring the implications of changing conditions by resting a choice on previous solutions or on standards.

Moreover it is necessary to look at the above operations in the light of the broader problems of town planning such as: location of quarters and towns, choice as to size and density of population, optimum communication network.

First to avoid errors, and then to be able to examine such problems, it is essential to consider as a whole the groups of operations relative to building: investments, fulfilment, utilisation. This approach seems the only one free of incongruity.

Findings through observation

Choices have a different bearing, dependent on the reasoning underlying decisions and the scope of operations undertaken in the field of building: social choice and individual choice economic choice and political choice, technical choice and aesthetical choice judicial choice and moral choice, objective choice and subjective choice, conscious choice and unconscious choice. (This contiguity of choices is presented to recall to mind their diversity and not to submit a classification.)

Different concepts apply to each kind of choice and, if a particular type of choice is applied to problems of different reach, the concepts applied will also have a different bearing.

In actual choice the various arguments underlying the choices are not all separate factors, but some may come in together, consciously or unconsiously, willingly or unwillingly, notwithstanding the intension that the choice should be an objective one, that is, supported by accepted arguments. Choice in building depends on all the social and individual requirements with which the building field is concerned.

Choice grounded on economic considerations is inadequate to provide optimum building solutions; nor is it fit to accommodate technical progress. Building choice is intended to select optimum solutions so that, in respect of such solutions, and not of the economic system, it is not in contradiction with the optimum activities of the system.

Technical, social and individual arguments in support of a choice in building and town planning are mostly expressed in terms of figures by physical, technical and technological measurements of means expended and of results.

The choice considered refers to a restricted field, in time and space. It rests only on essential changes brought about by the building construction and by the occupancy of buildings, and does not reckon with the other changes that do not affect the decision.

The problems relative to choosing building and town planning solutions, with a limited scope, are ascribed to the economic sphere containing such solutions. They are separated from this sphere owing to the fact that the changes they cause in this sphere are small enough in comparison with other changes brought about by other operations. The choice within this scope is considered as having no influence on the optimum conditions of other activities in this economic sphere and as not referring to its optimum condition.

The complexity of the problems involved in building choice and the many parameters that come into this lead to their being grouped into stages and branches. The stages consist in selecting first the main elements of the solutions and then their more or less detailed parameters. Thus, the following are singled out: the primary propositions relative to the solutions, general schemes, preliminary designs, working designs. The branches consist in dividing each stage of the building choice into different parts concerning: the economic choice, the organisation choice, and that relating to the various technical specialities.

The optimum solution may be chosen among a number of possible solutions by taking these in pairs for successive comparisons; a solution in each pair is ruled out and the other one is brought together with a new solution to form a new pair. If the selected criterium is inadequate to eliminate one of the two solutions, it is always possible to broaden its application by means of subsidiary criteria.

The choice of one of the two solutions in a pair is effected by different comparisons between a number of expense or result parameters, generally expressed by different natural measures and not by standard measure. As a result it is not required that the technical choice be reduced to a comparison of monetary items, as for the economic choice, were it even possible.

For the sake of clarity in effecting a choice among solutions distinguished by several parameters showing means expended and results obtained in different units, it may be of advantage to write these figures in the form of rectangular tabulations called moulds. The figures showing expenses and results form separate moulds. The various lines in the moulds refer to different parts of the items under consideration. The different columns in the moulds contain figures indicating different units.

If, to variations in the solution parameters, correspond, in particular fields, unbroken variations in the amount of means expended and of requirements met, the search for an optimum solution is in the nature of a problem with inter-related limits. The problem may be approached as the search for a minimum of means expended to meet specific requirements or as the search for a maximum amount of requirements which can be met by specific amounts of means expended. Such solutions are identical irrespective of the approach.

Long range functional requirements of housing

By L. Zoltán (Hungary)

The trend of technical development in housing can only be determined correctly if we settle the functional requirements and principles of development which future dwelling settlements will have to satisfy.

Individuals, families, cities, regions and countries make enormous efforts to maintain and to develop their present way of life. The social and economical order which will be able to make the "life-operation" of our settlements run more economically, in a more organised way and more far-sightedly, will have great advantages in the peaceful competition of societies.

Satisfying requirements of life within the framework of the flat is no longer possible. Even the most luxurious flat cannot ensure in itself the social comfort necessary for everyone. Flats cannot even supply such high-rank requirements as learning, medical treatment, sports etc.

The correct shaping of future settlements requires an analysis of life functions in a broader sense. They are formed by the prevailing social and economic situation. In this paper a method is discussed of examining living functions, proposed in Hungary by architects and technical experts. Our co-operation with sociologists, gerontologists, statisticians, economists, psychologists, pedagogues and a number of other experts is not yet considered sufficient. Nevertheless the propositions raise many new thoughts. They may help to ensure that settlements—simultaneously with the development of building techniques—keep durable, both socially and functionally, and that future housing estates are erected with a view to providing suitable environment.

Changing role of family life

In the first place the social role of *woman* has changed. In the past, although put on a pedestal, a woman was compelled to do the slavish household work. Our age has improved her status, ensuring for her the joy of creating, the human dignity of self-respect.

As in the past we examined with care the sensible arrangement of a good kitchen, similarly we have to examine everything that women still do at home. How much of this can be solved more advantageously by outer supply and how much by rendering the flat more complete? Problems must always be analysed within a settlement unit and never only within individual flats.

The situation of the *man*—the "pater familias" has also changed much. Hard physical work is disappearing. Society takes more and more worries—related to family—on itself. On account of the continuous decrease of work-time, there is more time for culture, sports and entertainments. Flats and housing units have to meet these demands.

The norms of housing investments prescribe the production of 8 school-rooms, accommodation for 75 in kindergarten and 50 in infant's nursery, a club of 100 sq. metres area, 1225 sq. metres shopping area and 350 sq. metres accessory establishments per 1000 dwellings.

The change in the demands and the evaluation of experiences always makes new tasks, e.g. inside the residential unit, teenages have to be given the opportunity of getting daily physically tired. It is undecided whether it is better to provide washing facilities in each flat, or communally within the settlement. Possibilities of mass-sports for adults, or individual hobbies must also be considered. Such changes in needs also have an effect on housing techniques. The requirements of family life and relaxation have to be satisfied more efficiently. Good conditions for sleeping are extremely significant. For the inhabitants of the metropoles only a week-end in the country-side or a vacation can provide them with proper sleep. A great part of wide-spread diseases is caused by bad sleeping conditions. A solution must be sought, which goes beyond mere sound insulation of the flat.

Cooking facilities

Up to date provision of cooking and eating facilities cannot be provided within the flat. Kitchens become less important. What will become general, serving food, prepared at home, or using the restaurant of the settlement-unit?

Both possibilities have to be taken into account. There is one demand for breakfast and lunch, and another for dinner. Families may take breakfast at home, lunch at the working place and dinner at the restaurant of the settlement unit by the end of the century.

The preparation of the raw materials of food, its transportation and distribution require the least amount of social work if we organise the technology of catering on city level from the producer to the plate of the consumer. The selling of basic food-products will be taken over by automats or other transportation systems.

Traffic

Traffic gives the bulk of the worries. With the communication facilities used today, especially with the car, the problem cannot be solved.

Existing metropoles cannot be adapted to the principles of future town-planning. Complete safety for pedestrians is the most important consideration. Within the settlement unit walking will remain the way of access to anywhere.

Within the inner parts of the city, individual car-communication cannot be maintained. Underground or above ground mass-transportation vehicles will have to be provided to take everyone to the settlement unit. Week-end traffic and continental traffic on the surface, under ground or elevated will make new large scale tasks to be overcome.

The town planning of the future must provide a formula for rational communication. In order to fulfil everyday duties, significantly fewer people should need transportation. Children, old people and workers satisfying primary demands will be employed in their own settlement unit.

The proposition shown in figure 1 is schematic. The main artery of the city has three levels. Town planners throughout the world admittedly design better ones. But, after all, how many of the dwellings built annually in Europe have the virtue of easing traffic in the settlement and not adding to it?

Leisure

Leisure time is the most valuable possession of our time. We do not defend it sufficiently. The rational use of working time is dealt with, in full capacity, scientifically today. The same cannot be said about the rational use of leisure time. Red-tape free offices, better organised sale and distribution of goods, good transportation, are legitimate claims also for the sake of defending leisure time.

Houses, manufactured in series will explosively increase the acreage of the cities. In many countries research is being undertaken on leisure time, and on time spent unnecessarily on public transport or elsewhere. The practice of townplanning today can make only little use of the results and propositions of this research. There is no doubt however that the demand for leisure time will have its effect on future building techniques.

Organic planning of cities

When considering the methodology of the mass-production of dwellings we cannot take the unit to be the number of flats built. This is an incorrect definition even if expressed in thousands. By building dwellings, we automatically create the living organism of a settlement.

The formulae and normatives defining, for instance, the amount or type of accessory or communal additional investments are merely mathematical definitions. We ought to define the optimum size of the organic city unit, the self-reliant life-functions of which can be ensured on a proper level. Experiences abroad and at home show that the most successful city unit has 4 to 5 thousand inhabitants. Within this city, families, and

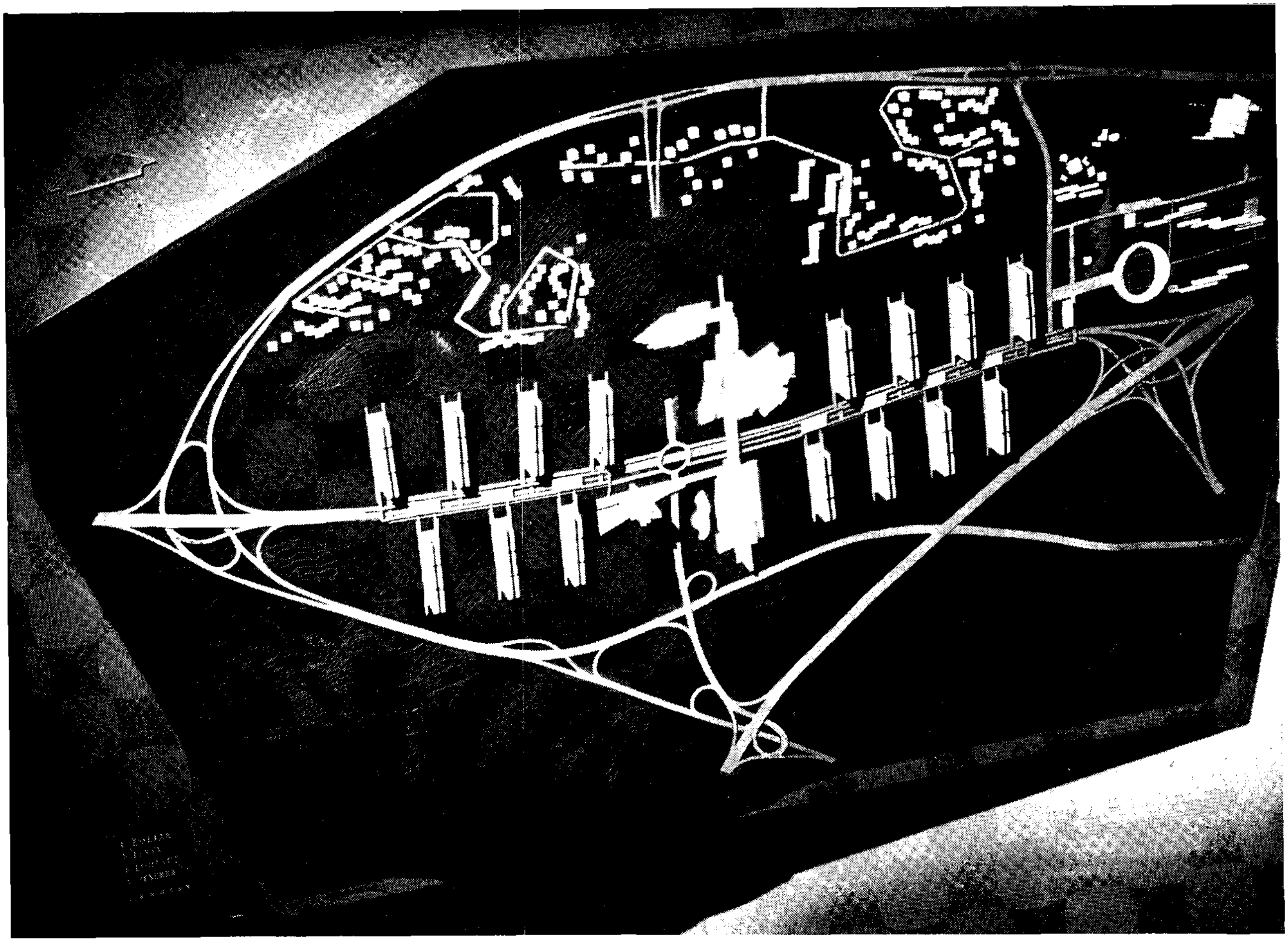

Fig. 1.

fractions of families have to be settled, according to their personal needs. The normatives of primary and accessory communal investments, related also to city units have to be elaborated too.

If cities could be organically planned and erected together with residential buildings, then their architectural solutions, costs and maintenance will also become significantly more economical.

Functional categories

From the point of view of satisfying social requirements the correct choice of functional categories and the forming of adequate proportions according to demands, is the most decisive. Demographical data and sociological research do not give enough to go on.

According to recent estimation the following proportions would better conform to today's needs; 60% of the total population needs family flats, 25% needs serviced family flats, 5% old peoples flatlets, 10% hotel-type flats for one or two persons and 5% requires other collective dwelling types (student's-homes, worker's hostels etc.).

From a sociological point of view, building experimental settlement units would help in shaping the correct proportion. On the fringes of Budapest the erection of an experimental settlement has been started. Not only the different building technologies, but also the common operating of a residential unit will be tested. There is a servicing centre between the different types of dwellings. This already offers more than the already well-known shopping centres.

Conclusion. The claims for flats, rising from social development differ according to countries. There are many similarities however in the tendency of progress. To promote technical development, these similarities might be elaborated and published by the international organisations.

The analysis of functional problems is not an end in itself; the lessons of such analysis successfully contribute to promoting development of contemporary urbanism.

When once we come to realise that functional requirements concerning housing are basically of a social character and that satisfying these demands can only succeed on a social level, then we will arrive at a technical conclusion as well.

Functional requirements can only be tackled on an urbanistic level and this level can not be reached without up to date industrial building techniques. The ever changing demands require flexible industrial systems.

It would be most desirable if the CIB, this international forum of technical progress, could concern itself with the functional problems of housing.

Group J
Developing Areas

Final report from the group rapporteur Professor Mrs. R. Shalon, Director, Building Research Station, Technion, Israel.

Within the general framework of industrialisation of building, our group has been mainly concerned with the problems specific to the developing countries.

Definitions

The very term "developing countries" is, however, equivocal and the authors of the various papers use different criteria, such as per capita income (J12), climatic and/or geographical situation (J8, U.N.), or agriculture as the predominant kind of economy (J12), and others for defining such countries.

Biétry (J4) suggested that a country be classified as "developed" or "developing" according to the kind of housing it has. Assuming that a family can aspire to a dwelling the cost of which is two and a half times the family's annual income, a developed country would be characterized by a small proportion of good social housing and a large one of free building, with practically no minimum-standard social housing or self-help housing. A developing country, on the other hand, would be characterized by minimum standard social housing and self-help housing in nearly equal proportions, with just a sprinkling of free building and of good social housing.

Scope and kind of building

As we all know, in most countries housing constitutes the major part of building. This is particularly true in the developing areas, and before going into the problems of industrialisation of building, it seems necessary to dwell at some length on the kind of housing and community facilities most likely to be built in those areas.

The authors of most of the papers submitted to our group recognize, explicitly or implicitly, the relationship which exists between a family's income and its dwelling (J4, J8). Consequently, they consider that most housing will be of the self-aid type (K6, J4, J8).

This is a traditional approach, time honoured, but challenged not only by those who give high priority to people's housing welfare, but also by some economists* who include housing among the objectives of general development programs. They suggest that the construction of adequate housing during the early stages of industrialisation and urbanisation of a country, can contribute to the development of human resources and to raising the productivity of labour by improving the health and vitality of the workers, raising their morale and increasing their drive. Housing can thus become an instrument for economic growth. This view is also expressed by Macura (J7). The building industry is also likely to play an important role by giving the first industrial training to migrants from villages to towns.

In my own country, where housing has to be provided not only to the low-income groups but also to immigrants, the Government invests heavily in housing construction. New dwellings of a fairly satisfactory standard, are provided to these groups on easy terms. When taking possession of these dwellings, the occupants have practically no financial means of their own and in the case of immigrants – no permanent employment either. What enables them to pay the rent or eventually to purchase the house is employment by the building industry itself, followed by new sources of permanent employment created, directly or indirectly, by the Government.

Though housing welfare is given high priority, social considerations are not the only reason for Israel's very extensive housing program, which reached a yearly average of 16 dwellings per 1000 population. The role which the housing program can play as a factor of economic development and as a means of distributing the population according to the regional development plan – provides an equally strong motivation.

I should mention that with all the importance attached to proper housing, Israel could not afford it, were it not for the very considerable financial help extended to her by Jewish people from the developed parts of the world. I shall revert later to the problem of financing housing in the developing areas in general.

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* Leo Grebler, Housing and Community Facilities as Factors in Human Development, U.N. Conference on the Application of Sciences and Technology for the Benefit of the Less Developed Areas, Geneva, 1963.

Considered from the social and economic point of view, the kind and the extent of housing and building necessary in the developing areas cannot be directly derived from the experience of the developed nations. As mentioned by Beken (J3), many of the countries in process of development possess numerous areas where the living conditions are far worse than those which existed in Manchester in Victorian times and which used to be considered a symbol of misery.

On the other hand, the fact that the social and economic progress of the developing countries today takes place under conditions totally different from those which prevailed during the European industrial revolution a century or so ago, should not be underestimated. Solutions which, measured by traditional criteria, may seem unrealistic, can in the long run prove more practical than those put forward by more sober men trying to apply the experience of the developed nations, without fully understanding the specific social, psychological, technical and economic conditions prevailing in the developing countries.

Considering the prevailing social trends and the general aspiration to a higher standard of living, it would be quite delusive to assume that townsfolk, living next to better-to-do people, would remain satisfied for long with sub-standard dwellings still acceptable in the villages. Whatever their income, they would soon become restive and social tensions would inevitably result.

It follows, that although self-aid housing is still a practical solution for rural areas, it is hardly to be recommended for urban areas, where it should be considered a temporary solution, for a period of say 5 to 10 years, at most.

The developing countries are therefore in need of very extensive social housing as a large, possibly the largest, part of their overall housing demand. According to the Economic and Social Council of the U.N. (mentioned in J6), it is estimated that 24 million housing units have to be built annually for the next 30 years in order to overcome the present shortage in the developing countries and to meet their future demands. The need for schools for many millions of pupils, hospitals and other community services is not less urgent.

The total building effort in most of the developing countries is, thus, about to reach truly enormous dimensions.

Appreciation of this situation and of the necessary rate of construction, has led most of the authors to recommend the use of prefabrication to varying degrees, it being the general consensus that this is the only method which holds out some promise of meeting the immense needs.

Unfortunately, the terms "prefabrication" and "industrialisation" are used in some papers rather loosely, their very significance and implications becoming blurred.

For the sake of clarification, I would therefore give you the U.N. definition of industrial building, quoted by Woodhouse (J12), which is the following: "A continuity of production implying a steady flow of demand, standardisation, integration of the different stages of the whole production process, a high degree of organisation of work, mechanisation to replace manual labour wherever possible, research and experimentation integrated with production". I would also suggest that we clearly distinguish in our discussions between industrialisation of building materials, such as manufacturing of lime, production of clay-bricks or cement blocks, and industrialisation of building construction.

Industrialisation

Prerequisities

Now, industrial development of building construction should be based on proper appreciation of the prerequisites for producing worthwhile results. This does not mean that everything in a country must be just right before industrialisation can start, but certain minimum conditions must be fulfilled, or at least their fulfillment planned simultaneously with the industrialisation of building.

The authors of most of the papers submitted, agree that the main prerequisites are: 1. a developed building materials industry; 2. appropriate mechanisation; 3. transport facilities; 4. investment funds for the construction of factories; 5. trained personnel and 6. a measure of standardisation and research.

Building materials

In most of the developing countries the production of building materials is not yet of the necessary magnitude and degree of continuity to enable them to proceed with industrialisation. Even the production of such basic materials as cement and bricks, falls far short of the minimum requirements. In India, for example, cement production in 1963 represented 11.5 % and bricks less than 15 % of the amount necessary for meeting housing needs (J9).

The industrial production, from locally available raw-material, of materials of adequate quality must precede the industrialisation of building as such. Most authors stress that the investigation of raw-materials, the improvement of the indigenous materials, and the development and adaptation of new ones, as well as quality control, standardisation and dimensional coordination should be given high priority in the overall planning of building activities. This is clearly pointed out in the papers: (J1, J3, J10, J11, J12, E10).

In this respect attention is drawn to timber and wood based panels, and panels manufactured industrially from agricultural residues (J6, J8, J10, A2). The raw-material for such panels can be found in most developing countries. As pointed out by Cowan (A2) such panels are the most flexible material and lend themselves to prefabrication, even to the extent of providing ready cut houses. They can and should be given sufficient resistance against wood destroying agents. It may also be mentioned, that the suitability of materials from the climatic and economic point of view should be given much more consideration than hitherto.

Mechanisation

In most developing countries mechanization is still in its initial stages. In India, for instance, the only machines used so far on the building sites in urban areas are concrete mixers and vibrators. Only recently have a few towercranes been brought in for some of the high buildings (J6).

In the whole Ecafe (U.N. Economic Commission for Asia and the Far East) region, where labour is abundant and available at cheap rates, the very desirability of mechanization of manufacturing processes and building operations may be questioned, because of its economic and employment implications (J10).

The situation in other regions has been similar, though considerable progress has been achieved in some countries (J1, J3, J4).

Prefabrication

Prefabrication and industrialisation of building are closely linked to the general industrial and economic development of a country. The conclusion that industrialisation of building in the developing areas ought to be introduced by stages is, therefore, self evident.

This is indeed advocated by a number of authors. Arousy (J2) suggests what he calls, "simple industrialisation", such as production of building elements up to 100 kg, not requiring vehicles or cranes, and easy to assemble by the workers. He stresses that industrialisation involving large factories equipped with machinery and tools, special trucks for transport and cranes for assembly in situ is, I quote, "completely unfit for the countries in process of development".

Not quite so extreme is the opinion of some other authors, but they too advocate small-sized building elements, simple techniques, etc. (J3).

The integration of prefabricated building components into conventional building, discussed by Woodhouse (J12), Peer (F26) and others may well be the first step towards full industrialisation, and at the same time is of permanent value in its own right. It has been introduced in many a country (J1, J3) with the object of reducing skilled manpower on the building site, speeding up construction, reducing the overall cost, and often also enabling economy in the use of imported products.

A further step of considerable importance is the prefabrication of small, medium and large elements on the site. This has seemingly been quite successful (J1, J3, J5, J9). A good example of this development can be found in Israel. Starting from small elements such as reinforced concrete roof trusses and beams, hoisted and incorporated by hand into conventional systems, prefabrication on the site has now developed to include stairways, concrete floors and other large elements, up to whole room units. The increasing use of cranes permits the use of an increasing number of larger and more sophisticated prefabricated elements. In residential building alone prefabrication which accounted in 1963/64 for 2.6% is planned to reach 17.5% in 1970 (J1).

In countries with no adequate roads and transport facilities prefabrication on the site is particularly appropriate. Another advantage is that it requires a comparatively small investment. On the other hand, prefabrication in factories ensures better and more uniform quality, greater economy of materials and a steady flow of production independent of weather conditions.

Manpower

To be able to organize and carry out efficiently building industrialisation large numbers of engineers and technicians are necessary. Where these are not available, the gaps could be filled temporarily by foreign experts, who should enlist the active cooperation of their local counter-parts and prepare them to take over as soon as possible. A number of papers deal with the need of skilled labour in the various building trades, and particularly in industrial building, such as machine operators, assemblers and mechanics. Singh and Mathur (J10) list the dearth of skilled labour needed for industrialisation and the lack of facilities for their training, among the factors which slow down the development of the building materials industry in the Ecafe region. Macura (J7) states that "It would be uneconomical to go through the formation of classical artisanship as the basis for large constructions, as industrialisation eliminates it by itself".

Biètry (J4) too suggests that it is wasteful to train workers for traditional building trades at a time when this kind of qualified worker is disappearing in the highly developed countries. This is a suggestion which will probably be rejected by many, for the lack of skilled manpower may well be the major cause of bottlenecks in traditional construction, which will remain of major importance at least for many years to come. On the job training, courses coupled with work, vocational schools - all these should be made use of to improve the standard of skilled labour in general, and to train labour for industrialised building in particular. This is a task in which international assistance could be most fruitful.

International cooperation. International cooperation is still needed in many of the developing countries to set up national research centres, to train researchers and to guide them during the initial period through all the stages of their work, from identifying the building problems to promoting implementation of research findings.

The industrial production of building components makes standardisation and dimensional coordination of all the components imperative. This is another field for international cooperation.

Last but not least, international cooperation seems to be indispensable in helping to solve the financial problems of housing in the developing countries. If these countries have to depend on their financial means alone, the provision of housing and other buildings will inevitably remain slow, with little prospect or need for industrialisation. Not only are the financial resources of the developing nations very limited, but the share allocated to housing, often considered a field of consumption and thus "unproductive", is particularly small. Thus in India (J9) where the estimated deficit in housing is of 10 and 80 million dwellings for urban and rural areas, respectively, the Five Year Plan for the years 1960–65 provided for the building of 1.75 million housing units and that for the years 1965–70 for that of 5.8 million, enough to cover a mere 12% of the existing deficit, let alone the additional demand due to the large population increase (2% per annum).

Though the gap between demand and supply in other developing areas seems to be narrower (J3, C8) it cannot be closed without very considerable international help.

The availability of funds for housing is, of course, related to the overall resources for development, obtainable through multilateral or bilateral channels. It may be mentioned in this respect that the Israel Delegation to the U.N. Conference on Trade and Development (UNCTAD) proposed last year a Development Financing Plan under which some 15 billions of dollars would be made available to the developing countries by an international financing institution at a nominal rate of interest of one percent. The difference between this rate of interest and the commercial one is to be covered by the developed countries. This proposal, I understand, is now under consideration by the United Nations.

It might be appropriate to express here our conviction that without such or similar financial aid granted by the "haves" to the "have-nots" there is no solution to the housing problem of the developing nations.

The following problems were suggested for discussion:

- Is full-scale industrialisation of building under the economic and social conditions prevailing at present in the developing countries at all feasible?
- If it is not feasible – what are the recommended stages of industrialisation and what are the prerequisites to each of them?
- How can these prerequisites be best met and what are their technological and economic implications?
- How can international cooperation best assist the developing countries in the fields of research, standardisation, documentation and training of technicians and skilled labour?

Discussion account

The discussion did indeed center mainly around these items in addition to the more general topics discussed.

It was stressed that although the developing countries constitute a heterogeneous group, differing widely in the extent of development already achieved in each of them, their common denominator is the urgent need for extensive housing to be built rapidly. This need has a direct bearing on the industrialisation of building, if we are to prevent the ever widening gap between the developed parts of the world and the developing ones.

It was pointed out that decent housing is necessary not only because of the importance of people's housing welfare and contentment, but also that it organically belongs to the objectives of general development programs of the developing countries. Although not all the values it creates are measurable in monetary units, it has been shown that the improvement in the health and vitality of the workers, the rise of their morale and productivity of labour, brought about by the social investment in housing, is a significant instrument for economic growth. Large-scale housing construction is not only a partial answer to unemployment prevalent in many of the developing areas, but it also encourages savings and domestic capital formation. It was stressed that highest priority should be given to communal services, such as water supply, sewage systems, and road construction.

On the problem of the feasibility of full-scale industrialisation of building, it was the general consensus that there is no room under the conditions prevailing at present in the developing countries, for full scale industrialisation; the factors which in the developed countries have lead towards full industrialisation do not exist to any great extent in the developing countries. In these areas, with a few exceptions, there is an abundance of labour available at cheap rates, often under-employed or completely unemployed. Neither do the developing countries have the capital required for industrialisation. They are, therefore, in need of labour-intensive production processes, rather than of capital-intensive ones.

Moreover, in contrast to the conditions prevailing in the developed areas, the production of building materials is not yet of the magnitude, nor of the degree of continuity, required by industrialised construction methods; the transport system is far from being sufficiently developed to enable efficient and economical distribution of products; mechanization is in its initial stages; there is little standardization and research; and last but not least, there is a shortage of University trained engineers and other technical personnel.

On the other hand, most of the participants in the discussions agreed that considering the immense need for building and the necessary rate of construction, industrialisation by stages seems to be advisable. But a balanced approach is necessary, and traditional housing should be improved side by side with the introduction of the more modern types of housing.

One of the most important prerequisites towards industrialisation of building as well as for overcoming the housing shortage by conventional methods, is the industrialisation of production of building materials. In this connection it was pointed out that production of materials of adequate quality produced from local raw materials, should be given high priority. Investigation of raw materials, studies aimed at improvement of the indigenous materials and the development and adaption of new ones, as well as quality are likewise very important.

A further prerequisite, which applies to all countries where industrialisation is considered, is the introduction of standardisation and modular coordination at the earliest possible stage. This is important because of their own inherent value as well as in anticipation of future industrialisation.

More economical use of labour and modern methods of training and management are called for.

It was the general convinction that large-scale financial help is necessary for the progress of the developing nations and that a larger than hitherto share of such help from international sources, should be directed to housing.

An important conclusion from the discussion, stressed both by those who advocate early introduction of industrialisation, as well as by those who would prefer to postpone it for a time, is that international cooperation is needed in the fields of research, standardization, documentation and training at the various levels of building activities. This appeal will, I have no doubt, readily be adopted by those member countries of CIB which have the good fortune to be developed, – by putting their accumulated knowledge and experience in the field of building, at the disposal of the developing countries, as is fitting an international organization of the stature of CIB.

Industrialisation of building in Israel as a rapidly developing country

By A. Alweyl (Israel)

The conditions which determine building methods in developing countries, are varied, but there are several common factors:

- the great housing needs for improving living conditions;
- the difficulties in financing building on a large scale, necessitating low-cost building;
- problems of industrialising the production of building materials with maximum possible use of local raw materials;
- problems of training skilled building workers;
- the problems of adapting building methods in relation to climatic conditions and local building materials.

The degree of industrialisation varies in accordance with the local economic situation and specific conditions in each country. However, the problems bear basic resemblance to each other. On this assumption this review of the development of building industrialisation in Israel is presented with emphasis on those problems which may be of interest to developing countries.

Scope of building activities

Since the establishment of the State in 1948, the population of Israel increased from about 750,000 to about 2,500,000 at the end of 1963, due to mass immigration and natural growth. In order to meet the housing needs created by this rapid growth, about 520,000 housing units were erected during this period, of which about 460,000 are permanent. Temporary housing was constructed mainly during 1949—1952 which was the period of mass immigration. At the end of 1963, only 4% of this type of housing was still existent. Approximately 70% of the present total population of the country occupies housing constructed since 1949. Of the total of 460,000 permanent dwellings constructed during the period 1949 to December 1963, 65% were erected by public housing authorities, and the remaining 35% by private enterprise. In recent years there has been an increase in private housing construction. By way of comparison: the number of new dwellings per 1,000 inhabitants erected in 1962 was 16.2 in Israel, 11.3 in the U.S.S.R., 10.2 in Switzerland and 9.8 in Sweden[1].

Building investments in Israel averaged about 61% of the overall investment in the national economy. Thus, building constitutes one of the most important factors in the economy.

First steps in development of building methods

The greatest difficulties in building were experienced during the first 5 years (1948—1953). There was need for rapid execution in order to cope with the urgent housing needs, despite a very limited budget. Furthermore, mass immigration coincided with an acute shortage of both skilled labour and building materials. Most of the buildings erected in public housing estates during this period, comprised one or two storeys. The structures were mainly of hollow concrete blocks, with concrete or tiled roofs. The blocks were prepared in situ and the quality was not always up to standard. As the output of building did not meet requirements, it was necessary to import prefabricated wooden houses from abroad. In this period too, initial experiments were made to industrialise building with varying degrees of success. Among others, the highly mechanised Tournalayer method was employed, by means of which an entire storey was cast in one section (2 apartments) adjacent to the building site, and transported to the site in steel forms which, after being dismantled, were returned for use in additional casting. This method, which did have some advantages from the point of view of saving in manpower, did not meet with success in Israel, for reasons of economy and climate. The method of casting walls and ceilings in standard forms was more successful, and a large number of the dwellings in public housing schemes, were built in this way. During this period, experiments were also made in the use of stabilised soil blocks with an addition of cement, but this too, was unsuccessful, as experiments revealed that these blocks required too much cement and an amount of labour in excess of that required in other building methods. The experience gained during this period, taught us that the problem of building labour cannot be solved by the use of special building methods alone, even when based on maximum mechanisation. On the other hand, there is no possibility of overcoming the problem of building materials by using materials which are not produced industrially.

Period of rationalisation and beginnings of industrialisation

In the period 1953—1963, a considerable development in production of building materials, and the use of rational and economical methods of building commenced, and by the end of the period, there was a most encouraging advance in building industrialisation and mechanisation.

Table 1 illustrates the development in production of some building materials.

A modern factory has been set up for the manufacture of aluminium window frames, and factories for the production of gypsum elements and various building sections, have been established, as well as factories for the manufacture of concrete blocks. The rise in production shown in the table is due to the establishment of several new factories. Thus, factory production of building materials based on the use of local raw materials, has reached a satisfactory stage, and the import of building materials is being restricted to steel and timber.

Much was also done to improve the standard of skilled building labour. Courses have been organised to enable workers to acquire specialised training. The number of workers who took advantage of this training scheme, averaged 2,000 per annum. The number of workers engaged on building and public works rose, from 31,000 in 1949, to 51,000 in 1951, 52,000 in 1957 and to 75,200 in 1962.

A new factor was the production of various pre-fabricated building components. A number of small plants are now producing pre-fabricated elements for roof trusses, ceilings, steps and various finishing elements. The use of these elements allows on the one hand a saving in imported building materials—timber and steel—and on the other hand, contributes towards the solution of the man-power problem.

Development of pre-fabrication

Three local plants are currently engaged in the production of prefabricated building elements, e.g. walls and floors of medium size. One plant situated in Eilat, produces from 300 to 500 dwelling units per annum. By this method, walls are constructed of two pre-fabricated concrete skins with an air-space in between. The elements are 80 cm wide and approximately 250 m high.

TABLE 1. Industrial production of building materials (1950—1962)

	Unit	1950	1953	1955	1962
Cement	Ton	380,128	464,755	663,548	953,601
Ytong	Cub. m.	—	—	35,853	95,264
Plate Glass	Sq. m.	—	1,613	1,372	2,075
Plywood	Cub. m.	—	10,711	21,286	54,413
Insul. Sheets (Cellotex)	1,000	—	—	1,587	2,025
Enamelled Baths	No.	—	—	14,402	20,000

The "MABAT" Plant at Shderot, produces about 600 dwelling units per annum. In this case, floors and walls are of reinforced concrete with round cavities, and the elements produced are 2.00 m by 2.50 m. The "RASTROM" Plant in Holon, produces about 500 dwelling units per annum. The elements are 1.00 m by 2.50 m and are cast with a layer of light concrete alternating between two concrete layers. Methods based on the pre-fabrication of large elements in situ, are being used in several places. In addition, a system employing large elements in the form of cell units (cubes) was introduced last year (the Diskin System). In the coming two years, another five plants will be erected. The diagram at Fig. 1 gives the output forecast for 1965–1970 in respect of all existing and additional plants and systems employing pre-fabrication in situ.

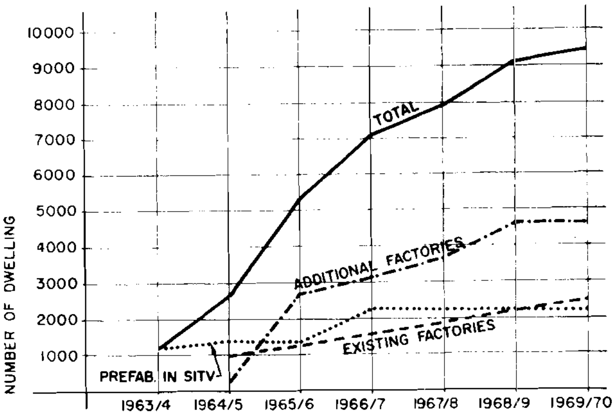

Fig. 1. Forecast of yearly output of prefabricated dwellings.

Summing up, the output of pre-fabricated dwellings in 1963–64 was 1200 units, which constitutes 2.6% of all residential buildings. The yearly output of existing plants for 1964–1970 will increase to 2,300 apartments. The output of the additional plants (now under either construction or planning) will be up to 4,700 apartments. Therefore, the total of complete prefabricated apartments will rise to 7,000 apartments per annum, representing about 13% of all residential building. In addition, the output of pre-fabrication in situ will increase to 2,500 apartments, comprising about 4.5% of all residential building. All the foregoing figures concern dwellings only. Prefabrication in other branches of the building industry (public and agricultural buildings) is so far very limited. It is anticipated that during 1964–1970 the percentage of pre-fabricated buildings in this sector will increase from 2% to about 5%.

Developments in the mechanisation of conventional building

Considerable progress has been made in the past few years in the use of mechanical equipment on building sites where conventional building is carried out, particularly with regard to production of concrete, vertical and horizontal transportation, cutting and bending of steel rods and to plastering. In addition progress has been achieved in the establishment of central plants for the production of ready-mixed concrete and steel bending.

Where larger projects are concerned, central production stations are gradually replacing the mixing of concrete alongside individual buildings. There is a tendency to further develop this system. Mechanical scrapers too, have already proved advantageous, by eliminating the most strenuous task of loading and transporting aggregates on the site.

Both experience and research work in Israel have proved that high standards of efficiency may be attained through the use of cranes provided that the work is properly organised, and that due consideration is given to other factors which influence the profitability of their use.

Following the considerable success attained with moulds and scaffolding manufactured as standard equipment, there is a tendency now to increase the use of such equipment. It has been proved that the use of standard forms and scaffolding contributes towards a considerable saving, especially in relation to skilled labour, in the work of assembly and dismantling.

The profitability of operating electrical equipment for cutting and bending steel rods, is dependent to a large extent, on the quantity of reinforcement concentrated on the individual site, as well as on the scope of annual production. On this subject too, a study has been carried out which enables an evaluation to be made in each individual case.

Additional development in the mechanisation of building construction in Israel, is dependent on the following factors:

- the scope of contracting companies. The smaller the number of contractors executing the building work, (large contracting firms), the wider will be the use of mechanical equipment, and vice versa, owing to the relatively large amount of investment capital involved;
- certain types of equipment (such as cranes) will be influenced by the scope of building projects, since their use will not be profitable where the scope of building is small;
- the continuity of work throughout the year;
- the adaption of the building project to the equipment available.

The influence of industrialisation

On the initiative of the Ministry of Housing, time studies were carried out by the Productivity Institute, with a view to determining the influence of pre-fabrication and the employment of different kinds of equipment, on the output of work, the results of which are given below:

Input of work on pre-fabricated buildings

Description of building: The elements for exterior and load bearing walls were 2.50 m high, 1.90 m wide and 17.5 cms thick, with round cavities 12 cm in diameter. The exterior wall finish was of exposed aggregates. The elements were connected and secured by means of concrete cast into the cavities after assembly. The non-load bearing partitions were 8 cms thick, without cavities, and one storey in height. The ceiling elements were 17.5 cms thick, with cavities similar to those provided in the walls, and 1.9 m wide, supplied in lengths according to size of the room. Walls, partitions and ceilings received an internal finish of a thin layer of plaster, and then colourwashed.

Buildings were three storeyed, with four stair-cases, and comprised 24 flats, the gross area of which was 55 sq. m. consisting of 2 rooms, kitchen and conveniences. Results of measurements are given in tables 2 and 3. Table 2 illustrates the input of work on production of elements in the factory, and the erection of the pre-fabricated components on the site. Table 3 completes the different amounts of work performed in the pre-fabricated structure under study, including work on foundations and finish executed by conventional methods.

As shown in table 3, the total input of work by this method is 12.9 hrs. per sq. m. As in conventional building, the figure ranges between 18–20 hours per sq. m.; it may be seen that the foregoing result, achieved in construction with pre-fabricated elements is satisfactory from the point of view of efficiency.

Influence of use of mechanical equipment on input of work in situ according to time studies by institute of productivity

The saving in input of work per sq. m. on conventional building through the use of cranes instead of hoists, is 0.67 hrs., representing a saving of 3.3% of the general work. This saving includes unskilled labour only.

Machinery for cutting and bending steel on site and in factories: The saving in input of work through the use of machinery for the cutting and bending of steel rods, is about 0.12 hrs. per sq. m. of apartment area.

There is no real difference in the saving of man-power where this work is carried out in the factory or on the site, as, in both cases, the execution is performed by machinery. The difference

TABLE 2. Input of factory work on production of pre-fabricated elements and in situ on their erection.

description of element	no. of elements for 12 dwellings	Production input-wk. hrs.		Erection (Assembly) input-wk. hrs.			
		for 12 dwellings	for each sq. m. of area	for 12 dwellings	for each sq. m. of area	for 12 dwellings	for each sq. m. of area
a. Wall	239	963.4	1.48	1280.5	1.97	47.90	0.074
b. Partition	36	50.4	0.08	43.0	0.06	7.75	0.012
c. Ceiling	148	476.1	0.73	383.0	0.59	23.25	0.036
d. Other Elements lintels, sills, mosaic sections etc.	228	672.9	1.04	175.6	0.27	15.13	0.023
Total for 12 dwellings:	651	2163.3		1882.1		94.03	
Input of direct work in work-hrs per sq. m. area of apartment.			3.33		2.89		0.145
Additional works:							
Works management			0.13		0.20		
Loading & unloading of elements			0.13		0.13		
Maintenance in factory			0.11				
Total input in work-hrs per sq. m area of apartment			3.70		3.22		0.145

TABLE 3. Input of work-hrs. on dwelling unit or for each sq. m. of area and the proportion of skilled and unskilled workers in percentages (%)

Description of works	Input in work-hrs for dwelling unit of 54.2 sq. m.	Work-hrs for each sq. m. of area	%	Man-power % Skilled	Man-power % Unskilled
1. Cast foundations	81.84	1.51	11.7	7.0%	4.7%
2. Production of pre-fabricated elements in factory	200.54	3.70	28.7	4.8%	23.9%
3. Erection of pre-fabricated elements on site	174.52	3.22	25.0	17.7%	7.3%
4. Finishing works	242.23	4.47	34.6	23.9%	10.7%
Total input of works in hours.	699.13	12.90	100%	53.4%	46.6%

however, lies in the fact that the workers in the factory become industrial workers instead of building workers subject to conditions on site.

Equipment for preparation of concrete on site and in factory: The use of mechanical delivery equipment on site to replace the transport of concrete by wheelbarrow, brings about a saving of 0.24 hrs. per sq. m. of apartment, in unskilled labour. Ready-mixed concrete brings about a saving of about 0.04 hrs. per sq. m. in comparison with mechanical equipment used on site.

Plastering apparatus: The saving in work through use of plastering apparatus instead of manual labour, is about 0.75 work-hrs. per sq. m. of apartment, principally in relation to unskilled labour and, in part, skilled workers. This saving is effected mainly in the preparation and handling of material.

Conclusions. Industrialisation of building, whether by mechanisation of conventional methods, or through the erection of factories for production of large-size pre-fabricated elements, provides important advantages, from the point of view of increased efficiency and speed of execution.

Side by side with these advantages however, exist a number of limitations in relation to the degree of industrialisation, the principal of which are: the general scope of building; the scope of building in relation to the different housing projects; continuity of building activities; prospects of financing the large investments required in relation to equipment.

An additional limitation in building with large-size elements is the extent to which the planning, organisation and financing of building is centralised. In planning the country-wide development of industrialisation, all these factors should be taken into consideration when determining the policy in relation to the erection of new plants for the manufacture of pre-fabricated large-size elements for buildings, and in relation to the encouragement of the various types of equipment for conventional building.

Our experience has shown that parallel with the industrialisation activities, it is necessary to encourage the development of the production of building materials, and the training of skilled labour in the various building trades, with the object of attaining increased building production, in accordance with the national programme. Industrialised building methods alone, without the above fundamentals will not solve the problems.

Production of interchangeable pre-fabricated elements for use in conventional building should be encouraged.

One of the essential tasks of building research in developing countries is the adaption of the methods of industrialised building to the specific conditions prevailing, in relation to climate and economy, and also the widest possible use of local raw materials.

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Types of building industrialisation fit for developing countries

By A. el-Arousy (U.A.R.)

The rapid increase of population among the poor classes in developing countries gives very serious problems, not least being the provision of sufficient housing. It evidently is essential to reduce the building cost to the minimum, to enable to face these needs. Here arises a difficult problem, namely: how to build a house extremely cheaply, without losing durability, social necessities or sanitation. The international importance of this problem is evident from the fact that its solution gives vital help to over half the population of our planet.

The author carried out intensive researches and studies in this field. The program of research was to find and test new building materials and new construction methods with regard to cheapness, simplicity and rationalisation while retaining strength, durability and heat insulation. The problems are:

- to find a proper non-inflammable roof for the farmer's house, (all known proper methods are too expensive);
- to find a rational cheap way for the government to build a large number of villages in the vast lands reclaimed through the High Dam at Asswan;
- planning and constructing buildings for the proper housing of the poorest classes;
- planning and constructing houses for factory labourers;
- planning and constructing low rent houses for people of limited income;
- building of primary schools and hospitals at a lower cost to face the demand of building one school per day;
- building cheap houses for the students whose parents live far away.

Up till now the results of the researches are:

- four new building methods have been developed to solve all the above mentioned problems. The reduction in cost is over 50%.
- a new light weight concrete made out of refuse material has been produced. It is a cheap good heat insulator to be used in walls and roofs.
- the concrete strength has been doubled, to get smaller, thus cheaper sections.

A difficult problem remaining is to find a cheap adequate flooring material. The above mentioned methods, based on industrialisation, have been tested in the laboratory as well as in the field, and have been used in practice on small and large scales, for private as well as for governmental work, and have proved to be successful.

Reduction of building cost is a vital necessity. In most of the developing countries, new houses are necessary not only for the new generation, but also to replace the existing houses of the poor. These houses are regarded now, with the gradual propagation of culture, as too miserable and unhealthy. Since no government is able to build houses for all the farmers and workers, it is of vital importance to be able to build a proper home at a cost that an ordinary labourer or farmer can afford. Otherwise the problem remains unsolved. A government can only give a limited indirect help, as discussed later.

Building industrialisation gives the right solution. It does not seem feasible to industrialise the buildings in countries with little or no recently established industry. But since industrialisation helps to reduce the cost to large extent, especially in non-luxurious buildings repeated in large numbers, and since in these countries skilled labour and technicians are rare, and since the type of industrialisation suggested for these countries is so simple that it can be introduced in any country, industrialisation of building is the correct solution, and it is more essential in developing countries than in the advanced ones.

Another important advantage of industrialisation in countries with limited powers and resources is the reduction gained in material, in skilled labour and in transport. Practice has shown that this can sometimes be more valuable than the reduction in cost. For example, the building of 33 villages in Kom-Ombo for the immigrants whose homes and land will be flooded by the waters of the Asswan High Dam, has brought up many difficulties. It was not the lack of money, but it was the deficiency in the quantities of cement, timber (formwork of reinforced concrete roofs) in number of masons, reinforced concrete technicians and in the means of transport. These deficiencies increased the prices and wages enormously. The built area was about 4,000,000 m^2: over 16,000 houses of average 200 m^2 each, plus the service buildings. As a trial, two of the villages were roofed with prefabricated elements. These roofs gave best results, especially as regards heat insulation which is important in this hot region. The cost was lowest. If all roofs were prefabricated, as well as the walls, a considerable reduction in material consumption, as well as in labour and transport would be gained.

Type of building industrialisation fit for developing countries

In advanced countries, industrialisation of building is used mainly to save labour, which is both expensive and scarce. Consequently large size elements are prefabricated. There is no difficulty in erecting the necessary large factories, equipped with all sorts of machinery and tools, as well as with special trucks for transport and cranes for the assembly in situ. Such a type of building industrialisation is completely unfit for the countries in process of development, where industry is still making its first step. A similar course of action for these countries would mean the importation of not only big factories with their complicated machinery, cranes and special vehicles, but also the importation of technicians and trained workers. Moreover, the local network of roads has to be improved or reconstructed so that these heavy vehicles can run over them. The result would be that any building would be far more expensive than if built in the ordinary way. About 15 years ago, a firm made this trial in Cairo, built a small number of apartment houses and stopped. It proved to be too expensive. The type of building industrialisation fit for countries in process of development is that which introduces industries as simple as the manufacturing of bricks or flooring tiles. The produced element must be:

1. Very light, max. weight about 100 kg, so that it can be easily carried by a maximum of two men. No big vehicles and no cranes are needed.
2. easy to manufacture, to transport and to assemble, so that native workers can perform the whole manual work.
3. very cheap, so that the poor can afford to buy them.

These requirements can be attained by concentrating the skill in the designing office where the building is carefully studied and reduced to small elements. Then these elements and their forms are minutely designed and detailed, so that little skill is required in the factory and in the field. In this way only small factories are required, using only sieves, mixers, moulds, vibrating tables and curing basins or steam boilers. Such simple factories are quickly and cheaply erected in or near the villages, and can, if required, be transported and reerected anywhere else. Also ordinary native workers can be used after a short training. The repeated factory work lets them learn quickly.

Wise planning of building

In my opinion the first step towards the solution of this world problem, namely: "How to build cheaply, but properly", necessitates the cooperative harmony between two main points: the planning and the construction, i.e. the mutual work of both the architect and the structural engineer. The duty of the architect is to design the plan of the building so that it achieves the necessary social, climatic and sanitary requirements with the least surface areas of walls, roofs, windows, etc. The task of the structural engineer is to find out or design cheap building materials, economic elements and new rational methods of construction. Again the architect has to adapt himself to the new materials and constructional methods used by the structural engineer. An example of this mutual work is the dwelling for the poorest families, described at the end of this paper, of which the monthly rent does not exceed one Egyptian pound (two Dollars) inclusive of light and water consumption.

New construction methods

Keeping the above mentioned ideas in mind, the author managed to introduce four new methods of construction depending on prefabrication. New structural elements have been designed for walls, columns, wall beams, roofs and stairs. Some old elements have been developed to give better service. Also a new building material was introduced, and some old materials have been improved. The methods may be used for one or multi storey buildings, for very primitive as well as for luxury ones. The methods and the elements have been experimentally tested as regards strength, heat and sound insulation, fitness of the mould, facility of concreting, method of tamping, facility of taking off the mould, of transporting, handling and assembling. These methods are partially and shortly illustrated in the examples mentioned hereafter. Full details would take too large a space.

A new building material

Rice husks (cover of rice corn) are found in piles in the rice mills in Egypt. Not being eaten by cattle, and being very bad as a fuel, they can be obtained gratis. If mixed with cement, after chemical treatment, a very light sort of concrete is obtained, excellent as heat or sound insulator, fire resistant and not attacked by insects. This material can be used in the form of prefabricated already plastered slabs, say 100 × 50 × 10 cm, as roof slabs between purlins, or a wall between small reinforced concrete stiffening posts. Also as wall blocks to be built on edge in the ordinary way, size say 50 × 25 × 12 cm, preplastered or not. Another form is as a wet mass to be spread as a layer of, say, 6 cm thickness over the top roof of a building as a cheap heat insulator, also as loose grains to fill out the space between the double walls of refrigerators, being much cheaper than cork. This material gives a series of cost reduction since,

1. the material itself is very cheap
2. the volume required is small; roofs and walls are 8 to 12 cm thick
3. the big reduction in weight so gained reduces considerably the dimensions of the carrying elements: the beams, the columns and the footings.

Sources of economy

The efficient sources of cost reduction obtained by these new methods of construction can be listed as follows:

- the correct planning of the building, so as to get the maximum benefit with the least areas of roofs, walls, windows etc;
- economy in the quantities of raw materials obtained through profiting by modern techniques both in designing the structural elements and in manufacturing them, i.e. gaining the utmost profit from the material;
- use of cheap local materials as far as possible;
- elimination of shutterings and formwork;
- dispensing with most of the plastering work in situ, without injuring the appearance of the structure or its function;
- reducing the cost of steel reinforcement by using prestressing where possible;
- economy in the expenses of sanitary and electric installations through skillful design;
- reduction of labour cost by simplifying the working process;
- simplifying the work on site as far as possible to enable the owner (farmer or labourer) to perform as much as possible of this work himself—(self help);
- reduction of the price of doors, windows and furniture through simplified design and mass production in specified dimensions, and by replacing the wooden frame by a precast concrete one;
- also by making use of the ornamental unmovable precast concrete windows wherever possible.

Examples: a) A roof for the farmer. In my country, the farmer can easily build the walls of his house, but the roof gives him a big problem. Timber is too expensive, also inflammable. A reinforced concrete slab is also expensive, being too complicated, requiring a contractor to transport the necessary material and formwork from the town together with the skilled labourers. Therefore he constructs the roof with palm trees and bushes. Since in every house there is an oven for preparing bread, a roof often catches fire and falls down burning all the contents of the house. The wind carries the fire to the roofs of the other houses, and in one or two hours the whole village is burnt. The author designed the following roof which is cheap, fire protective, heat insulating, can be placed over any kind of wall and is so simple and light, that the farmer himself can construct it without equipment or technical help.

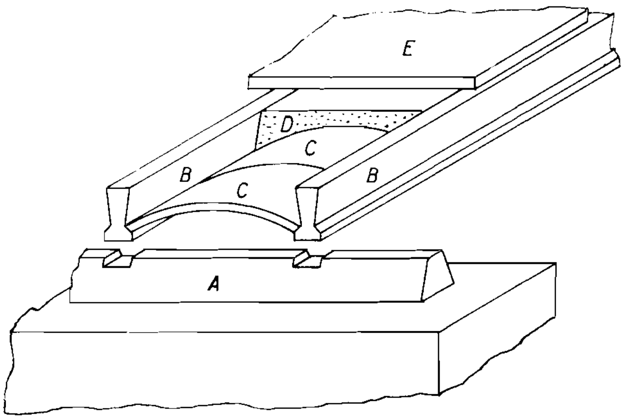


Fig. 1. A simple cheap roof for the farmer.
A: wall beam (reinforced concrete);
B: roof beam (reinforced concrete);
C: curved plates;
D: clay;
E: clay mixed with straw.

A small beam A, about 10 × 10 cm, with notches every 50 cm, is placed over a bed of mortar on a wall, and a second one on the opposite wall. Beams B, weighing 40 to 100 kg according to span, are placed with their ends in the notches of the wall beam A. In this way the beams B are exactly equidistant and form a plane. Plain concrete arched plates 45 × 20 × 2 cm (weighing 4 kg) are then placed in between the beams as shown in Fig. 1. A layer of clay D is placed to make the top surface plane and to give the required heat insulation. Another layer E of clay mixed with straw is placed to prevent surface cracks in the clay. In the north districts, where it rains sometimes in winter, it is enough to raise the level of one of the wall beams to get a good slope to let the water run down quickly. In countries where it rains more intensely, a steeper slope and a proper water-proof layer would be necessary.

The beams are manufactured varying each 25 cm in length and then transported to the villages, where the farmer can buy his necessities. Although this roof costs the farmer only about \$ 1 per m^2, yet the government can still further decrease the price by paying some of the cost direct to the factories, to encourage the farmers to replace their dangerous roofs.

b) Housing of the poorest families. For the poorest classes of people, living in miserable huts built with refuse material at the borders of towns and villages, the scheme shown in Fig. (2 + 3)

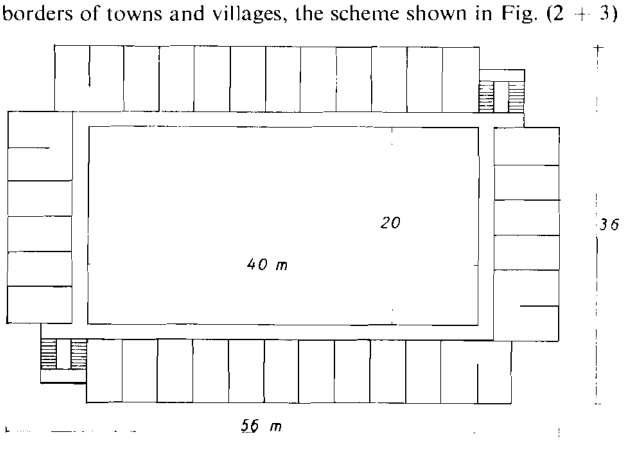


Fig. 2. House block (plan arrangement)
28 single, 4 double dwellings

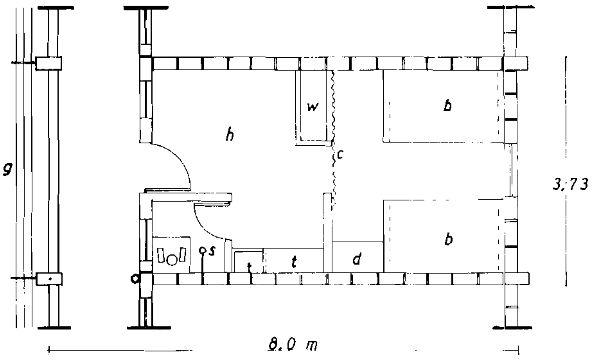


Fig. 3. Plan of single dwelling in house block.
b: bed; d: table; c: movable cloth curtain; w: wardrobe; h: hall; s: shower; t: cooking range; g: drying area.

has been studied to give best accomodation with least cost. The 5-storey building contains 180 dwellings semi-furnished with built-in furniture out of precast elements instead of expensive wood. Each dwelling contains a bed-sitting room with two wide beds, a table and a wardrobe for clothes; a small kitchen with shelves, cooking table and a basin; a bathroom containing a shower and a proper closet with syphon-box; a small hall serves also for sitting, eating or even sleeping. The inside walls are only 1.8 m high to facilitate cross ventilation and to make it possible for one electric lamp to give light to the whole dwelling. The areas of windows and number of doors are kept to the necessary minimum. In every dwelling there is enough sunshine, day-light and ventilation, together with accomodation for washing the clothes and hanging them. The inside yard of the building gives a protected playground for the children. For families with many children, or with elderly dependents, two dwellings can easily be connected together. The disposal of the sewage, in case there is no drainage system in the community, can be effected by building 2 septic tanks and a trench underneath the yard.

The monthly rent of each dwelling is about one Egyptian pound $ 2 a month, with net profit of min. 4%. This building can be used, with few modifications, for housing of students, asylum for old people, sea-shore vacation housing, etc.

The 20 cm thick walls are built with hollow blocks giving a good degree of heat insulation. The lower parts subject to abrasion receive cement plaster, the higher parts only a colour spray. The roofs are prefabricated elements resting on wall beams cast inside the hollow blocks of the cross walls, where also small intermediate columns are cast. Sanitary installations are designed to use only the minimum of material. The top roof is heat insulated, and all floors are covered with cement tiles. The stairs and corridor balustrades are also prefabricated.

Conclusion. The only possible way with which we can face the ever increasing demands of housing is the industrialisation of building. It reduces both cost and material consumption and needs much less skilled labour. For developing countries the industrialisation must be very simple to conform with local conditions, and thus it can be easily established.

Governments should facilitate and encourage the building of the required factories and, as mentioned before, reduce, if necessary, the prices of the product by paying a part of the costs to the factories so that the people can build for themselves their own houses according to different plans made to suit the different requirements. It would also be useful to establish in each village an office to offer the farmers guidance and help in the different aspects of life, say: agriculture, health, education, etc. and also in building, in order to develop "Self Help" in house construction and repairs. In towns governments should help the proper housing of the poor also by offering the land gratis on which apartment buildings are built for them.

Analysis of the application of industrialised methods with reference to Turkey as a developing country

By G. Beken and R. Kafesçioglu (Turkey)

In Turkey, which is making great efforts towards development, existing buildings are inadequate in number and quality, with respect to the actual needs. Very difficult and important problems must be solved to meet these needs. The categories of buildings, which create greatest pressure on social structure and call for changes because of the insufficiency of the existing building stock and of new construction, are housing and primary schools.

Although Turkey has characteristics similar to those of the developing countries, as well as its own distinctive features, to apply the experiences acquired, or the resources utilised, by other countries will not help to solve its problem and would produce sometimes wrong and undesirable solutions.

Housing problem of Turkey

The urbanisation movement has developed mostly after the Second World War. Urbanisation expands increasingly from day to day as in other developing countries. This can be seen in the following census table:

Census date	Rural population percentage	Urban population percentage
1927	83.6	16.4
1960	75.4	24.6

In 1927, Turkey had a population of 13,648,000 inhabitants; in 1960 the population amounted to 27,809,000 i.e. the increase was 103.8% in the whole country. During the same period the urban population increased from 2,236,000 to 6,834,000; i.e. a 207.9 per cent increase.

The urbanisation movement in Turkey presents characteristics different from those of the developed countries, but similar to those of the developing countries, as well as having its own peculiarities.

The urban population is increasing out of proportion to the number of jobs available. "The push exercised by the village" affects the urbanisation movement much more than the "pull of the city".

Reasons for this are:

- the average rate of the population increased by 29.5 per thousand; the increase in rural population is even greater.
- no new tracts of land could be used for cultivation.
- 25.7% of the farmer families have no land to cultivate.
- agricultural working services are generally in the form of small units.
- agricultural labour income is lower than the income of urban labour.
- introduction of technology in agriculture lowers man-power requirements.
- the possibilities of the inhabitants of rural areas are restricted in educational, sanitary, etc., services.

The urbanisation movement is directed towards big cities. In those who immigrate from villages city-consciousness develops only after a long lapse of time. Turkey's culture, and its system of values, differ from those of Western countries. The technological possibilities of the cities are superior to those of the rural areas. Turkey's planned development also influences its urbanisation. Aids received from the international organisations are directed towards development in urban areas.

The urbanisation movement increases the housing needs in the cities. Since 1945 there has been a strong flow towards cities, especially towards the large ones. Because of the lack of an adequate number of suitable housing units, numbers of uncontrollable and illegal shanty towns have sprung up on the outskirts of our cities to meet the above mentioned requirement.

It is estimated that the number of dwellings in these shanty towns amount to 240,000 and accomodated 45% of the inhabitants of Ankara, 21% of Istanbul and 18% of Izmir in 1960; it has increased to 370,000 in 1964 and houses now 52% of the inhabitants of Ankara. The admitted fact is that the speed of migration towards cities will remain the same until the Regional Planning Program, which is the complementary part in the Development Plan, and a new national settlement project based on it become finally effective. In Istanbul, for example, natural population increase is estimated to be about 149,000, and the number of the immigrants 355,000, in the first half of the 1970 decade; the natural population increase can be estimated as 333,000 and the number of immigrants 665,000 in the second half of the 1980's.

The housing needs due to the increase in urban population are estimated for the first five-years development plan of 1963 – 1967, as follows:

	dwelling needs due to population increase	total needs
1963	95,936	128,725
1967	116,611	170,852

In the population increase, immigration accounts approximately for double the natural increase:
in 1963 of the 128,725 units – about 60,000 units
in 1967 of the 170,852 units – about 80,000 units
are the figures of housing units to be erected, in order to accomodate those who immigrate into cities.

Actual housing production possibilities in Turkey

In Turkey, like in most of the developing countries, only a limited part of the financial possibilities can be allocated to the building sector. In order to meet the requirements in this sector, instead of searching for new financial resources, efforts are being made to keep investments on the level of 20% of the total. Moreover, the financing of housing construction has been left to the initiative of the private sector at the rate of 97% and only a limited amount of appropriations was allocated from the fiscal budget for the purpose of building residences for government officers, and for measures destined to prevent the expansion of the shanty towns and to improve the conditions in those areas. Another form of aid is the extension of building credits through banks or insurance companies.

Organisations encouraging building activities, and helping to reduce building costs are inadequate in Turkey. The production of building materials in Turkey, is sufficient to meet the requirements of the volume of construction. The building materials industry is organised according to the pattern of European countries, without any modification to satisfy local peculiarities and the country's special needs. Almost all construction methods being applied at present in Turkey are traditional but not rational. This situation causes a great deal of loss and waste of time, material, and labour.

The labour situation in Turkey is similar to conditions in the developing countries. Building workers have no permanent jobs like workers of other industries and are seasonally employed because construction can only take place during certain seasons. In Turkey there is an abundance of unskilled construction workers. The skilled workers are comparatively scarce. This is due to the fact that unskilled labourers immigrate to big cities to find jobs. Consequently the number of skilled workers is far from meeting the needs of the building industry.

The following are the figures showing the urban housing achieved under the above mentioned limitation.

Years	1962	58,748 units
	1963	53,586 units
	1964	52,500 units

These figures exclude the number of shanty town dwellings built during these years. The number of those dwellings built yearly is unknown, but certainly increasing every year.

Measures to be taken under the development plan in order to fill the gap between the needs and the actual housing production, and the possibilities of utilising the industry to the fullest degree for the purpose of solving this problem, are summarised as follows:

- measures to be taken in order to reduce the production of luxurious housing in the private sector, which produces approximately 1/3 of housing needs, spending amounts approximating almost to the total of the housing investment; measures destined to lower building costs, in order to increase low-cost housing production;
- to take measures in order to increase the production of low-cost, rented or owner-occupied housing, with proper sanitary facilities;
- to use the public sector's investments only for the construction of buildings of the above mentioned standard level;
- to provide those who construct their houses by self-help, with land, material and public installations; to direct the existing strong potential in the field of shanty construction, towards controlled shanty construction, by providing technical help to self-help builders.

There exist signs which indicate that the housing problem will not be solved within the foreseeable future. Evolution may gain speed and results leading to the goal may be obtained only if these measures are supported by the industry in the technical field. Results of researches and methods of solving the housing problems used by the developed countries can be selected and applied in Turkey, but there exist also conditions which necessitate the search for new methods. The introduction of industrialisation in the building field may be necessary for:

- the industrialisation of the production of building materials,
- the building, which by itself is an industrial product.

The analysis of the present possibilities in this field will show that the building materials industry is today on the level of meeting the requirements concerning the present housing construction, and that its capacity with respect to new increases in number and quality, and possible difficulties to face, are:

- the increase in new housing construction stimulates the production of a greater number of new housing units of better quality, and the production speed. This situation creates a suitable basis for development, through its encouraging and positively directed pressure;
- the basis for a greater volume of production of materials achieved by the building industry, which gained ground and covers today all the needs of a specified number of buildings, stimulated secondary branches of industry in order to meet the increasing needs;
- the foundation of new organisations to produce new types of material, suitable to local conditions and of better quality, will not expose them to the various pressures from similar industrial organisations, established parallel to those of the developed countries and which have already amortised their foundation expenditures;
- newly produced materials will not compete with various materials, the use of which have been established in this country, but will fill the gap and meet existing needs: e.g., brick of best quality constitutes only a very limited part of the whole production of new materials for walls; – e.g. lime, grit, etc., of good quality may always find a place in the materials market. On the other hand, in this country, iron and steel industries, as well as the secondary industries deriving from them, have not developed; therefore, the origin of the greatest part of the elements used in construction could be plastic materials, and the establishment of an industry producing plastic building materials may take place with less difficulty in Turkey than in developed countries;
- generally, the establishment of such plants meets with difficulty with respect to external and internal financing resources. These countries will make the higher percentage of their investments in the field of production, in order to achieve their development, and the share from the financial resources of the building materials industry, which may be considered as a consumption field, will be restricted and limited, in comparison with other investments;
- if the use of newly produced material creates the necessity for technical knowledge, different from the one already acquired, difficulties will arise in providing an adequate labour-power;
- if the newly produced material is not of the kind that can be readily accepted and easily used by the majority of people, it will not establish itself in the building industry.

Above, we have studied the various aspects of the development of the building materials industry. Now we will try to look for the possibilities of the industrialisation of building and examine how industrialisation may help to solve the present housing problem in Turkey.

Due to the close relation with the secondary industries, the building materials industry found the opportunity to follow the developments in technical fields and to make great use of them. But, the situation is far from being the same for the building industry, which includes various other industrial branches. The inadequate development in the building industry is not peculiar to Turkey, but also to some of the developed and developing countries. One of the important reasons for this is the fact that the character of the production of building and especially housing construction, which in turn is a production of the building industry, differs from that of other branches of industries, from various functions to be performed and from several operations and materials to be used in building. Consequently, the industrialisation of building procedure has not been realised in a short time and without difficulty. Only recently, efforts towards revolution in the field of building have been made. Thus, the building industry has been established as a production of a certain pattern.

Through the development of the building material industry and its effect on building, industry may be best assisted from the technical point of view. In the developing countries and particularly in Turkey, the establishment of an entirely industrialised method of building may be inadequate to solve the housing problem on a large scale. This method may only be applied in certain places to meet the needs subject to certain conditions.

The reasons for this are:

- during a certain period, the above mentioned system necessitates a great amount of initial capital and the undertaking of a yearly production of a higher number of units. This may only be possible in the countries in which the housing demand is suitably organised;
- in the developing countries, in which a liberal economic system is applied, there is much difficulty in the field of preparing suitable ground, which is limited to certain conditions;
- the difficulty, and in many cases impossibility, of transportation of heavy building elements;
- the difficulty of a country-wide establishment of a building industry which needs the support of secondary branches of industry and skilled labour power;
- costs of fully prefabricated buildings are generally higher than the costs of buildings erected by other methods, in the countries in which prefabrication is newly established. This situation also creates difficulties in introducing such methods in Turkey.

Finally, according to the above explanations, we must admit the fact that in Turkey, the building industry must not take the form of an industry of heavy building elements. The establishment of a small sized building elements industry, which will not make necessary the introduction of very complicated techniques, will be more suitable to our present conditions.

In Turkey, the necessary industrial support must be provided to increase the speed of integration of those who migrate into cities. Various health problems of a social character, due to changes taking place during generations, may be eliminated, or their inconveniences reduced by this possibility. For this purpose housing may be used as an effective agent facilitating the adaption of the immigrants, accustomed to their former conditions of living, to their new environments. Even the minimum possibilities facilitating living in the house may be of great use. Thus, the feeling of satisfaction and pleasure due to this, may create the necessary conditions for the acceptance of the changes. The dissatisfaction due to the former living conditions may accelerate the process of acceptance of change.

In order to obtain positive results from such a method, it is necessary to start from the habitual living method or from a level showing minimum difference, and to make the immigrants accustomed to the change. If big efforts are made for the purpose of obtaining great changes, there is always a risk of stopping or diminishing the speed of the desired adaption.

Housing instead of being used as a refuge for the continuation of application of old habits, must be considered as an element giving birth to the phase of entering into a newly settled living order.

These conditions may only be realised with the help of the industry, and success can be achieved by an adequate knowledge proceeding from the analyses of the attitudes, studies of habits, and beliefs. Today, many elements of urban housing are prepared according to the living conditions of other communities in Turkey. This situation either makes the adoption difficult or hinders the use of these elements. The industry must create the means which will produce the best change, as far as possible, with respect to a happy and productive life, starting from the social level of initiation of the immigrants, who will occupy the urban houses. For the purpose of meeting the needs directed towards a certain change, necessary elements must be planned in order to be added to each other easily, in series, or in some cases, replaced. Only through this method may the desire for a better mode of living be stimulated. For example, if a large closet in the house in which the beds are put, is built in order to serve in the future as a closet for a folding bed-stead, or if a draining board can be easily added in future to a kitchen sink which meets the present needs, then, and in turn without calling for any modification, the necessary conditions for the development would be created.

Conclusion. To reach the capacity for meeting the present needs cannot be expected in Turkey by the application of existing building systems. Building activity may make progress if this system is nationalised and factors destined to lower the housing costs and to increase the speed of production are introduced in the traditional methods.

The development of an industry producing small-size building elements by employing a low number of skilled workers, may help to reach the desired goal. The production must progress gradually, by starting with most simple elements. Such a system will not necessitate skilled workers on the building sites, proportional to the increasing number of housing units; thus, in accordance with conditions in Turkey, employment fields will be created for numbers of unskilled workers. Today the products of the building industry are of the quality to meet only the demands above a certain level. The greatest part of these are below this level. Therefore, existing limits must be enlarged in order to meet the demands varying from the needs of a primitive living system, to the developed needs of an urban living system. Desires for better living conditions will create needs in course of time. While passing from the simple to the developed, the existing elements may be used with some additions, without being eliminated. The existence of a chain of industrial products, in which elements may be added to each other, is necessary, from the point of view of development.

J 4

J. Biétry

A building programme for a developing country

By J. Biétry (France)

It is convenient to class the population of a country in four income groups:

Group 1: The wealthy, who earn more than 1,000 Francs ($ 200) a month.

Group 2: The middle class—civil servants, "white-collars", skilled workers and small traders—who earn between 200 and 1,000 F. ($ 40 to $ 200) a month.

Group 3: Those in steady employment, earning just enough to live on: 200 F. ($ 40) a month.

Group 4: People with no fixed income: out-of-town people newly arrived in the city, seasonal agricultural or very badly paid workers, and owners of very tiny properties.

The proportion of each of these income groups in the population of a country reflects that country's stage of development.

In a highly-developed country, group 4 does not exist; neither does group 3. Group 2 is in a minority. In a developing country, on the other hand, groups 1 and 2 are in the minority, while groups 3 and 4, often in equal proportions, account for most of the population.

How can families in each of these four groups be housed? As a first approach, we may accept the conventional rule that a family can aspire to a dwelling whose cost is two and a half times the family's annual income.

Those in group 1 can thus aspire to housing units costing more than 25,000 F. ($ 5,000). It is easy to build a dwelling for that price anywhere.

Group 2 is entitled to aspire to dwellings costing between 6,000 and 25,000 F. The upper bracket of this group can thus aspire to housing similar to our social buildings, either as tenants or as ultimate owners under a hire-purchase system. In highly-developed countries, this income group usually benefits from financial aid for its housing. This would be much less justified in a developing country, if only by reason of the high interest rates generally applied.

The lower bracket of group 2, along with group 3, can hope for housing units costing 6,000 F. ($ 1,200). For this price it is possible to build proper, minimum-standard, small housing units (useful area 30 to 40 square metre), meeting all the absolute requirements of the occupants. Such units, mostly ground-level constructions with a patio, a courtyard or a small garden, exist on all continents. This is minimum-social housing.

In this income group, it is not very logical to aspire to ownership, because one scarcely earns enough to live on. Nevertheless ownership facilities are often offered.

For group 4, whose members have no income, it is not possible to plan a dwelling that can be paid for in the usual way, for these people can pay neither rent nor annual instalments.

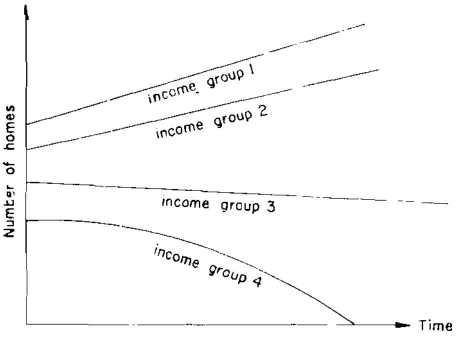
Only one solution is possible, namely "self-help" building, known as *systéme castor* in French and *ayuda mutual* in Spanish.

This is the solution traditionally adopted almost everywhere. The family builds its own hut, or the population of the village build the house of the newly-married couple, some of those concerned being more or less specialized in the work. The self-help system uses the same labour force to build imported structures, thanks to the use of imported materials, instructors, and proper plans, all provided by the public authorities.

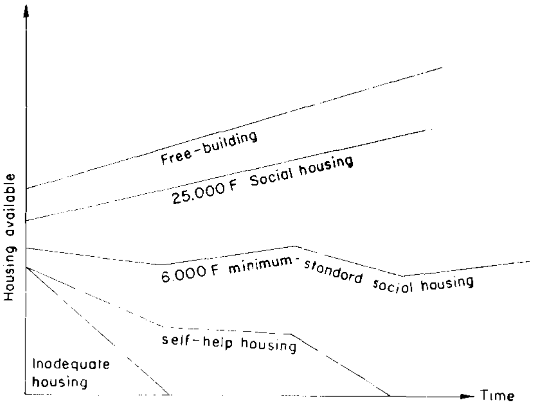
Figure 1 shows the desirable evolution of the breakdown of the population by income groups; we see the general population growth, the disappearence of group 4, and the development of groups 2 and 3.

Figure 2 shows the desirable overall housing picture corresponding to the evolution of incomes. This housing programme must take into account the fact that a housing unit that is built is made to last; the breakdown of housing units by income groups must therefore be ahead of the breakdown of the population by income groups.

Thus inadequate housing, which represents a large part of present-day housing (and which is occupied, moreover, not only by families in group 4, but also by families in group 3 and even group 2 in places where the housing crisis is severe) will not be replaced totally, but only partially, by self-help housing, the balance being made up by minimum-standard social housing (for 6,000 Francs a dwelling).



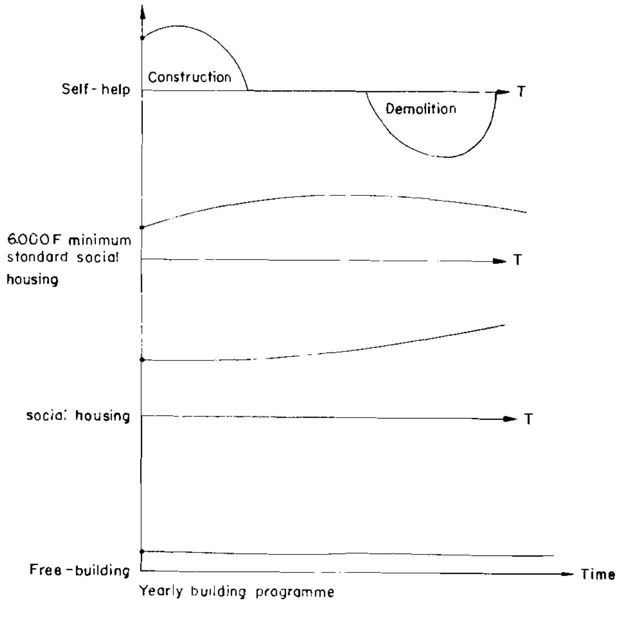
Breakdown of homes by income groups



Number of housing units in different categories as a function of time

The self-help solution must also be considered as a temporary one: when the income level rises, it is abnormal that families should continue to build their own houses, even with advice and help. The normal situation is for houses to be built by professional builders. Moreover the self-help housing should therefore become redundant as soon as possible, that is to say demolished.

Minimum-standard and normal social housing must be built annually in equal quantities at the beginning. As time goes on, incomes will rise, the number of minimum-standard housing units built annually will reach a maximum and then drop. On the other hand, the number of social housing units costing 25,000



Yearly building programme

Francs will continually increase. As for housing for group 1, it should be built at a steady rate.

It is not difficult to lay down these programmes. I think that it is a mistake to devote too much time to preliminary studies of needs; the income situation is known, in broad outline. This knowledge is sufficient to lay down the first year's programme. And there is ample time subsequently to make adjustments in the light of observations.

The question that arises after the programme has been laid down is the way in which it is to be implemented. In general, the present rate of construction in developing countries is insufficient, very much so. This is due to lack of money and of labour, and also to indifference. As a general rule therefore new means are necessary to implement the desirable programme. We shall deal here only with the technical aspect of the question.

To build more, there are two solutions: opt for traditional building and train qualified workers, or decide upon industrial building methods.

If the former solution is adopted, it is necessary to train a labour force which is disappearing in highly-developed countries, after having reached its apex in the eighteenth and nineteenth centuries. In these countries it will be increasingly limited to the maintenance of older buildings. But developing countries do not have many older buildings to maintain.

In the second solution, the workers' skill is made up for by the use of machinery; the labour force then consists of machine operators, erectors and mechanicians. More intelligence, good sense and quick judgement is demanded of this labour force than manual skill; it is today's industrial labour force. And it is readily convertible to other industries, which is not the case with traditional skilled building labour.

The adoption of industrialised building methods sets the problem of investment; developing countries often consider that they cannot make investments in building.

Two considerations must come in here: it must not be thought that a skilled worker's training costs nothing; on the contrary it is a substantial investment. To build one house a year, six month's work by a skilled worker and six month's work by an unskilled labourer are required. The training of a skilled worker in a developing country costs the national economy about 3,000 F.; the creation of a production capacity of one house a year thus costs about 1,500 F. under this system.

The industrial process which demands the highest capital outlay, i.e. the assembly of large factory-made panels, requires an investment of 5,000 F. for a production capacity of one minimum-standard social dwelling a year; and processes such as on-site prefabrication or pouring concrete in large moulds involve investments ranging from 1,000 to 2,000 F. This, as we see, is in the range of the investment required for training a skilled worker.

The second consideration is the practical impossibility of training skilled workers in sufficient numbers to cope with the large-scale building programmes that are necessary. This impossibility is due to the lack of instructors. The whole world's annual housing construction needs a total of tens of millions of units; which means tens of millions of skilled workers. If the problem is thus looked at in its entirety, it is clear that only the industrialisation of building methods will make possible the construction of dwellings at the necessary rate.

The self-help system does not come into this industrialisation picture; during the transitory period when it is necessary for the improvement of the housing of the poorest peoples, it requires skilled labour for conducting the self-helpers; but the need is relatively light: one erecting instructor for the building of 50 dwellings a year.

The general lines along which a building programme should be implemented are therefore as follows: the self-help system (with preferential allocation of the country's own skilled workers as instructors) for group 4 housing; and industrialisation, to the very extent of the country's investment resources, for groups 3, 2 and 1.

J 5

L. Carretié Juliá

Architectural problems in the industrialisation of building in the developing countries

By L. Carretié Juliá (Spain)

This paper discusses the need for an international consultative organisation on the industrialisation of building (O.I.C.I.) in order to determine the industrialised techniques best suited to the architectural character of a particular region.

The human element of a country varies according to both demographic growth (difference between births and deaths), and migration balance (difference between emigration and immigration). In Spain, considering the future probable development of birth rate, mortality and migrations, the annual average rate of growth has been evaluated at 11.5 per thousand. This figure which, for various reasons, differs from the one obtained by the geometric growth formula was partly established for the following reasons:

- lower transoceanic migration;
- greater emigration to Europe;
- the number of aliens will stay the same as in the past ten years;
- the policy of protection to births and family;
- the mortality coefficient will be 8.5 per thousand during twenty years (1).

It is evident that this demographic movement is one of the main reasons for an increase in the rate of building being required. The total dwelling needs for the period extending from 1961 to 1976, taking into account, apart from the demographic increase, other principal factors which contribute to accentuate the problem are shown by the following figures:

	dwellings
estimated deficit at January 1st 1961	1,000,000.–
necessities coming from the demographic growth	1,550,828.–
existing buildings obsolete	911,072.–
requirements for home migration movements	252,000.–
	3,713,900.–

The annual average is consequently 232,118 dwellings.

According to the "Bulletin annuel de statistiques du logement et de la construction pour l'Europe – published by the United Nations Economic Commission for Europe in 1959 it was calculated that, in other European countries, the annual population coefficient growth (for all Europe) is 7.68 per thousand inhabitants. The number of dwellings built during the period 1955–1958 is 5.15 per thousand inhabitants.

Considering the Spanish demographic growth (11.5) per thousand and the European average, it appears necessary to build 261,470 dwellings in Spain each year (in the period 1960–1976) to maintain the European rate of the years 1955–1958. This European rate has been established without considering East and West Germany and U.S.S.R., which differ greatly.

As a rule, and particularly in countries in full development, this important construction volume – foreseen in Spain by the "Plan Nacional de la Vivienda" – presents various problems. This volume, which cannot be reached by traditional construction methods, needs to find a new technique – industrialisation.

How can we successfully solve this, differently controlling and directing it, and resolving any problem which might arise? Would the creation of a Consultative International Organisation of Industrialisation of Construction (OICI), orientating and investigating the industrialised techniques, and able to determine the architectonic character of each latitude or country, facilitate this difficult work?

The really industrialised precast techniques which are developing through the world can be classified in four main groups:

- small precast elements systems;
- previous precast structure systems;
- selfbearing panels systems;
- other systems i.e. deployment or mechanised elevating.

As regards transport and assembling we should distinguish between the light, medium and heavy precasting. According to the point of mechanisation, there are:

Permanent factories, which set up installations of a considerable cost in grounds, sheds, machinery, auxiliary workshop, etc. Its limitated action radius (100 km) requires a large construction industry.

Semi-permanent factories, with provisional installations and which need smaller investments. Recommended particularly for a minimum of 300 to 1,000 dwellings.

On the spot factories, with limited investments (simple sheds or open-air). Recommended for 200 to 500 dwellings as a minimum.

These techniques, which will generally have to cover important construction programs require much more technical and economic study which, of course, present initial common characteristics and which will be better examined by a common centre.

Necessity to use industrialised methods in developing countries

In the developing countries the sudden decrease of rural population makes more acute the problem of urban concentration. Apart from the dwelling problem – a consequence of the disproportion between the population and the architectonic production – the lack of specialisation is deeply felt. In Spain 700,000 workers are employed in construction, i.e. 5.75% of the active population of the country. Nevertheless 85% of them are coming from the country. Of the total construction workers only 35% are qualified ones while 55% approximately are unqualified. The remaining are administrative and technical staff, management, etc. Even if industrialisation of construction is reaching a high level in various countries, the new technique is small compared with the whole architectonic activity. The greatest part of the actual production is realised with traditional processes with the help of precasted elements. Nevertheless a tendency to employ new techniques can be noted.

The following schedule will show the type of construction used for buildings erected in Spain in 1962.

	Structure				Walls		
	reinforced concrete	iron	wood	various	cement stone	blocks	bricks
1st 6 months 1962	3,934	125	186	504	646	157	3,944
last 6 months 1962	7,002	209	151	–	866	404	6,092
total	10,936	334	337	504	1.512	561	10,036
percentage of total number of buildings	90.30%	2.75%	2.78%	4.17%	12.49%	4.63%	82.88%

	Roofs			
	Fibro-cement	slate	tile	terrace
1st 6 months 1962	197	70	3,118	1,362
last 6 months 1962	114	156	5,396	1,696
	311	226	8,514	3,058
percentage of total number of roofs	2.57%	1.87%	70.30%	25.26%

Without complete data about the volume of construction with totally industrialised techniques, the total volume of this type of construction can be estimated at 8% of the whole construction realised. Should we increase the volume of construction with industrialised methods the number of skilled workers could be reduced to 10% from the 35% mentioned above. The need for industrialised methods is evident if we consider that the production rate can reach 16 dwellings a day with two teams and an assembly centre of an action radius of 80 km and that, as regards the economic point of view, we know that the cost reduction varies from 15% to 35% for 5,000 dwellings. Should we consider that wages would be increased this reduction would be more important. In Spain the following increase in the labour force has been noted:

	november 1958	november 1963
1st class hands	7355	14618
assistants	6370	10911
specialised workers	5207	10454

Architectural problems in the particular circumstances of developing countries

The position of architecture in the world can be considered as follows: only 20% of the whole production is influenced by architects and of this 20% only 2% are under complete control of an architect. It can be admitted that only 5% of the world buildings are designed by architects. This percentage is greater in the developed countries. This situation evidently causes damage to the creation of a good architecture. Industrialisation needs complete control by the architect. The architect will have to take care of the relation between the traditional and the industrialised. The traditional solutions have generally such a force that the majority of the local solutions are connected with them.

Architecture is not only dedicated to building public monuments. Its first mission is to create a "habitat" which will be better each day and, for this, the inspiration will be found in the local solutions. In Spain there are many different architectural styles and materials, as a consequence of the geologic, climatologic and social factors in which building has developed, e.g. (Catalan, Extremenian, pisé and Alpujarra vaults). These are, to date, the most functional, economical and worthwhile solutions. Therefore it is evident that industrialisation has to have national character because whilst techniques may change, the former buildings remain. But industrialisation, a complex technique with common phenomena, must have a principal focal point e.g. OICI.

Flexibility of industrialisation

For all the above, a flexibility in industrialisation becomes necessary. Its creation cannot be equal everywhere. The "art-craftsman" view of architecture cannot last, because of its incapacity to overcome the existing problems; but a standardised, worldwide architecture cannot be followed up. The introduction of standard international elements is experienced in places where machinery has a vital importance (docks, airports, railway stations, etc...) and they become the heart of the city. Machines can be universal, architecture cannot. Local necessities must be more and more respected and a medium between these and the required technical evolution should be found. The contrary would be an unfortunate measure. (The same joints, panels, type of factory which have good results in a certain place, may not be adequate for a different one). In Spain, the semipermanent factories and those on the spot which do not require excessive installation expenses seem to have an economical success (see figure 1). For those areas in which closed, low and open volumes are convenient, for example, inside courts, etc., the prefabrication of three-dimensional elements may be preferable. This means that our architecture must possess the same original aspects required by technique, and the solutions will be different in each place and therefore will take their own characteristics from the spot.

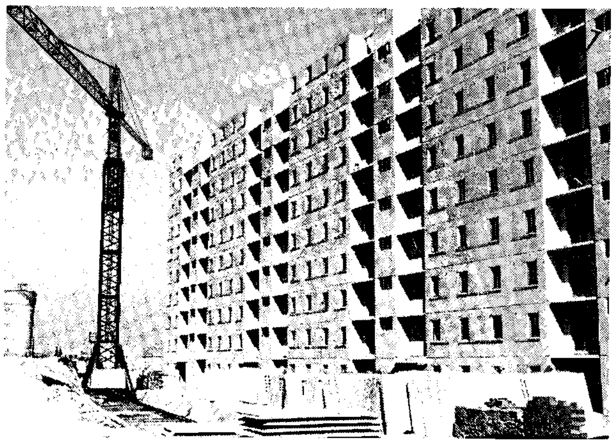


Fig. 1. Industrialised building should not be strictly standardised. It should retain characteristics of its locality.

Conclusion. We have considered the main causes due to which it is necessary to industrialise construction, and we have seen that prefabrication techniques are capable of settling the present needs. Nevertheless, the dangers involved in this evolution have also been mentioned. An international control, with a panoramic vision of the problem, may avoid the confusion mostly due to the excessive number of small construction firms which in most cases do not have the proper technical assistance and professional advice. In the particular case of Spain, there are 32.000 construction enterprises.

The first common phenomena of industrialisation are:

- normalisation and rationalisation of projects, plans and construction process;
- coordination between construction and auxiliary and complementary industries;
- availability of prefabricated materials;
- mechanisation;
- speed in administration and official contracts.

These topics should be studied by an International Control

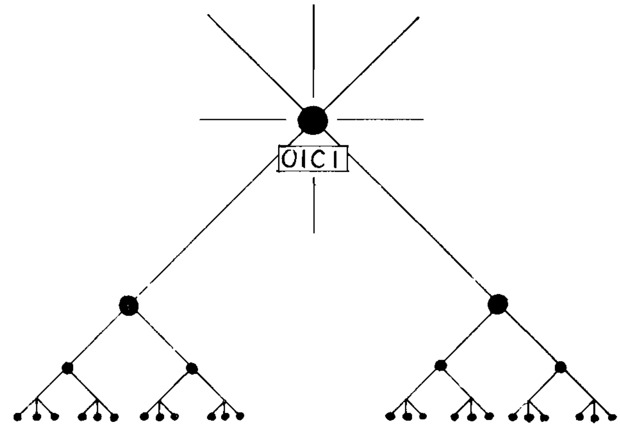


Fig. 2.

acting as focus and guide of efforts, considering at the same time the prominent features of standardisation and craftsmanship. The confusion is originated by the influence of many non-coordinated centres in architectural creation. The industrialised architectural production has to be in full agreement from the local to the international level.

We could certainly say that not only a few countries but also the world is now in a period of development. The future construction perspective needs powerful media to cover extensive programmes. This will undoubtedly involve an international approach between professional people, and countries cannot remain apart. This ambitious task could be carried out by combining the many component forces, namely: economic, social, political, administrative, technical and esthetic. They are common forces from all the countries, created by the necessity of promotion, firstly at local levels and then among higher ones.

This is an international subject, but its local aspect must be seriously respected. The creation of an International Consultative Organisation on the Industrialisation of Building (OICI) with adequate delegations and branch-delegations may be the way to attack the problem with some guarantee of success. We have considered the convenience of this creation and we think it is the right procedure to follow up the development of a world wide technique, "industrialisation", which, being at the service of a science, "architecture" must be used to solve many different problems.

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J 6
F.A.O.

Industrial panels from wood and agricultural residues in the service of better housing for developing countries

Prepared by the Forestry and Forest Products Division of the Food and Agriculture Organisation of the United Nations, Rome

World population is growing at the explosive rate of 60 million human beings a year and is expected to swell from some 3,200 million to around 7,000 million by the year 2000. Almost two thirds of the world's present population live in the developing countries where population growths are staggering (between 1960 and 1963 India's grew from 429 million to 458 million and Latin America's from 211 million to 229 million)[1]. Simultaneously with the feeding of hungry mouths, provision of shelter is a matter of immediate concern.

The problem of housing has two facets—chronic and epidemic. The situation prevailing in the developing countries may be deemed as chronic and the scarcity caused by war damage, hurricanes, earthquakes etc. may be categorized as epidemic. Most of the war damage was caused in the highly developed countries and is not altogether relevant to the present study but steps taken in rehabilitating those areas can help the developing countries as a guide in planning.

In the developing countries, the situation has been such that in general the population was dependent upon a rural economy. The population was spread over the land in small dwellings. Many of the villages could well be called clusters of dwellings. The needs of the people were limited and these dwellings were erected with local aid and material, the money aspect playing only a minor role. Sanitation, as we understand it today, and plumbing were conspicuous by their absence. Even though the art of building has flourished since time immemorial, its impact was limited to important cities or temples, the countryside being left to look after itself as best it could.

The all out campaign by the various agencies of the UN against hunger and disease has resulted in increasing the lifespan of the populace in the developing countries and has also caused them to desire a better way of living. These circumstances combined with an ever expanding population created a situation where an already difficult housing position has become even more acute. The impetus given to industrialisation in these countries has encouraged the mass movement of people from rural "scatterings" to highly concentrated urban areas and industrial sites. Existing accommodation in the latter areas was already ill-fitted to the needs of the local inhabitants and this influx of men, women and children further aggravated the situation. Makeshift arrangements could not but deteriorate into shacks and slums.

Housing demand and need for industrialisation

According to the Economic and Social Council of the UN[2] an estimated 24 million housing units need to be built annually in the developing countries for the next 30 years to overcome the present shortage and to meet future demands. How then to cope with this astronomical task? The centuries old methods of construction, though often excellent in themselves, will hardly take us anywhere. As in the past only a fringe of the population might get the benefit of housing in that case. A break-through is the only answer. Industrialisation of house construction is urgently needed. Most of the ingredients for industrial development are there—demand, urgency, social consciousness, skills and the constructional materials required.

Experience in more advanced countries clearly shows that building output may be increased many times by prefabrication, and production by industrialised techniques simultaneously reducing the cost of construction. For example, in the Soviet Republics of Central Asia it has proved feasible to reduce the cost of house construction by 15 per cent and to reach the quantum of construction to 10 dwelling units per 1,000 inhabitants per year compared to that in some other countries of 6 units only[3] According to recent accounts[4] industrialised methods in the Soviet Union have increased precast component production for building construction 15 fold within the period from 1954 to 1963, which is expected to save nearly $1,680 million in 1964 and release nearly one million building workers for other activity. By these methods the overall weight of the building could also be brought down to only one third that of traditional bricks and mortar. Nearly 200 factories are engaged there in large panel house building. In Sweden A.B. Hultopedo Industriena has programmed to build 25 houses a day[5]. In the UK several consortiums have been formed for the mass production of standardised components for prototype homes. A period of 11 months, normally required to erect a house may be cut down to only 6 weeks. A saving of 20 per cent in site labour is envisaged. In the near future even blocks of 10 to 30 storeys will be taken in hand[6]. The importance of industrialisation in housing can be gauged by the fact that leading manufacturers of petroleum products are also undertaking joint ventures with building corporations to exploit new methods of prefabricated building[7]. These facts show that industrialised methods of house construction are gaining in importance not only in highly industrialised countries but also in some of the more remote areas of the world.

In the developing countries considerable finance needs to be earmarked by the governments to provide the necessary impetus to industrialised housing. In the long run such a venture may even bring substantial revenue to the national exchequer when it is realised that on average housing accounts for 4 per cent of gross national product and 20 per cent of total investment. There is need for greater attention on the part of UN agencies to housing, especially when it is seen that only one per cent of the UN budget is devoted to this activity[8]. Government aided corporations or consortiums need to be formed to tackle the housing problem. The size and the component of such bodies would necessarily vary with the type of housing undertaken.

In order for industrialised techniques for housing to be successful there is need to mass produce prototypes, sacrificing to some extent individual taste. Large size factory-made panels with specified quick fit and integrated individual units are required. Minimum on-site construction and minimum wet-method techniques are essential. In an urban house, for example in Latin America, built by traditional methods, building materials account for approximately 52 per cent and labour 41 per cent of the total cost[9]. Thus if both these items could be reduced by prefabricating the components, a very substantial saving in unit cost would be secured.

Wood based panels

Wood products are hard to beat as building materials for factory finish, ease of working, aesthetic appearance, warmth of texture, high strength (weight for weight higher than steel), universal availability, dry construction etc.

Despite some trend towards lessening the use of timber in 1955, even in highly industrialised Europe 17 million m^3 of sawnwood was consumed in new housing. About 3 per cent of all new dwelling units were wooden houses and an estimated 2 to 2.5 million m^3 of sawnwood was used in their construction[10]. An estimated 98 per cent of all prefabricated houses built in the USA in 1957 were of wooden frame construction[11]. In the UK there has been great interest in housing construction based on Canadian style timber houses which is expected to cut the construction time to half with a considerable saving in fuel consumption for heating the rooms[12]. The pressing education problem is being partly met by recourse to wood construction for school building[5].

Because of the scarcity of traditional timber, some inherent limitation of wood properties and high prices ranging in the market, some non-wood materials such as aluminium, plastics, light weight concrete have displaced wood to a certain extent in house construction. This has been more than compensated by the so-called wood based panels which have been increasingly used for multifarious purposes. Development of wood based panels has overcome many of the inherent defects in natural wood and made available products with greatly improved properties.

Manufacture and uses

These panels manufactured industrially from wood or agricultural residues according to different requirements under rigid quality control, may also be custom-made and produced in large sizes ready for use. Such panels are identified by their nomenclature—plywood, fibreboard or building board, particle board, blockboard etc. In many instances they are interplaceable, but essentially each possesses special properties pertaining to specific jobs. Thus plywood made by gluing at right angles to each other three or more veneers obtained by peeling or slicing wood, gives panels of exceptional strength both along and across the grain commensurate with light weight. Plywood is marketed in different thicknesses of 3 mm and above and usually in 8′ × 4′ or larger size panels. Fibreboard is manufactured from pulp obtained from small pieces of wood or agricultural residues such as bagasse etc. by subjecting it (the pulp) to high pressure and heat to give hardboard or to low pressure and dried to yield insulation board. The fibreboard panel has uniform properties and is marketed in several sizes, thicknesses and densities. Common sizes are 8′ × 4′, 10′ × 4′, 16′ × 4′ and the thickness varies from 2 mm to 10 mm and above. Greater thickness is more common with insulation boards.

Particle board, the latest to enter the field, has seen a phenomenal expansion. In its manufacture, particles of wood or agricultural residues are bonded together with a resin or adhesive, under different conditions of temperature and pressure to give a panel of good rigidity and uniform properties. Single and multiple layer panels in different densities and of special properties are produced. Particle board may be obtained in several thicknesses but ¾″ is most common. The size commonly in demand is 8′ × 4′ but larger sizes can be had. Blockboard, on the other hand, is a special type of plywood construction possessing high stability and rigidity. Plywood, and other types of panels, can be made waterproof, fire resistant and resistant to decay. They can be produced in innumerable types of designs and overlays to meet individual requirements and tastes. Properties these boards enjoy in common are the ease of working with the usual wood working machinery and tools, and the warmth of texture associated with wood.

The following table shows apparent world production of these panels in 1960 and the developing countries' share of total world output.

TABLE 1. Apparent Production of Plywood, Fibreboard and Particle board in 1960

Type	World 1,000 m tons	Developing countries 1,000 m tons	Developing countries Per cent of total world
Plywood	10,020	669	6.5
Fibreboard	4,250	258	5.7
Particle board	1,775	53	2.9

Source. International Consultation on Plywood and other Wood Based Panel Products, FAO, Rome July 1963. Secretariat Paper VI.

Recent years have seen a great expansion in the manufacture of these panels and many new plants have gone into production in the developing countries.

Panels manufactured by compressing straw, stitching or else overlaying it with thick strong paper and boards made from disintegrated wood waste, have been used in a number of places in housing units. Other boards such as mineralised wood wool, plasterboard etc. are beyond the scope of this study.

Wood based panels have revolutionised the use of wood products in different spheres, especially in housing. Not only have they made a very much larger wood-surface available but they have lent a new meaning to panelling, ceiling, partition, flooring etc., materially assisted in the mass production of furniture and made available handy material to the amateur builder.

Repairs and renovations, additions and extensions to buildings already in existence have created a very substantial market for wood based panel products with their inherent adaptability and ease of fabrication. Built-in furniture, cabinets, cupboards and so on in new flats and multiple storeyed buildings have claimed a substantial share of these panels.

In the more advanced countries these boards have shown a rapidly increasing use in building construction over the last decade. The large size of these panels, their smooth surface, uniform properties and high strength have proved them to be ideal constructional material for a thousand and one uses. They have also been used extensively for shuttering in concrete formwork giving excellent finishes.

Plywood has proved to be very suitable for roofing, ceiling, wall panelling, outer sheathing and flooring[13]. It is extensively used in the fabrication of flush doors, as is blockboard. The following table clearly shows the tremendous use to which plywood (and veneer) is put in European countries[14].

TABLE 2. Consumption of plywood and veneer in Western Germany 1957—by end uses

End use	Thousand cubic metres		Per cent	
Furniture and joinery	320		51.4	
Building industry	220		35.4	
Packaging	30		4.8	
Vehicle building	12	20	2.0	3.3
Railway coach and wagon building	8		1.3	
Others	32		5.1	
	622		100	

Source. European Timber Trends and Prospects. A new appraisal. 1950–1975 FAO/UN, 1964

Fibreboard with different surface finishes has been increasingly used for roofing, panelling, partitions, built-in cabinets, flooring, flush doors etc. Experiments carried out in Sweden and in the UK have shown that composite floor boards of fibreboard are very suitable for flooring in residences and offices including multiple storey buildings[15]. Trials done in Nigeria on wall boards (fibreboards) have shown that jungle exposure caused no more deterioration than exposure in England[16]. The thermal and acoustic properties of insulation fibreboard are excellent and have resulted in continuing demand. Its use could be extensive in tropical countries where, with the reduction in size of tenements, thermal insulation will become an important factor.

In Sweden of the total 436,000 m³ of fibreboard consumed there in 1960 more than 86 per cent was utilised in various ways

TABLE 3. Consumption of Fibreboard in Sweden 1960 by end uses

End use		Per cent
Building Industry		
(a) Repairs		34.4
(b) New construction		11.1
(c) Indirect through other industries		39.3
(d) Unspecified		1.6
	Total	86.4
Furniture		1.1
Toys		0.1
Other factory-made products		6.1
Protective arrangements		1.5
Packaging		1.0
Signs, exhibitions		1.8
Hobbies		0.4
Storage		1.3
Unspecified		0.3
	Total	13.6

Source. International Consultation on Plywood and other Wood Based Panel Products, FAO, Rome July 1963. Secretariat Paper 5.7.

in building construction (see table 3). In the USSR approximately the same percentage goes into building construction[17].

Particle board with its low cost and high rigidity and lumber like thickness can be used straight away for work for the purposes enumerated above. It has been found that in some cases by the use of particle board for interior walls and partitions there is a two third saving in timber and one third saving in cost[17]. In the USA for floor underlays alone the use of particle board rose from 105 million sq. ft. or 26 per cent of total output in 1962 to an estimated 140 million sq. ft. in 1963, and is likely to go up to 165 million sq. ft. of the total expected production of 515 million sq. ft. in 1964[18]. In the USSR of the total of 330,000 m^3 consumed in 1962, about 57 per cent was used in building construction and the remainder in furniture[17]. The following table gives a general idea of the pattern of use of particle board in Europe[14].

TABLE 4. End uses of particle board in selected countries of Europe in 1959–61 per cent.

Country	Furniture	New building including built-in furniture	Building repair and renovation	Industry railways motor veh. etc.	Agriculture mainly farm building	Shipbuilding	Other	Total
Austria	75	10	10	2	–	1	2	100
Belgium	75	25						100
Denmark	35	60		–	–	5	–	100
Finland	17	31	45	–	–	5	2	100
France	40	15	33	8	2	–	2	100
W. Germany	52	25	10	6	4	2	1	100
Italy	60	40						100
Norway	20	70			10			100
Spain	45	15	15	5	5	4	11	100
Sweden	44	42		–	4	7	3	100
Switzerland	50	50		–	–	–	–	100
U.K.	60	40	–	–	–	–	–	100

Source. European Timber Trends and Prospects. A new appraisal 1950–1975 FAO/UN 1964.

In some places whole structural components and housing units themselves have been erected with these panels. Thus in Chile, about 3,000 houses have been constructed entirely from thick extruded type particle board[19].

These wood based panels got their break-through after the war when raw material for construction became scarce. Plywood and fibreboard which were already known and particle board whose manufacture had just started were readily seized upon. Their performance in practice surpassed the hopes of even the most optimistic and not only served as a suitable substitute for traditional materials but also outbid them in many a sphere.

Conclusions. These panel products, which can be manufactured from practically all types of wood or wood waste and from various types of agricultural residues such as bagasse, straw, flax shives etc., have a large and ready source of raw material in the emerging countries. Their industrial manufacture in these countries would not only make an excellent material available for local housing needs but also help in utilising available resources and add towards industrial development. The fact that in most of the developing countries wood has been an important traditional material of house construction and that there is familiarity with wood-working will surely result in a welcome response for these panels by their people.

As has been indicated earlier, wood based panel products can be given sufficient resistance against wood destroying agencies, moisture and fire, and there seems to be no reason why these boards should not prove as useful as they have been in the more developed countries. The woody structure of these panels and their insulation properties are great assets in countries with tropical or sub-tropical climates, adding to a more comfortable way of living.

Progress in Thailand, Chile, Malaya and India towards the utilization of these panels in housing and other construction has been encouraging. Much more stress however is needed on the industrialised aspects of construction to meet the world's expanding requirements of housing units, and fitments such as furniture associated with them, and this is where industrial panels based on wood and agricultural residues can and will play an increasingly important role.

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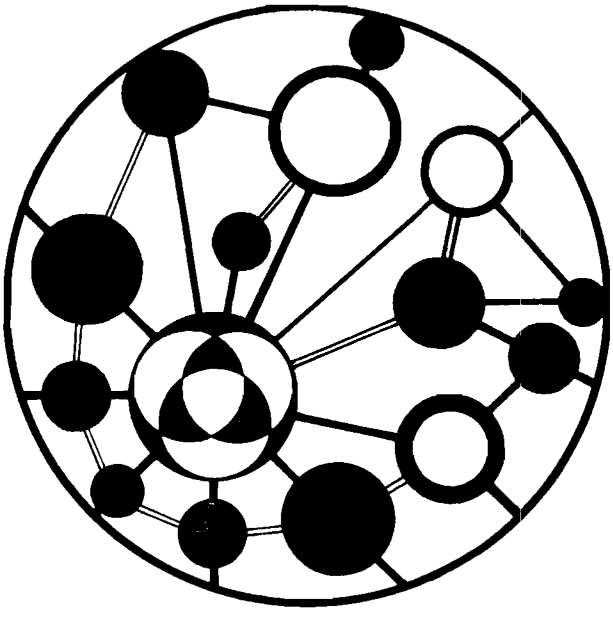
The industrialisation of building in developing countries

By M. Macura (Yugoslavia)



When we discuss the industrialisation of building activity in developing countries we must not overlook certain more or less known facts which are an expression of particularities of these countries. They can influence in a significant way the formation of the conception of process by which the building technique in these regions is lifted to a higher level, reducing thereby the inevitable upheavals to the least possible measure.

Building is not an aim in itself, and neither is industrialisation. Their purpose is the rational realisation of architectonic designs and urbanistic wholes which must be in conformity with the needs and economy of the country and correspond to all conditions—social, economical, technical, functional and esthetic—which are determined by the principles and standards of modern architecture and urbanism.

The term "developing countries" does not cover a determined homogeneous notion, but a series of very different regions. Such regions frequently include a number of countries with identical characteristics. In some cases their boundaries correspond to the state frontiers, while some others represent parts of states which also have highly developed regions.

The simplest dwellings form in these regions the majority of the architectonic fund, though there are some modern buildings as well. Some of them are the last word in technique and architecture. Built as a manifestation of an exceptional economical effort or of the policy of former colonial powers, they form a sharp contrast to indigenous architectural realisations.

Modern architecture and building technique are the product of an integral process which represents a component in the development of civilisation and culture that grew in a small part of the world.

In most underdeveloped regions the views and feelings out of which modern architecture grew do not exist. There is neither tradition nor the scientific knowledge on which it is based. The production of material and the number of qualified workers which are indispensable for contemporary buildings are insignificant. And the need of architectonic space—without which modern life and work are unthinkable—is immeasurable.

While in technically developed countries the sources of construction manpower are mostly exhausted, in the developing countries there are very often enormous reserves which at this moment, being unproductive, weigh upon their economies.

The influential factors which bear upon architecture and building technique—and thereby also upon the process of industrialisation of building activity—appear in technically developed and underdeveloped countries as values in reciprocal relation.

The influence of nature, as expressed, in the first place, by the geographical, climatic and ecological qualities of the region, creates in most developing countries special conditions of man's life and work and thereby acts upon his mind, philosophy of life, the feeling of need—which is more relative than most Europeans think—upon his work abilities, social relations and other things which are all indirectly expressed in the characteristics of the buildings.

This influence is manifested in the characteristics of buildings in a direct way as well. The protection from sun and extreme temperatures, from permanent and strong rains, from dust or excessive humidity in the air, from strong winds, from insects and other phenomena which act independently or in combination, puts before an architect and an engineer some special problems.

The economical factor, as defined by raw material resources, the level of development of the national production and the volume of participation in the international commodity exchange—in itself changeable—influences strongly the building activity.

It is a characteristic trait that in the initial phase of economic development the establishment of new productive capacities diminishes the volume of means destined for general architecture and accomodation. Also, investments in this field grow only after the discovery that it is a precondition for further economical development, namely:

- on one side construction represents an efficient impulse to the economy of a country as a whole, because it engages a number of various producers and a widely developed commercial net;
- on the other side, the finished buildings satisfy one of the basic needs of people and make it possible for them conspicuously to improve their living standards, whose growth provides the efficiency of production.

The sociological factors are expressed by the social relations in the community as a whole and in its single components. Of a particular importance are those which are manifested in the family as the basic cell of society.

Predetermined by the general culture and the education of the population, coloured by the prevailing customs and habits, their influence is felt mainly in the urbanistic planning of a city. On the other hand, those elements which are integrated under the notion of the living culture influence directly the contents and the qualities of the flat. The individual feeling connected with the flat and with living in a flat are very different, and when they are not satisfied they cause the far-reaching internal and external traumas and conflicts, both in individuals and in the frame of society.

The conception of the development of the country and the adopted political system influence architecture and building activity as a whole, and from more than one position. They, generally speaking, represent in the new states the movers of the intense general development by which they must reach in far shorter time the level accomplished by a spontaneous process which in other countries lasted for centuries. Such a development proceeds neither easily nor painlessly. It is accompanied by economical, political, social and psychological changes which are manifested in various forms.

The influence of pre-conceived ideas, collective or individual, act in urbanism, architecture and construction more strongly than in other fields of economy. Such phenomena can be eliminated only by well-studied, purposeful and realistic programmes and plans which are an integral part of the conception of the general social and economical progress.

The programme and the plans of development of urbanism, architecture and construction in these countries, must simultaneously treat the concrete tasks and the process of improvement of these activities in the frame of general rational progress. The construction in those countries can be carried through on two approaches.

The buildings of exceptional importance must be designed and realized on the basis of highest accomplishments of modern science, architecture and construction technology.

The buildings for standard use, which form the majority of the planned architectural space, represent the field in which is concretely manifested the evolution of architecture and building in the national framework.

The aims of construction of standard buildings are:

– realization of urbanistic and architectural space, together with a higher living standard of the people.

– aiding the economic life of the country and the increase of the national income.

– vocational training of a part of the population – now unqualified and economically inactive – and its inclusion in modern production.

– gradual improvement of the construction technology and the attainment of a higher level, with the perspective adoption of industrial construction.

The process of improvement of construction can be accomplished only by respecting a certain sequence, which is different from that by which the technically advanced countries reached their present level. It would be uneconomical to go through the formation of classical artisanship as the basis for large constructions, as the industrialisation eliminates it by itself. Forced industrialisation would equally be inexpedient because in most of these countries there is no developed industry of modern construction material; there are neither efficient transport facilities which are indispensable, nor the investment funds for the construction of necessary factories.

The first stage of building improvement, based on the use of local traditional construction materials and the corresponding construction procedure, is expressed by the improvement of the intellectual component in the process of building, which is the cheapest and for the final result a decisive component of that process.

By this we mean the elaboration of regional plans and plans for urbanization projects of buildings, the specific technology and the corresponding system of financing of building.

The second stage includes, beside the tasks from the first stage, some new ones as well. The construction of communication systems, of municipal services, the investments in the industry of new building materials, construction tools, mechanized workshops for the production of smaller prefabricated elements represent its essential characteri tics.

The third stage consists of the process of industrialisation itself.

The international cooperation in the task of industrialisation of the building in these countries is a precondition for its efficient and quick fulfillment.

The centre of gravity in this cooperation must be the desire to form in these countries their own intellectual and material forces. The participation of foreign experts – from whom much is expected in initial actions – must be diminished after a time to the normal level of international consultation.

The formation of domestic architects and specialists has been begun mostly in foreign universities. The system of formation of a specialized cadre in the country must begin from lower and middle schools, and then continue in high schools.

The perfection of experts and architects trained in the country through practical work or in investigation centres abroad – even now a rather frequent practise – must be developed in the widest possible measure.

The adoption of a common system of technical documentation, which we have exhaustively discussed with Professor Lars Magnus Giertz, seems indispensable.

Professional literature (textbooks for schools and manuals for practical work) is also indispensable for efficient and expedient work.

Continuous seminars should be held at which foreign experts would simultaneously participate preparing themselves for work in these countries. Experts from the developing countries themselves, who have been trained abroad, should also participate.

The conclusion drawn points to a very wide and complex task before the contemporary world. Architectural and urbanistic space is one of the essential preconditions for the existence and the work of the people, and its realization demands enormous means and efforts.

It is in the interest of all peoples that the developing countries be included as quick as possible, with equal rights, in the advance of world community and that they participate in the progress of science, technique and economy.

Considerable thought must be undertaken by the representative of mankind – the Organization of the United Nations.

The task of our international organizations CIB and U.I.A. and us experts is to assist it in the fulfillment of this task.

This report has been made on the basis of the analysis of experience in underdeveloped parts of Yugoslavia, unofficial information of Yugoslav experts working in developing countries, the data from professional and general literature on these countries, discussion on this question held in Delft (Holland) under the sponsorship of U.I.A. and on the basis of this author's report submitted on the latter occasion.

J 8

S. B. Mendelsohn

The impact of industrialisation on the architectural design of housing in developing countries

By S. B. Mendelsohn (Israel)

This paper is intended to be a progress report highlighting some of the approaches, studies and interim conclusions made so far in a wider research entitled, "Towards an architecture for the needs of the Developing Countries", which is being carried out in the Faculty of Architecture of the Technion Israel. So far this study is very much in the developing stage itself. The basis for the work is a study of problems that beset typical countries in different regions of the world and the impact of these problems on the development and progress of architecture of which industrialised building must become a more prominent part.

Developing area

The term developing area can be applied geographically speaking mainly to three regions – Asia, Africa and Latin America. The bulk of the developing countries in these regions lie between the Tropics of Capricorn and Cancer. They are regions which include countries in desperate need of achieving higher levels of living for the majority of their populations.

The basic problems

The overriding problem which faces the world is the rapidly expanding population. Statistics produced in recent years show that the existing population will be doubled within the lifetime of the present adult generation.

This problem could involve the world in a serious crisis and unless properly anticipated will seriously affect the liberty and freedom of the individual. It must however be looked upon as a positive problem. Unlike the threat of a nuclear war or man thinking he is forced to use negative reasons for his preservation, the increase in population is arising out of man saving himself from disease and early death. Life expectancy in many of the traditionally depressed countries has increased considerably and 'three score years and ten' no longer only applies to the more advanced nations. The paradox is that the birthrate is declining.

This will mean that in only a few years time the expanding population will have a much higher proportion of old persons. The sociological implication of this for architects in designing dwellings will be considerable and will radically affect policies, programmes and planning. But the basic problem of the near future will be an expanding population on (generally speaking) an inextensible land surface. According to provisional estimates compiled by the United Nations Statisticians, the population of the world on January 1st 1965 should be over 3,100 million souls, increasing at a rate of 1.5 percent. The fixed land area is put at 36,586 million acres. There have been reclamation schemes which have added to the land surface. The Zuyder Zee in Holland will serve as an example for many future projects. In densely populated countries and conurbations vast populations are already living in boats or elevated houses over rivers. From Japan has come dynamic projects for housing vast populations on elevated townships in Tokio Bay. Reclamation is however very small in proportion, very costly and dependent on suitable topographical and climatic conditions.

Desalination of sea water by nuclear power will enable large areas of desert land to be made fertile. This however may take some time to implement and finance.

There are many other interrelated problems arising out of population expansion which will continue to affect architecture and all aspects of building and planning.

To focus on some of these we can see how the problems are interrelated and how they produce other problems which are a danger to progressive development.

For example: Low Production = Deficiencies = Poor Nutrition Poor Housing = Poor Education = Disease = Lack of Medical Care = Low Energy = Low Production.

To promote economic development industrialisation is needed in the developing countries. In this the building industry could train, employ, and relieve a great number of the existing unemployed and thereby at the very outset help to eliminate other problems.

The needs

The need for housing is, and will be, by far the greatest need in building and the real problem in architecture throughout the world for the foreseeable future. (In addition it is estimated that, in the three regions of Asia, Africa and Latin America, the school building programme will require space for more than two hundred million pupils by the end of the 1970's – and these figures do not include necessary replacements of existing buildings).

In many countries the demand for housing is four times as great as production and even in some of the developed or more advanced countries the production of housing is merely meeting the need created by slum clearance. With this and the implication arising out of the growing populations, increased production of building is essential.

Some European countries, that have heavily invested in industrialised building have nearly doubled their housing production. In Russia between 1953 and 1957 housing production rose from under 1.3 million to over 2 million units per annum.

Existing methods and elements of design

Government housing and self help housing. Throughout the world Government housing usually depends on what the population can afford to pay. In the developing regions this has led to self help programmes of enormous magnitude. Here the government building has been very small in proportion to the demand which in some cases has been so great that it has led to squatters taking over newly-completed housing blocks that have remained empty because nobody could afford to rent them. The Caracas Superblock programme in Venezuela is a case in point. In other towns such as Lima in Peru a great number of squatters tired of their living conditions and without hope of them ever improving invaded large areas of government land and built the "Barriadas" or squatters settlements. The usual procedure was to put up a simple shelter of matting and poles to serve as their home until they had built enough of their permanent home to move in. It usually transpired that the government, faced with either forcibly evicting about one hundred thousand tenants, or legalising their acquisition at a small rental chose the latter.

In self help housing the elimination or part elimination of labour costs has enabled millions of families to achieve a basic form of shelter. This has resulted generally in one storey development which in time must prove uneconomical especially in utilization of land. If self help housing is to proceed without creating other problems then buildings of combined units will become necessary. This will call for more comprehensive instruction in building and may well lead to building science being a compulsory subject in secondary education in the foreseeable future.

In aided self help housing the standards are minimal, based on plans which can be extended. The initial area includes a place for cooking and the basic services and an area for sleeping/living. Extra bedrooms and living areas are added according to the improved resources of the owner.

In rural areas where much of the life is spent out of doors in the fields, the house is a shelter mainly for sleeping in with shade provided for outdoor living space on the porch or verandah. In all the three regions of the developing countries there are examples in rural areas of livestock (on which the families livelihood depends) being very much part of the family and with covered accommodation provided.

The basic construction and materials for 1 storey low cost and self help housing can be narrowed down as follows. Walls of stabilized earth, bricks, concrete blocks, cinder blocks or insitu concrete, with or without permanent shuttering (asbestos), or adobe walls. In some areas a sandwich of adobe with permanent shuttering has been suggested. Many areas have used timber walls consisting of frames and boarding but with the great demand and the dwindling supply, the cost and the infestation experienced in many areas, timber will not be favoured as a basic material.

However timber remains the most flexible and easily worked natural building material. With the advancement of timber technology and the creation of new timber aggregate materials, and the results of the Timber Developments Association research, it may remain an essential material both in structural and non-structural elements. This may call for programmes of increased afforestation to anticipate future needs.

Other materials in use for walling or panelling are bamboo, woven palm leaves and river reeds. Although these are unusual materials there is no doubt that simple panel components could be developed using these materials, following research.

Roof coverings are generally asbestos sheets, corrugated iron sheets, concrete slabs or insitu concrete. In some regions the roof finish depends on the velocity of the prevailing winds during the stormy season.

Trends in prefabrication so far appear to be very limited. Asbestos sheets or corrugated iron sheets for roofing appears to be the most extensive prefabricated element in use.

Some factors in developing industrialised building

There are several technological factors which are associated with this:

- Research into more efficient methods of building and their implementation in particular areas.
- Research into the development of existing materials and the technology of new materials.
- Research into production techniques.
- Inter liaison between countries and authorities on various stages of experimental research.
- The setting up of common standards and moduli for extensive use in building throughout regions.
- Industrialisation of components where possible.
- Site prefabrication where possible.

In countries with a developed economy and industry the direction towards industrialisation in building has been very marked in recent years. This together with increased research into materials and methods has given a new impetus to the building drive.

But the ever increasing need from an ever increasing population in developing countries without a developed economy and with comparatively little industry and know-how makes the problem very acute.

It is clear that if, as in most prefabricated structures, the building elements are factory made, leaving little to do on site, then the cost ratio between material and site labour would be very different than for traditional construction with maximum site labour. This could seriously affect the savings in cost of labour to the owner who builds his own house. On the other hand if prefabricated components were mass produced for a consortium of governments with combined budgets, the cost per component would be reduced through bulk ordering. Haulage costs will involve other problems, especially in countries with an undeveloped road network. In these cases the eventual development of prefabricated elements would depend on the positioning of factories for the housing need, or the development of simpler elements which could be cast on the site, and light enough to be handled by two men.

Standardised components bulk purchased by a consortium of Governments, with agreement on modular coordination would greatly reduce budgets.

A Federation of building industries serving several countries may continue a mutual aid programme, and would result in a basic standard of architecture and construction being ensured.

The direction towards industrialisation in building is associated with the technical considerations already listed. But it is also associated with many other factors in its context of architecture as a whole.

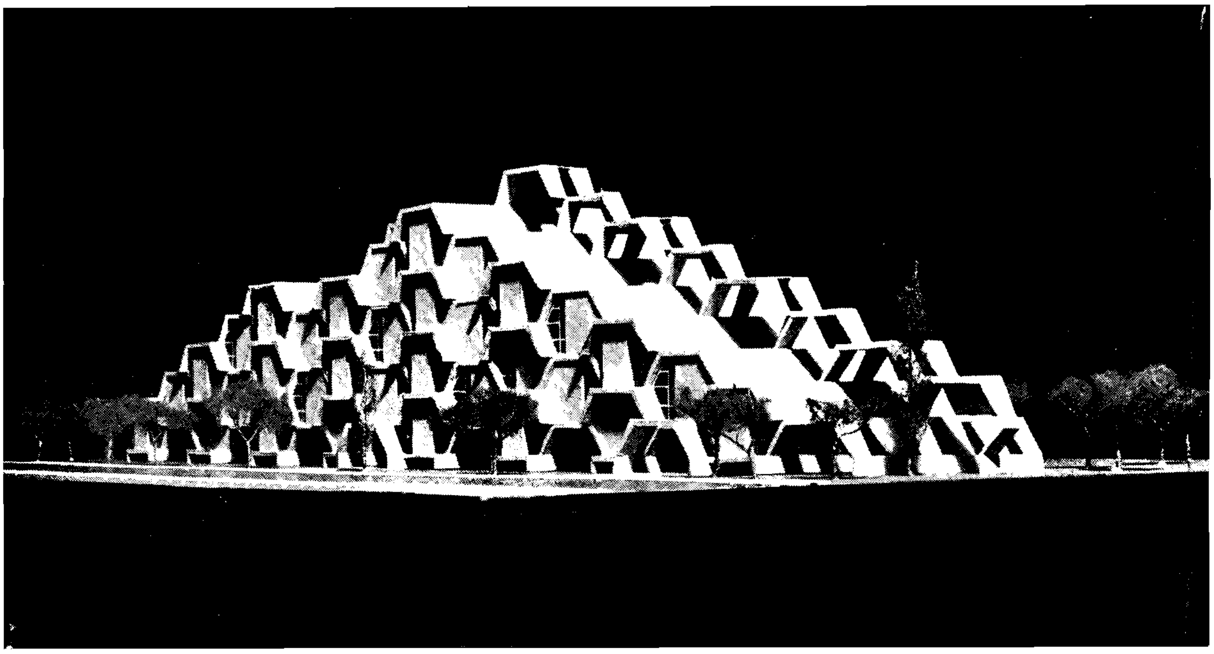


Fig. 1. The Saddle Shape vertebra method for prefabricated houses Architect I. M. Goodovitch Ministry of Housing and Development, Israel.
Mr. I. M. Goodovitch has described the aims of this building thus. "Panta Rei" (Everything flows) Heraclitus "Saddle vertebra shape construction — to combine vertical and horizontal — to follow the natural flow of forces — in a syncopic sequence— to create perpetual linking in all directions — from prefabricated standard units to erect a non-standard image, which can be changed according to needs, acccording to landscapes."

Space

The inherent problem that exists in self help and low cost housing now being erected throughout the three regions is the question of space occupied by one storey dwellings. From the statistics available it appears that one storey building is the most economical, despite the saving in services and road costs for more

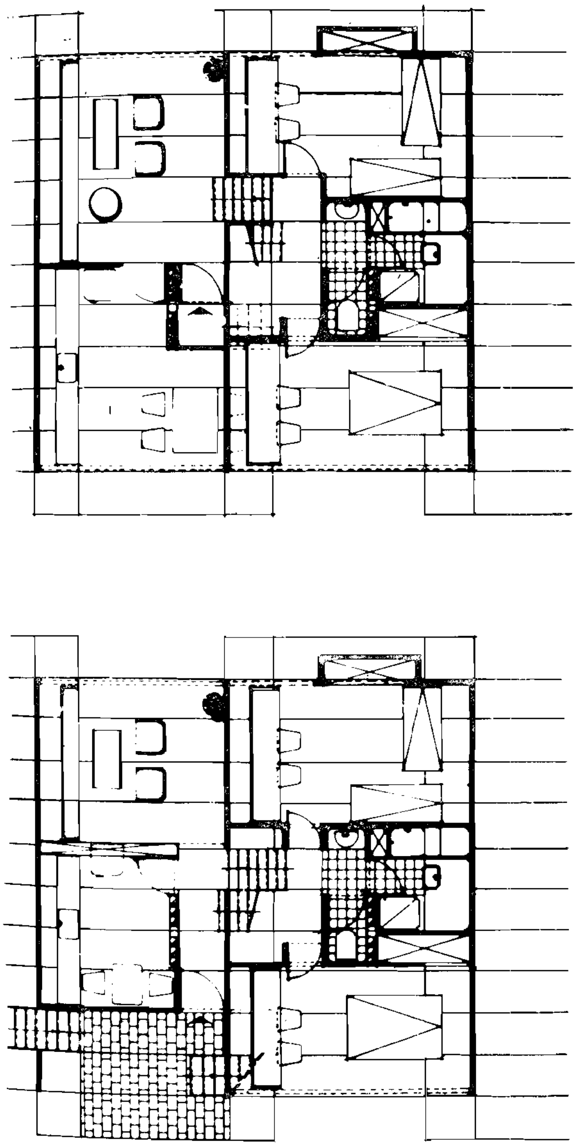


Fig. 2. Plan types A and B

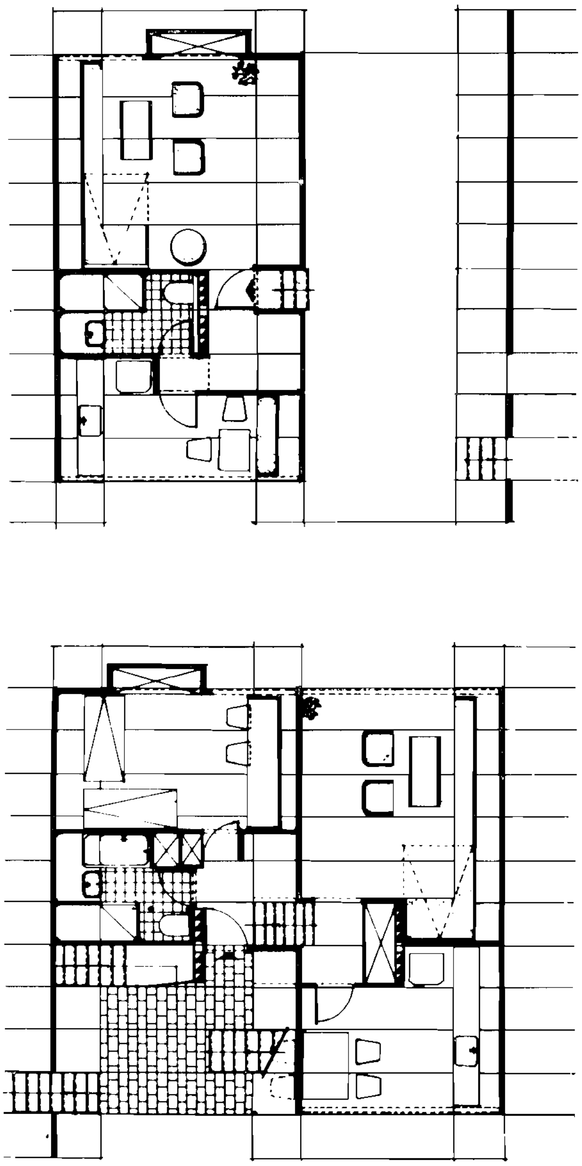


Fig. 3. Plan types B and C.

concentrated dwellings in higher blocks, and despite the increasing value of less available land.

The economical utilization of the land, the enclosure of space between buildings according to the scale of the human being and his characteristics, the enclosure of space as a result of the climate, or the desired microclimate, are aspects which affect the layout, design, and construction of buildings.

As more emphasis is placed on the design of low cost housing for the needs of the great majority in the world, the trends will and are pointing towards concentrations of units—perhaps large or small clusters of units of differing elevation and silhouette, but in any event an aggregate of combined units rather than single one storey blocks.

The study and the utilization of space within dwellings has led and is leading towards new forms for housing. This is directly affecting production of components and construction. Sometimes the reverse is the case. New structural forms have been utilized for housing.

In Japan a young Israeli Architect, Israel Goodovitch, has developed and built a very simple form of saddle shape units composed of precast concrete sections which were perfectly suited to the technical design of reinforced concrete. These units are now being developed for use by the Ministry of Housing in Israel. The illustrations show his work in Japan. The first estimate shows that this form of building is 30% cheaper than that for the normal housing block of similar capacity.

One of the most important contributions to the development of high building and the reduction of circulation space was made by Le Corbusier in the first Unité d'Habitation at Marseilles. The concept of an internal street serving flats on 3 floors has been since developed in many countries. In England the Housing Division of the London County Council have also made many contributions to housing architecture and the ingenious use of space to reduce costs.

Although the constructional developments in prefabrication in Europe, the United States, and Russia do not yet apply to most of the developing countries, it is clear that a great deal can

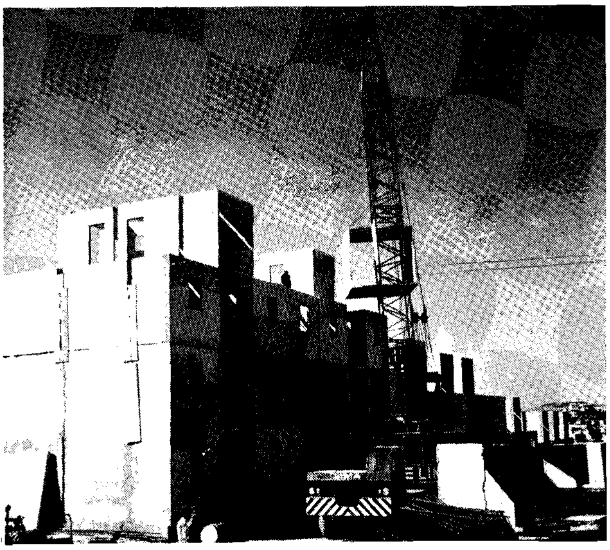


Fig. 4-5. The Diskin System of Prefabrication has been developed in Israel since 1955. It is remarkably simple and flexible.

The units consist of 3-dimensional elements with the two bearing walls being the partitions within the flats. External walls are non-load bearing and can be in recessed panels to form balconies or in various materials from brise soleil to solid panels. The elements vary in size to give between 90-130 sq. ft. and weigh relatively 8-13 tons. The elements can be prepared on site or brought two at a time on a standard size lorry. Buildings have been designed using one element throughout. The latest development as illustrated includes stone aggregate finish to the external side with full insulation included within the thickness of the wall. The reinforced concrete elements are vibrated externally in steel formwork which is dismantled 12 hours after casting. With steam curing the elements can be hoisted after 36 hours of final casting. The elements include floor finish and skirting. The fairface internal finish eliminates plastering. The cost compares very favourably with all existing prefabricated systems.

be gained from the development of ideas in the utilization of internal and external space in housing. This approach must affect the architecture of needs and the eventual industrialisation of building in the developing countries.

Direction of solutions

One of the interim conclusions so far in the wider research is that if there is to be an architecture for, and out of the enormous needs of, the developing countries it cannot progress affectively in a piecemeal fashion without an inter liaison and development of ideas.

There is therefore a need for the research to be carried further than the written word into the field of practical and development research.

Although work of this sort is being carried out to some degree by the United Nations Authorities and Agencies, a much wider and more comprehensive research planned simultaneously in the three regions of the developing countries, Asia, Africa and Latin America will be needed if the present and future problems of needs are to be anticipated properly. It will require a far greater emphasis on design according to the resources of the regions.

At this stage it is suggested therefore that research teams of architects, planners, engineers, sociologists, economists, specialists in building materials and specialists in production methods are set up to study and coordinate existing information and set courses for the development of housing in different regions. From a thorough analysis of each area, the teams or development groups could proceed with planning and building examples of development that could serve as a pointer for that particular region. There is no doubt that in this way many latent resources would come to light. It would also ensure against the expansion of a man-made landscape that by its mediocrity and monotony, and by errors of decision, would subdue the aspirations and liberty of those that it serves.

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Work study and industralisation in the building industry

By H. V. Mirchandani and J. S. Sharma (India)

The building industry in India is one of the important industries because of its intimate relationship with the development plans of the country and its large employment potential. At the same time it is the only large industry which is as yet far from being well organised. No statistics or data are available in respect of the total number of builders in the country, their class or capacity. The only central organisation in the industry is the Builders' Association of India which represents the builders and contractors. It has eight affiliated local organisations spread all over India and has a total membership of about 800.

Hardly 5% of the builders are capable of carrying out works costing over Rs. 10 lacs ($ 2 million) while over 50% builders confine themselves to works up to Rs. 2 lacs ($ 42,000). Except for the top few builders, the rest of the firms have little or no permanent establishment of technically qualified staff or skilled workers. The common practice is to employ technical staff as well as skilled and unskilled workers on a job basis. The responsibility of tendering for and securing the job is generally that of the builder himself. The Government is the largest client for the industry and it resorts to competitive bids for award of work. To secure government contracts, financial standing and stability are relatively more important than technical skill or ability. This is due to a dearth of technically qualified builders having adequate financial resources. The private sector relies largely on negotiations with known firms of builders or contractors, although competitive tendering is also resorted to in some cases. The contracts are usually of two types – measurement and lump sum. The former is preferred by the private sector and public works department working in the Civil Sector, while the latter type is popular with the Military Engineer Services.

The construction practice has remained largely manual, except in large projects or in a few urban areas. The only machines used in urban areas are the concrete mixer and the vibrator. Use of power tools or mechanical appliances is equally rare with the possible exception of floor polishing machines for terrazzo floors. Imported tower cranes have been recently utilised for some of the high buildings in Calcutta, Madras and Bombay. Altogether, this industry, in spite of its expansion and the volume of work it handles (Rs. 3600 crores) in the Third Plan period continues to adopt substantially the same methods as it did in the 19th century.

Demands in the building industry: Acute shortage of housing is felt in urban and rural areas, while most of the available accommodation is substandard. The estimated deficit in 1966 is placed at 10 and 80 million units for urban and rural areas respectively. The cost of this requirement on a conservative basis is likely to be of the order of Rs. 400,000 millions. As against this, the Third Five Year Plan envisages an investment of Rs. 15,300 millions which would at the most provide about 1.75 million houses. Even in the Fourth Five Year Plan (1966–71) the provision of Rs. 28,900 millions for housing will provide for another 5.8 million houses which falls far short of the requirements. These figures emphasise the yawning gap between the resources and the demand, which is ever widening due to the increase in population (2% per year) and higher cost of construction (5% per year).

TABLE 1. Requirement of important materials for meeting housing requirements in 1966

	Requirement			Production in 1963
	Urban	Rural	Total	
1. Bricks (Million Nos.)	120,000	480,000	600,000	8,565
2. Cement (Million Tons)	30	60	90	10.12
3. Steel (Million Tons)	5	10	15	3.4
4. Lime (Million Tons)	10	20	30	0.31
5. Timber (Million Cft.)	245	490	735	No data*

* Production in 1958–59 reported to be 134 million Cft.

Requirement of building materials: – The production of important building materials is woefully short of the requirements in the building industry. A comparative idea can be obtained by estimating the requirements to meet the housing shortage in 1966 as brought out in Table 1. This table also shows the actual production in 1963.

The actual shortages would be very much higher if the requirements for industrial and other types of buildings and other civil engineering constructions such as dams, irrigation works etc., are taken into account.

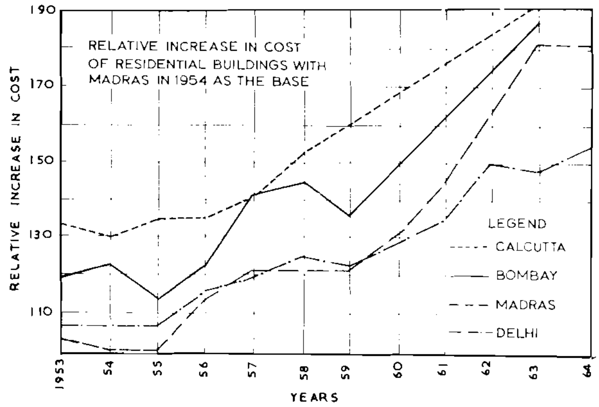
Manpower requirements: – The requirement of the various trades has been worked out on the same basis and are given in Table 2.

TABLE 2. Manpower Requirement for meeting the housing shortage in 1966 (Based on 1500 man days in 5 years).

Skilled	(Thousand Nos.)
Masons	3,360
Carpenters	1,835
Fitters	410
Black Smiths	455
Miscellaneous (Painters, White washers & wiremen etc.)	600
Unskilled	13,000
Total	19,660
Say	19.66 millions

As against the above figures the total labour force in the construction industry in 1961 is reported to be of the order of 2.06 millions. While no tradewise break up is available, acute shortages are already being experienced in the various building centres, resulting in abnormal increases in the wages of skilled workers.

Price pattern: – Except for a slight depression in 1954–55 the construction costs have been steadily rising, closely following the cost of living index. The price pattern for selected cities in India is shown below. It may be seen that the building prices have increased at an average rate of 5 per cent per year (3.9 to 6.8 per cent) during the period 1953–63. It has further been observed that the increase in material costs is of the order of 30.5 to 140 per cent during this period while the direct labour costs have registered a rise of 28 to 43 per cent.



Approach for higher productivity

The brief survey of the industry shows that the industry in its present state is not capable of measuring up to its task and that a fresh approach is over-due.

The reorientation of this industry is to be directed towards producing more with the available means as well as towards finding new materials, methods to meet the ever increasing demand The former envisages the application of all techniques for eliminating waste and utilising the available resources of men, material and equipment in an improved and efficient manner. It is in this field of endeavour, that workstudy can make a significant contribution. The basic approach in workstudy, that of examining the existing situation, exploring possible alternatives and devising the most practical solution, would alone lead to greater efficiency and higher productivity. While workstudy on individual trades or operations would lead to certain savings, still greater savings would lie in adopting the workstudy approach right from the design stage. There is little doubt that standardisation at its lowest permissible level would have to be accepted inspite of its short-comings and that would have to be enforced by suitable means so as to reverse the present trend towards proliferating designs, space standards and architectural forms. Workstudy could be of great assistance in evolving these minimum acceptable standards and is therefore an invaluable tool in the hands of all the sectors viz., the client, the designer, the builder and the research worker.

While the techniques and approaches of workstudy would no doubt achieve worthwhile results, the ultimate solution that it could suggest, or which is inevitable is that the building process should be industrialised so as to provide houses for the masses. But this industrialisation has to be related to the prevailing conditions and carried out with due regard to its likely impact on the social set-up and economy of the country. Adoption of fully prefabricated systems entails establishment of a large factory at a high cost involving foreign exchange, import of heavy transporting and hoisting equipment; relatively higher consumption of cement and steel; and an entirely different approach towards town planning so as to provide adequate roads and approaches. The immediate solution would therefore lie in adoption of part prefabrication systems of the type which could be easily carried out at or near the site of work and the prefabricated components so chosen as to be handled without the use of heavy machinery. Thus the approach towards industrialisation of the building process has to be pragmatic, utilising the technology of the West and relating it to the conditions prevailing in India.

Responsibility of various sectors

The burden for introducing workstudy and industrialisation of building processes would lie on all sectors of the industry. The government, being one of the largest clients of the industry, must provide the necessary initiative or encouragement. While standardisation of the needs or laying down of norms of cost and consumption of resources have necessarily to be accepted, this does not imply stagnation of design or doing away with architectural ingenuity or expression. It would rather have to function within some restrictions, and yet evolve aesthetically acceptable solutions. In accepting these restrictions on his freedom of choice, the client would not only gain the immediate perspective by having his requirement satisfied efficiently and speedily, but would also be able to contribute to an overall development of a productivity conscious industry.

Likewise, acceptance of these restrictions by the designer (which includes architect and the engineer) and his initiative in evolving functional design is indispensable for achieving higher productivity. Responsibility for adopting new forms of construction and utilising new materials largely depends on the designer, who alone can win over the client.The former must also re-examine his own working, so as to identify design types and procedures which entail waste and delay in construction, and campaign for their abolition.

The ultimate burden of reorientation falls on the builder. All efforts put in by other sectors are likely to be ineffective, unless the builder is willing to accept the inherent risk in using anything new however well it may be based on experimentation and trial. The builder has to develop new organisation and expertise to increase his productivity and adopt new forms and materials. He alone could provide the practical bias necessary to make the building industry more vital and progressive.

The research worker would have to be the 'backbone' in this quest of higher productivity. He would be doing so by carrying out extensive surveys and experimentation to utilise all possible substitutes for existing materials as well as to evolve new forms which consume less and less of scarce materials. In addition, he would have to equip himself to extend his ideas on the actual field and prove their practical utility. The research worker is best situated to examine any aspect of the industry, which is having adverse effect on its efficiency and formulate worthwhile suggestions for removing these disabilities. While he has to reorient his own approach to gain greater acceptance from the industry, he also needs its willing cooperation to give practical form to his research effort.

The government in its role as the controlling and regulating agency of all national effort has to provide the frame work and conditions in which progress could be made. Its task lies in encouraging the industry to organise itself, set up its own survey and research facilities, and have a powerful voice in evolving government policies which affect productivity. The government could also carry out periodical surveys to determine the handicaps facing this industry and devise a suitable solution to overcome them. For instance, greater use of building equipment could be encouraged by providing 'Hiring Pools' in selected centres and making the use of certain types of machinery obligatory in all projects by suitable legislation. Likewise, setting up of trade training facilities in various parts of the country could be encouraged both by government initiation, as also by preferential recruitment of trained personnel and provision of incentives to existing personnel to go in for training.

Research work at C.B.R.I.

The Central Building Research Institute, Roorkee (India) established in 1950, has oriented its effort to tackle a wide range of problems connected with the building productivity in the fields of materials, construction and environmental control. In the field of building materials, it has succesfully demonstrated that industrial wastes like fly ash and blast furnace slag can be readily employed for production of light weight aggregate and pozzolanic cements thereby increasing the production of aggregates and cement. Work has successfully been carried out to obtain improved quality of brick from black cotton soil (a heavy clay leading to warping and cracking of bricks). Savings in cement and steel consumption have been affected by adopting design procedures recommended by the Institute and by using prefabricated components evolved by the Institute for roofs, floors, doors and windows, frames and lintels. Considerable work has also been done in evolving rational designs for under-reamed short bored pile foundation in black cotton soils and testing methods for ready determination of the bearing capacity of the soil. Illumination, ventilation and noise levels have been studied to evolve suitable standards for Indian conditions and providing the design data necessary for effective control of the climate inside a house.

In recent years, a productivity section has been built up to carry out work and cost studies on selected building operations so as to examine the existing methods and evolve improved techniques for obtaining higher productivity and lowering of cost. Some of the studies are described below:

Laying of reinforced concrete slabs. Studies conducted on the operation of laying of slabs have shown the need of deciding the sequence of concreting, establishing mixer's positions right in the beginning and of unloading and stacking the materials in convenient position with reference to the mixer's position. Considerable rationalisation has been found to be necessary for determination of gang sizes for sub-operations involved in concreting and for laying down the sequence of concreting, with reference to the size of the area to be concreted and access arrangement. As a result of these studies, recommendations have been framed[1] for typical site layouts with the help of which gang strengths can be determined for all sub-operations in concreting jobs from 100 Cft. to 1000 Cft. per day. Application of these studies have resulted in lowering the direct labour costs by over 50% in some cases, apart from the economy in manpower and equipment resources.

Brick laying. Studies on brick laying have established that the lower productivity of a bricklayer is largely due to unbalanced use of his hands. This has led to the evolution of an improved trowel and recommendations for stacking of bricks, spreading of mortar and height of working for optimum output. Studies on modular bricks and blocks have established the superiority of the modular units in relation to the traditional bricks. For instance, the output in terms of wall area, when working with modular blocks (8″ × 8″ × 4″) has been found to be 77 per cent higher than that compared to traditional bricks (9″ × 4½″ × 3″).

Brick-on-edge cavity walls. Consideration of the various alternative forms of brick walling had led to experimentation on brick-on-edge cavity walls consisting of two leaves of brick-on-edge, separated by a 2″ cavity and tied together with metal ties. These walls have been found to be adequately strong for houses and panel wall, with the added advantage of better resistance to rain penetration. Studies have shown that the output in sq.ft. of wall is very nearly the same as that of traditional one brick thick (9 inches) walls but results in saving of 30 per cent in bricks, 27 per cent in mortar, 11 per cent in space occupied and nearly 30 per cent in weight.

Manpower utilisation at construction sites. Studies on utilisation of manpower at construction sites has indicated that the general level of productivity for skilled workers is around 75 per cent and for unskilled workers around 65 per cent. These studies have further revealed that out of various tradesmen the highest productivity is obtained in case of bricklayers (79.43 per cent) followed by bar benders (72.85 per cent) and carpenters (71.08 per cent). Among the unskilled workers the bricklayers utilise their helpers to the maximum (70.4 per cent) while the carpenters make very little use (53.8 per cent) of their helpers. Further studies are in progress to determine the optimum relationships between the skilled and unskilled workers.

Precast concrete factory. A number of studies have been carried out on a concrete precasting factory. These have resulted in formulation of the recommendations for improving the layout, programming of the casting schedules, determination of balanced gangs for different operations, and for stacking and disposal of raw materials and finished products. Implementation of these recommendations have resulted in an increased production of over 50 per cent and cost reduction of 16 per cent.

These workstudies have also established that the scope for improvement, even in the traditional construction techniques, is almost unlimited and that productivity could be considerably increased by relatively simple changes in the construction practice, tools and equipment and proper utilisation of building materials and men-power.

Prefabrication. The work in this Institute has so far been confined to prefabricated components with an accent on site prefabrication. These studies have established the economics of adopting small precast units for roofing which could be manually handled and placed on partly precast beams. Besides saving in cement and steel, adoption of these forms of roofs leads to substantial savings in cost and speeding construction. For covering large spans, considerable experimentation has been carried out on various forms of shell roofs. Designs have also been evolved for precast prestressed concrete trusses having spans up to 45 ft. As compared to steel trusses, these trusses gave a saving of 25 per cent.

An intensive study of various prefabrication systems is now in progress by full scale experimentation and trials. This would help in evolving a system suitable for Indian conditions. In this joint endeavour the Institute is actively collaborating with the Indian Standards Institute, National Buildings Organisation, Central Public Works Department and the Hindustan Housing Factory at Delhi.

Conclusions. Survey of the demand and supply position in the building industry establishes the need of a complete reorientation for higher productivity. This aim can only be achieved by a concerted effort by all sectors of the industry by creating conditions suitable for adoption of new ideas and materials. Studies at the Central Building Research Institute have well established the utility of workstudy for effecting almost unlimited improvements, in the building industry, whether in the field of design ,planning, construction, utilisation of materials or for throwing up new ideas for experimentation. The limited work carried so far suggests the advisability of further extension of this sphere of work so that the benefits can be profitably exploited and the productivity increased with very little or no investment. Almost every sector of this industry stands to benefit by having work-study trained staff in its organisation and providing them with necessary facilities and scope for implementing their recommendations. Another conclusion that may be drawn is that industrialisation of the building process is inevitable but needs to be tackled with a certain measure of caution in Indian conditions. It is advisable that reliance may be placed on part prefabrication near the site of work in the first instance consistent with greater production and use of building machines and equipment. Side by side, efforts and emphasis are necessary to develop related industries for producing light weight materials, suitable transporting and lifting equipment and evolve and adopt suitable prefabricated systems in selected urban areas having concentrated building activity. It is only by these diverse yet co-ordinated efforts that the building industry could come up within a measurable distance of its task and contribute to the overall development of the country.

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Development of the building materials industry within the area of influence of the United Nations Economic Commission for Asia and the Far East

By R. Singh and G. C. Mathur (India)

The building material industry in the Ecafe region could be categorised as: (i) the age-old building material industry producing materials like bricks, lime, timber; and (ii) the modern building material industry producing materials like cement and steel. The age-old building material industry consists of innumerable small enterprises scattered all over, particularly around the places of concentrated building activity. These industries are not properly organised and are run on unscientific lines. Though brick, lime and timber industries are the main stay of construction in the region, they have largely remained aloof from modernisation. These have reached a stage of development when with the existing techniques of manufacture they are incapable of improvement in the quality and quantity of production. As a result, against heavy demand, there has come about scarcity of bricks, lime of standard quality is generally not available and first-class timbers are in a very short supply.

The modern industry, producing building materials like cement and steel, is well organised. But on account of heavy expenditure which is required in the establishment of such industries, it has not been possible for many countries in the Ecafe region to set up new materials industries. The new materials are in great demand and are essential for implementing the programme of development, particularly for industrialisation.

Scope of industrialisation

Industrialisation of building in the Ecafe region would have to be adopted to accomplish accelerated development and to cope with the huge programme of construction economically. However, the developments in the building materials industry to support industrialisation are expected to be rather slow. The factors which account for this are:

(i) Traditional materials continue to be the main-stay of construction for reasons of economy and availability;

(ii) For most type of constructions, the use of traditional materials and construction techniques are prevalent and acceptable;

(iii) New materials and construction techniques, particularly prefabricated building techniques have to favourably compete in cost with the traditional type of construction;

(iv) Save for an improvement in quality and speed, mechanisation in building is generally costly as labour is available at cheap rates.

(v) There is dearth of skilled labour specially needed for industrialisation and facilities for their training.

Pre-requisites to industrialisation

In addition, there are other pre-requisites which have to be achieved prior to industrialisation of building. These are standardisation, quality control, dimensional co-relation, modular co-ordination, space norms, mass production, prefabrication of building components, mechanisation in production and of assembly and erection work, research and development, organisation of works and productivity. Their role is briefly discussed below.

Standardisation. In order to think in terms of industrialisation of the building process, the movement of standardisation needs to be promoted extensively. This will enable economy in the production of materials, avoid wastage and delay in building work. It would gradually define and set a uniform practice of building. To do so, mechanisation to a certain extent may have to be accepted. In most countries in the Ecafe region building standards and codes of practices are being evolved.

Quality control. For standardisation in quality, control on uniformity of production is essential. For better quality, efficient utilisation and improved performance of construction, quality control in most countries of the Ecafe is to be exercised.

Dimensional co-relation. In order to directly utilise the factory produced building materials and components and to progressively adopt prefabrication in building, it is imperative that dimensional co-relation between the manufactured building materials and products and the built-up space which is being created by their use, should be achieved. This would facilitate building work at site, avoiding wastage of materials and labour, and quicken the speed of building.

Modular co-ordination. A further development in standardisation and dimensional co-relation is modular co-ordination. A 4 inch module which corresponds to 10 centimeter has been found to be productive for the purpose of planning and construction. It will also set a pre-condition on the building industry to conform to modular dimensions in the manufacture of building products and components.

Mass production. To accomplish a huge programme of construction, with speed and economy, mass production both in the manufacture of building materials and construction is called for. Mass production would entail industrialisation of building.

Space Norms. Space norms and standards for repetitive type of buildings, which are to be constructed in very large numbers to carry forward the programme of education, health, industrial housing, slum clearance etc., are required to be evolved for efficient and economical utilisation of space and building materials. Such norms when in conformity with modular planning would permit wide scope for the introduction of prefabrication in building.

Prefabrication. Adoption of prefabricated building techniques is dependent on a range of developments as discussed above. It pre-supposes prefabrication of building elements and components and a long range programme of construction. The absence of these would make prefabrication uneconomical, for the production would be incommensurate with the heavy investment required in establishing factories for prefabrication of building components and for procuring machinery and equipment for assembly and erection work at site. In most centres of Ecafe the scope of adoption of prefabrication may appear to be limited. However, it has become essential in order to achieve a rapid programme of development, to increase the speed of building through progressive prefabrication leading to industrialisation of the building process. Therefore, in the exigency of circumstances, site fabrication and partial prefabrication at places of concentrated building activities, may have to be adopted as a matter of necessity for the establishment of new industrial townships, expansion of big cities and for housing for the masses.

Mechanisation. Industrialisation to a great degree would spring up from the use of machines in production, assembly and erection work, which would increase with mass production and prefabrication. As labour is available at cheap rates in the Ecafe region the possibilities of mechanisation of certain of the manufacturing processes and building operations may have to be decided after carefully examining the economics and the employment aspects of the problem.

Research and development. To achieve progress in all aspects related to building, research is of abiding value. Facilities for research have to be augmented in the countries of Ecafe and research should be given due place and importance, particularly in the building industry. A fund of knowledge and experience in the field of industrialisation of building and the development of the building material industry is available in the industrially advanced countries. Much research and development work is, however, still required to adopt such knowledge to suit the indigenous conditions as regards material resources, climatic conditions and local, economic and social requirements. Demonstration projects and pilot plants for production would go a long way in the acceptance of these advances.

Organisation of work. To derive full advantage from the use of machines and prefabricated building components, the building works have to be organised and managed on scientific lines. The organisation of work should satisfy the requirements of productivity. On account of variations in local conditions changing work sites and labour force organisation and management of works involves considerable effort and thought. In the present state of affairs this offers a great room for improvements to achieve higher productivity.

Developments in the building material industry

Some specific developments in the building material industry to support industrialisation of building process in the Ecafe region are cited below.

Brick Industry. Establishment of mechanised brick plants would enable organised production of bricks all the year round and ensure uniform quality and mass production at economical cost. Moreover, the same plant could manufacture a wide range of structural clay products like hollow bricks. perforated bricks, clay panels, roofing tiles, flooring tiles, engineering bricks, paving and facing bricks. In India a number of mechanised brick plants are being established to produce modular size structural clay products to support industrialisation of building process.

Lime Industry. The lime industry, which has gone into the background due to the advent of cement, should be revived. By introduction of modern methods of burning, standard quality of lime could be produced. Production of hydrated lime in factories would make available lime in ready-for-use form and pave the way for the manufacture of ready-mixed mortars and plaster with the admixture of cement, gypsum, pozzolana, etc.

Timber industry. Almost all the countries of Ecafe region are rich in timber resources. Improved methods of felling and logging will increase the yield of timber. The timber mills should produce standard size timber sections to avoid wastage. Apart from the primary species of timber, secondary species could be identified and processed for use in construction. To do so facilities for seasoning and treatment should be augmented. Production of a variety of secondary timber products such as hardboards, softboards, plywood boards and particle boards should be increased. Standardisation of timber components such as doors and windows, roof trusses etc. would lead to economical utilization of timber.

Cement industry. The use of cement in itself promotes industrialisation to some extent since to produce quality concrete and to lay it, machines are to be used. Moreover cement concrete, precast concrete products and prestressed concrete components are the basic materials which have given rise to wide-spread adoption of prefabrication in building. It has become a matter of urgency to step up the production of cement for industrialisation of building. The need for economy and speed in building has introduced the use of ready-mixed concrete, ready-mixed mortars and plasters; the use of ready-mixed concrete involves complete industrialisation of the building process.

Steel industry. There has been general scarcity of steel in the countries of the Ecafe region due to demand for priority development activities. The steel industry is required to produce structural steel sections of economical shape and sizes such as light gauge cold formed steel sections, tubular sections, deformed and twisted bars, slotted steel sections, high tensile deformed bars and high-tensile steel wire for pre-stressing. Secondary steel industries such as re-rolling rod and wire drawing mills to produce the above materials should be established.

Utilisation of industrial waste. Due to industrialisation waste products such as furnace waste, slags and sludges are becoming available in large quantities. The production of building materials from industrial wastes is likely to have a great impact on the industrialisation of building processes. Furnace residues are finding increasing use as aggregates for no-fines concrete and for large building blocks particularly suited for use in multi-storeyed construction. To extend the use of cement, fly-ash which is a pozzolanaic material could be mixed with cement for concreting and other construction purposes, varying from 20% to 30%. By processing lime with fly-ash, cellular concrete could be produced which, in the form of large blocks, provides prefabricated material.

A variety of building materials such as slag cement, foamed slag for light-weight aggregate, air-cooled slag as dense concrete aggregate and slag-wool for insulating can be produced from the blast furnace slag. Use of these products in construction would promote industrialisation of building processes to a great extent. Similarly, sludge from sugar mills could produce building grade lime for various applications.

Light weight aggregates lead to manufacture of light-weight components of large size which require mechanical handling. Light-weight aggregates can be manufactured not only from the industrial wastes like furnace clinker, blast furnace slag and fly-ash, but also by bloating clays, coal washery wastes and carbonatious shales.

Conclusions. To achieve industrialisation the following are recommended:

- The age-old building material industry like brick, lime and timber, should be organised and developed on modern lines and new building material industries such as cement and steel industry should be encouraged.
- Standardisation in the building industry should be promoted and quality standards, dimensional co-relation and modular co-ordination should be established.
- Space norms and standards should be evolved, mechanisation for mass production of materials should be adopted and to a certain degree prefabrication of materials and mechanisation in building at site and organisation of works should be introduced to bring economy and speed in building.
- Research and development work to adapt modern methods of manufacture and use, practiced by advanced countries should be undertaken.
- Specific development in the building material industry to support industrialisation:

a) establishment of mechanised brick plants;

b) modern methods of manufacture of lime and factory production of hydrated lime;

c) improved methods of felling and logging timber, standardisation of sawn timber sections and timber sections for doors, windows roof trusses.

d) production of ready-mixed concrete, mortars, plasters and manufacture of precast concrete and pre-stressed concrete products in factories and at site.

e) introduction of light gauge cold steel sections, tubular sections, deformed and twisted bars, slotted steel sections, higl tensile steel and wire.

f) utilisation of industrial waste for production of building materials like light weight aggregates, concrete blocks, slag cement, cellular concrete blocks etc.

Trends towards industrialisation of building in South Africa

By T. L. Webb (South Africa)

All over the world industrialisation of building is becoming apparent, but sharp differences in the form and extent of such industrialisation are manifested in different countries. In this respect South Africa is in a unique situation with approximately one-quarter of its population advanced, technologically speaking, and three-quarters of its population developing. In general, the situation is further characterized by a housing shortage, as well as the basic factors of long distances, low population densities, relatively cheap traditional building materials, a conservative building industry, and a preference in both the low- and higher-income groups for individual single-storey housing.

This paper only reviews developments in the earliest phases of industrialised building development. At the time of writing, only a negligible amount of building estimated at about one per cent of the £200 million per annum spent on building, is being done using industrialised building techniques.

Industrialised building has been increasing both in the extent of its use and its degree of sophistication since its earliest beginnings in South Africa just after the war, but it was only during the first half of 1964 that it even approached the modest one per cent of building.

In this paper the present position is assessed and some likely future trends in countries where industrialised building is commencing are predicted.

Factors leading to industrialisation

Salient interrelated factors that have led to the industrialisation of building are a shortage of skilled labour and of traditional materials; an increasing demand for building in general, and housing in particular; the fact that traditional methods are unable to cope with the increasing requirements, and the possibility of lower costs of new methods in the light of the increasing costs of traditional methods. The advent of alternative materials, technological advances and consumer acceptance must also be listed as factors.

Early manifestations of industrialisation of building

It is in the early manifestations of industrialised building that many of the intrinsic difficulties associated with it are apparent. Once the initiated few have begun to discuss industrialised building and the concept spreads, a half-understanding and a lack of appreciation of the implications frequently leads to misconceptions, such as that construction times and man-hours are reduced by 30 to 50%, that fantastic numbers of houses are being built with very limited labour and that any desired variety of floor plans and finishes can be offered. On the other hand, allegations of poor performance, poor finishes, high costs and undesirable uniformity and standardisation are not uncommon. This is probably because, as is true in any new development, it inevitably takes time for architects, builders, artisans and clients to understand what is going on; moreover, certain vested interests are concerned about the effects on their business.

A further characteristic of the early phases of industrialised building is the fact that many different systems are offered. Some of these are based on developments in other countries and some are developed locally but in isolation, and without the planning and interchange of information which are essential for success. The general attitude is one of groping for facts, methods and techniques, and a tendency to try and use existing factories, machinery and techniques rather than to embark on a properly planned system. The very real difficulty of maintaining effective up-to-date and balanced contact between the promoters of systems, the manufacturers of materials and components and local and central authorities responsible for the planning and implementation of major schemes is also evident. While the above are particularly serious pitfalls for any developing country there is also undoubtedly, initially, ample evidence of resistance by local authorities, occupants of the buildings and the building and construction industry itself. The first buildings are often characterized by high costs, snags in construction and poor detailing and finish. In this connection it is also significant that the man-in-the-street, particularly, is more sensitive to failures or shortcomings in unconventional building than in traditional building. If developments are promoted too rapidly, disproportionately high costs and inadequate planning for amenities or for design result.

The impact of industrialised building

By considering the present and probable future impact of industrialised building on the various aspects and sectors of the building industry, many difficulties can be avoided and more logical and productive planning embarked on.

Building labour. The change of emphasis from the skill of the individual artisan to the co-ordinating ability of the supervisor, the importance of unskilled factory-type repetitive labour and the need for excellent site organization are obvious consequences of industrialised building. These trends are associated with a change from hand to machine labour and generally tend to make industrialised building uniquely suitable for unskilled labour. This tendency is an imponderable in the extent and form of the growth of industrialised building in developing countries, but once a threshold level of skill, equipment and organization has been achieved, its widespread use will probably be favoured. Furthermore, the inevitable rise in the cost of unskilled labour is unlikely to affect the overall cost of building by industrialised techniques as much as a proportionate rise in the cost of skilled labour would increase the costs of building by traditional methods.

Because industrialised building essentially takes place in a factory, it will result in a considerable improvement in working conditions and, by eliminating many of the variables consequent upon site conditions, also facilitate quality control.

Design. Because industrialised buildings usually have to be erected in large numbers and the need to avoid complex features limits variety, the design of suitable buildings for erection using industrialised processes poses special challenges to designers. Because of the high capital cost of setting up and equipping a factory, the building design must be sound and simple; it must furthermore be adaptable to mass production and, generally speaking, suitable for a wide variety of climatic conditions. The design requirements are such that they call for uniquely close co-operation between the architect, planner, builder, engineer, local authority and financing organization.

Building legislation. The advent of industrialised building brings in its wake the need for uniform and functional regulations based on rational requirements. Any legal or administrative snags which militate against industrialised methods of building will have to be anticipated and disposed of and building legislation should be applied sympathetically and intelligently. There is also a very real need for discretion in applying regulations, codes and specifications for components, materials and the finished structure, without lowering acceptable standards of health and safety.

Planning and policy. Development, planning and building policy on a national and regional basis must be such as not only to permit but, where possible, actively encourage large-scale production. Planning must proceed in close collaboration with the building industry and should be flexible enough to enable the proponents of industrialised building techniques to modify or adapt plans, methods and materials of construction. Policy should encourage the developments of only a limited number of construction methods and also be such as to favour the best methods. Provision must be made and time must be allowed for a thorough investigation of all promising new methods and a valid comparison, both technical and economic, with others, traditional and non-traditional. Good planning implies the selection, modification or development of a system which is suitable for local climatic, labour, economic and social conditions and compatible with the transport and material supply positions. It is essential to integrate all services into any scheme. It is unwise to attempt to accept indiscriminately a system developed for other very different conditions. Traditional methods of planning, administering and executing building must be drastically reviewed if industrialised building is to be exploited fully.

In most countries more satisfactory and dependable methods of predicting the nature and extent of housing requirements well in advance of the planning work than is the case at present are required. Because of the need for longer term and more accurate planning where industrialised building is concerned, special attention to such predictions is justified.

Economic factors. In broad terms a comparison with traditional building methods in terms of the initial maintenance and running costs is generally a valid approach to the economic evaluation of industrialised building methods. Two cardinal economic principles are the need to select systems which are well adapted to contracts of the size involved and care to avoid the situation where too many systems are chasing too few contracts. Planning to permit bulk purchases and to ensure efficient supervision and good site co-ordination on the site and between the site and head office are further important economic factors. For many systems, the continuity of successive contracts needs to be assured for optimum economic results.

An economic pitfall to be avoided is the risk of rushing into the use of systems using materials which may come into short supply or some other type of skilled labour which may not be available.

Building materials and components industry. Industrialised building leads to a demand for more uniform quality and more stringent specifications for building materials and components. Modular co-ordination within a system or even in respect of different systems and the dimensional standardisation of elements or components, are further requirements which become mandatory in all but the most primitive systems. Industrialised building also implies the need for special or new materials, the equipment and facilities for their production and distribution, and the tighter scheduling of production and deliveries; also it permits little, if any substitution. It is favourably influenced by highly organized bulk purchasing, delivery and storage and in time leads to bigger and bigger standardised units and structural elements and these in turn require special manufacturing and transport facilities.

In developing countries, all of these factors can complicate or profoundly modify the evolution and final form of industrialised building.

Research activities. Especially in developing countries the advent and growth of industrialised building makes increasing demands on research organizations by requiring the development of new methods of industrialised building and the improvement of existing methods, techniques and materials.

The development of new and, in some cases, unique methods of assessing or evaluating the performance of non-traditional materials or methods requires investigation, frequently along radically new lines.

The determination of minimum standards and optimum requirements for novel industrialised buildings can only be based on research. This is necessary because the novelty and unique characteristics in respect of structural adequacy, durability, thermal performance, fire hazard, rain penetration and acoustics, and the effects of moisture, must all be taken into account in the light of local climatic and other conditions and the living habits of the people.

Long-term studies are required on planning to permit the optimum utilisation of industrialised building with special reference to the choice of techniques and materials, labour conservation, provision of services, town and site planning, costs and contract procedures.

There is a unique need for a critical approach in all research related to industrialised building as, because of its novelty, the orthodox approach is often invalid and unexpected findings not uncommon. Short cuts often have to be developed and steps must be taken to transmit the findings very quickly.

Dissemination of technical information. While there is, as in all types of building, a basic need for a readiness to give technical information and for a preparedness to receive and to apply it, the development of competitive industrialised systems very often does not favour such interchange of information. Factors such as prejudice and a preoccupation with a particular personal development further militate against prompt and effective communication. Unquestionably there is a need for the dissemination of information over a wide spectrum covering building material manufacturers and suppliers, builders, the professions, local authorities and the central government. There is, probably far more than in the case of traditional building, a need for international planning and exchange of information to ensure early availability of findings and to avoid costly duplication. CIB can play, and is playing, an important role here but it is necessary to ensure that this information is always presented in the context and form and at the level at which developing countries require it. The complexity of the task and the economic consequences of errors in industrialised building highlights the need for unusually close collaboration between the building industry, the relevant professions and government agencies, all of which have to operate in close harmony if even the obvious pitfalls are to be avoided.

Communication can be facilitated by the use of the SfB system or, as has been done in South Africa, by an adaptation thereof, which is particularly suitable in industrialised building, and its promotion can proceed easily in developing countries untrammelled by traditional concepts.

Conclusions. If industrialised building methods are to play their logical role in developing countries, it is necessary to limit drastically the number of methods and ensure the very closest collaboration both technical and in policy matters between all agencies concerned. There is a need for prompt and balanced research aimed specifically at the solution of a clearly-defined problem and its prompt and valid application. It is likely that the two main types of industrialised building, the heavy type, as typified by concrete slab construction, and the light type, as typified by prefabricated timber or other light-weight panels, will develop parallel with one another in developing countries. As in older countries those methods involving concrete or other heavy units will prove suitable for large projects and particularly multi-storey structures involving the erection within a comparatively small radius of about 500 or more living units per year for a minimum period of about five years, in the more densely populated areas and the methods based on light-weight techniques of construction for small schemes or where transport conditions are difficult and where the climate makes their use a feasible proposition.

It is likely that batch, rather than flow, techniques will play a dominant role during the first few years. Furthermore, as experience and production increase, it is likely that costs will fall and quality improve. It is also probable that the development of industrialised building techniques in developing countries will in many ways parallel its development in older countries and that the factors that determine its success or failure, or the extent to which it is used, are probably more common to both than would be anticipated.

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Industrialised building in the tropics

By W. M. Woodhouse (U.K.)

Most of the countries in the tropics are 'developing countries', that is to say countries which are poorer than the 'developed countries'. It is, of course, not possible to use such definitions with precision because all countries are at different stages of development. The U.N. classifies developing countries as all countries in Africa, (except South Africa), in North and South America, (except Canada and U.S.A.), in Asia (except Japan), and in Oceania (except Australia and New Zealand). They represented (in 1960) about 48 per cent of the world's population of 2,995 million; the balance being made up by China—22 per cent, and by the developed or industrialised countries—30 per cent.

Apart from geographical contiguity the developing countries do not form a natural unit. They vary greatly in race, culture, climate and politics; nor is it easy to draw a hard and fast line between them and the developed countries. The range between each group is very wide. For example, in 1962 the annual income per head in India was £ 25, while in U.S.A. it was £ 868; and the production of electricity in Ghana was 56 kw per head compared with 2,765 kw in the U.K.

A developing country will possess some or all of the following characteristics: a low real income per head; a one or two crop economy; a high proportion of its inhabitants engaged in agriculture; a very small amount of capital equipment in relation to the number of inhabitants; and natural resources, which are not being used for the benefit of the inhabitants.

The housing situation

A marked feature of the developing countries of Africa, Asia and Latin America is their high rate of population growth, particularly in urban areas. This is clearly shown in the survey of the world housing situation, prepared for the U.N. Housing, Building and Planning Committee.[1] The annual average housing requirement, in these developing continents, to meet population increase, present deficit, and obsolescence over the next 15 years was estimated at 8–10 dwellings per 1,000 inhabitants. This rate was only achieved, or exceeded, in a few of the more advanced regions of the world. For example, U.S.S.R. averaged 14 dwellings per 1,000, Switzerland 9 per 1,000 (and U.S.A. 7.5 per 1,000). Some countries in Europe could only build 4 dwellings per 1,000, and India and Indonesia less than 2 dwellings per 1,000 people.

Before discussing the impact of industrialised building in this situation it may be useful to define what it means. Some countries speak of 'non-conventional' as compared with 'conventional' or 'traditional' methods of building. The U.N. defines industrial building as:

"A continuity of production implying a steady flow of demand; standardisation; integration of the different stages of the whole production process; a high degree of organisation of work; mechanisation to replace manual labour wherever possible; research and experimentation integrated with production." Likewise, the U.N. definition of prefabricated building is:

"the transfer of varying proportions of the operations of manufacture from the building site to factories or workshops, which may be independent of the site or associated with it. In this connection the term 'partial prefabrication' is sometimes used. Prefabrication is also sometimes known as 'non-traditional'."

The essence of industrialisation is the possibility of increased productivity and higher standards being achieved through a degree of standardisation, the use of appropriate mechanisation, and by the co-ordination of supply and demand. In some countries, notably in the U.S.S.R., the housing industry has passed, through several stages, from the prefabrication of small components to that of large ones: others, such as France and Denmark, while they have not yet found these methods cheaper than conventional ones, have considerably reduced the man-hours needed on the site. In the present world housing situation speed may be more important than cost. In some countries, regardless of cost, it is recognised that mechanisation of building processes helps in meeting the demand for quantity, which traditional methods alone could not do.

Basic requirements

A major problem is whether and how the experience of the more advanced countries can be applied in the developing countries. It is sometimes said that prefabrication has no advantage when labour is abundant—as is the case in many developing countries. Generalizations, however, convey little—when the term might mean anything from a whole dwelling unit delivered by truck to the production of a few basic building elements in a less developed country. In countries where skilled labour and capital are scarce, and there is a low volume of construction, partial prefabrication may be quite feasible in the early stages. The introduction of full prefabrication in building is related to general economic and industrial development, and this is difficult in areas where the density of population is low.

In any country the development of building materials and construction industries cannot be accomplished separately from general economic and social development. Exchange of experience and dissemination of technical information between developed and developing countries is essential in order to avoid mistakes and accelerate development. At the same time, when changes of this kind are being introduced, natural and climatological conditions and national customs must be carefully considered.

The U.N. Housing Committee considered that among the basic conditions for industrial house construction were the integration of different phases of house building, construction in accordance with standard designs, standardisation and modular co-ordination in building, and the unification of building codes and regulations. Elaboration of standard projects is one of the most important factors in the organisation of the construction processes on which depends the technological side of production and, therefore, also its cost. A standard project must, however, meet the living standards of a given country and be in line with its technical and economic possibilities.

Both economic and technical considerations are involved in the choice of materials or prefabricated elements. As Mr. J. van Ettinger has said:[2]

"In the next twenty years or so the countries where abundant labour and manpower is available will have to make effective use of building methods involving manual labour, due allowance being made for the shortage of skilled workers. In countries where wages are high and steadily rising it is principally a matter of whether one is prepared to steer a definite course and spend a lot of money on research now with a view to achieving specific ends in the future or whether one is satisfied with a development that takes its own course, so that all that can be done is to make the best of it." Again he says:

"The range of possibilities and rapid development of new discoveries on the one hand and the absence of objective data on the other make it very difficult to come to the optimum choice... Often the choice must be restricted to what is available in raw materials and finished products in a given region. Transport over long distances is only possible for light materials... some regions can only be made habitable with what is potentially available in them and with such products as can be derived therefrom. In this connection the choice of the standard of quality is most important; it is not so much a technical solution of a one-time problem, but rather the achievement of optimum quality for the society as a whole—i.e. the maximum difference between usefulness and costs."

Standards

The need for standards is a most important prerequisite of industrialised building. This is emphasised in another paper prepared for the U.N. Housing Committee which deals with the development of construction and building materials industries with special relevance to industrialisation.[3] It suggests that national governments should prescribe norms and standards of amenity and construction suited to local needs, produce type designs based on these norms and standards, carry out experiments and tests before mass production, and standardise components such as doors, windows, cupboards, etc. as much as possible. Before embarking on industrialisation on a greater scale certain basic conditions should be satisfied, for example, aggregates suitable for heavy or lightweight concrete must be available; also cement, lime, steel; a supply of electricity and water; facilities for maintenance of mechanised plant; and in particular there must be adequate communications.

There is an increasing interest in all countries to speed up construction to meet the needs of rapid urbanisation. The scale of building is growing and thus the need for more industrial capacity. In recognising this governments should create the right climate for rational building with the object of reducing costs, and of increasing productivity and at the same time attaining a more conscious quality.

In most under-developed countries, and in quite a number of developed ones, there are few clearly defined standards for 'unconventional' building methods. Various manufacturers may use different techniques of production processes, but based on the same general building methods. The only way to evaluate each type of method, in these circumstances, is to formulate minimum technical requirements, and then to consider the suitability of the materials used and finally to evaluate each type of building.

The advantages and disadvantages of industrialised building may include: (in favour) quality control, speed, need for less skilled labour on site, and no delays on account of bad weather because the work is done in a factory; and (against) high capital investment—only justified for large orders, uneconomical for transport over great distances, products must be similar—any diversity will mean higher costs, etc. The pros and cons are discussed in other papers at this CIB Congress.

Trends and possibilities

One feature of building today in many tropical countries is the growing use of cement.[4] The trend is towards a change from traditional practices, often based on short-lived materials, to more permanent ways of building, which are cheaper to maintain. Increasing production of cement will directly benefit the introduction of industrialised building systems, many of which use concrete in a variety of panel constructions - heavy, light, or composite. (Fig. 1). Industrialised building can be manufactured at a permanent base factory or at a temporary one, which can move from site to site. In each case the capital cost is high; the problem of transporting panels, which may weigh up to 12 tons each, may well determine the location of the factory. A South African Government Committee, which examined industrialised building plants in Europe, recently concluded that, for its own low cost housing needs, a base factory would be uneconomical if it produced less than five hundred houses a year for five years and was more than 80 miles from the building site. Other industrialised building systems, based on timber or metal framings and incorporating a great variety of panel treatments from asbestos to plastics, were also examined. The durability of some of these materials has yet to be proved satisfactory in tropical regions, and special reference was made to the cost of maintenance.

The size of an economic market for industrialised building, in a non-industrialised developing country may well be critical. Developing countries' trade with each other is, at the present, very small; often the market offered by each individual country is too small to support economic production. For instance, in a cement factory of 35,000 tons capacity the cost of production may be £ 10 a ton, whereas in a million ton capacity factory it may go down to £ 5 a ton. Likewise steel produced in a 50,000 ton plant may cost £75 a ton to make whereas only £45 a ton in a million ton plant. Only eight of the developing countries (including Spain and Yugoslavia consumed more than 500,000 tons of steel a year in 1961. The disadvantages of uneconomic markets can sometimes be overcome through regional planning by economic integration, joint industries, and trade agreements. Brazil, Chile and Argentina, for example, are considering plans for a joint motor industry. Whether this could be applied to building remains to be seen. The lighter forms of construction, which are specially suitable for building in the humid tropics, would meet manufacturing and transport conditions best in such cases.

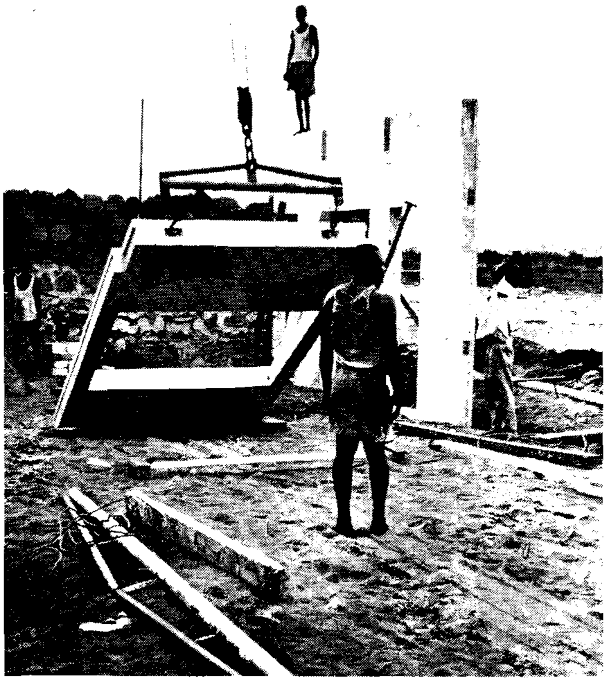

Fig. 1. Factory made heavy concrete panels. Ndjili, Leopoldville, Democratic Republic of the Congo.

This paper attempts no more than to indicate the background to some of the problems. Many of them have yet to be resolved in the developed countries. In the developing countries the cost of materials often accounts for a considerably higher proportion, relative to labour, of building costs than in some developed countries. Local industry is often in its infancy; transport, import dues, storage and profit all increase the cost of imported materials or finished goods. One way of reducing costs is, therefore, to improve local production and to try and exercise the greatest economy in the use of imported products. In itself this implies the rationalisation of the whole process of building and a more methodical approach to conventional or non-conventional building techniques. In Britain the design of housing and of educational and medical buildings has benefitted greatly from the establishment of planning and development groups. Similar methods could also be applied in developing countries, but they must be accompanied by a fairly high level of building technology. Increased training facilities are needed to this end in many developing countries.

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Group K
Communicating the knowledge

Final report from the group rapporteur I. Karlèn, Director of AB. Svensk Byggtjänst, Sweden.

Ever since its beginning CIB has concerned itself with the questions of information and documentation inherited from one of CIB's predecessors, International Council for Documentation on Building, CIDB.

At the present time, work within CIB is carried out as follows:

1. In the case of certain fixed measures, e.g. abstract service, the work is performed in a routine manner by the collaborating parties.

2. A major part of the development work is done through working commissions with one of the member organizations acting as the working secretariat. At present the CIB working commissions in this field are as follows:

W1 International Building Classification Committee—IBCC—a joint CIB-FID committee with subcommittees for UDC, SfB and Classification Research

W31 Master list of properties of building materials and elements

The results of the work carried out by these committees are given in reports from CIB and in working reports from IBCC.

3. The more important questions are dealt with in connection with the CIB congresses or general assemblies.

4. In addition hereto, there is a continuous exchange of information and documents of different types between the member organizations.

The mentioned facts are the background against which CIB's members have discussed questions concerning the matter of communicating knowledge.

Within the building field an information ring has thus been created within CIB in which both international and national organizations are collaborating.

The documents presented at this Congress within Group K and, to a certain extent within other groups, constitute a basis for the discussion on the communication problem taken in a wider sense—a basis which I am endeavouring to extend by adding other material apart from that presented at the Congress.

General comments on information methods

In his paper K4 Janiszkiewicz presents a compact survey of the communication problem from a Technical and Economic Building Information Centre.

In order to prepare information material the prime requirement is a technical, organizational and economic analysis of the production plan and of the plan for technical development. This analysis should be able to reveal exactly what information is required at the various stages of the production process. Relevant, topical information should be collected at these stages before the work is started there. It should then be borne in mind that the scope of collecting the material depends on the "levels" of the principal groups of its receivers. The level can be defined by means of at least two components: education and the function fulfilled. The information should be prepared so that it is most easily available to the group concerned, in order that this group might organize and execute the work properly under definite conditions and in a definite time. The most difficult problem in the whole cycle of "elaboration, collection, transmission and utilization of information" is to ensure that the information is properly received and utilized. The problem is made no less difficult by the fact that it consists of a number of factors: i.a. sociological, psychological and physiological factors. When preparing the way in which information is to be utilized all these factors should be cleverly used.

According to Janiszkiewicz, finally, the utilization of information within the enterprises engaged in planning and building must be carried out in a planned way.

The technical information which is to be given to the practitioners from external sources should be transferred and applied to existing practice. These questions are taken up in Kristiansen's paper K5. Suggested here as a complement to research reports, digests, abstracts from research and documentation bodies are the information media information sheets on products, where reference is made to the work being done within CIB W31, and information sheets on constructions and building details.

Kristiansen's paper deals with experiences with information sheets on constructions and building details acquired in Finland and Norway. Kristiansen states "The tremendous growth of technical literature in building research makes it impossible for those concerned with building practice, to keep their knowledge up to date. To reduce this problem there are various series of digests which present news, research results and principles for planning and building in a way that makes it possible to cover the field more quickly. Thus the information reaches half way to practice.

The next step, to transfer and apply this new knowledge to existing practice, demands more again. It demands time and experience and is rarely achieved other than by very few firms which have a development section of sufficient size within their staff.

For all other designers and contractors there is a strong need for this kind of information, which gives new knowledge transformed into design and specification ready for use in design and on the building site itself."

The following demands are made on information sheets on building details sheets: "Information sheets on building details and constructions should explain the reasons why the design and performance has its specific requirements. In design and specification, they should show precisely how new knowledge combined with best current practice may be interpreted and applied to constructions and details ready for use by the practitioners".

Some important observations are made in the paper. Kristiansen considers also that the time is ripe for discussions within CIB on the real content of information, how it should be presented and how it is adapted.

It is hoped that the receiver of information, whoever he is, obtains his information in the correct form. An intensive programme of "awakening" and training is however probably needed to run parallel with the improvement of the written information.

In his paper K3 Fink gives a thought-provoking figure: "Acquired knowledge and capability developed during an education do not last for a lifetime. It is asserted that the professional knowledge of technicians becomes obsolete at a rate of up to 10% annually." What is called for is "postgraduate training" but also an improvement of the intellectual receiving capacity and working methods. Fink states that documentation is an integral part of any dissemination of knowledge and gives examples of forms of information which do not consist of documents and which he stresses are important. The acquisition of knowledge, and the maintenance and utilization of knowledge are practised by different people in different ways dependent upon whether they possess the auditive, haptic, motory or visual types of imagination. Dissemination of knowledge should therefore be arranged and carried out with proper regard to several types of imagination. Courses as aids to training are described by Andrew in K1 and Zignoli—Castiglia in K7. Out of these papers it may be mentioned that Andrew paints a black picture of the present methods of training employed in the building industry compared with the enormous development of the industry in recent years. He thus levels criticism which applies to the organisation of further training at all levels, and requests intensified training at all these levels. Examples are given from the Cement and Concrete Association's courses for different categories in a special Training Centre. Where possible, emphasis is here laid on practical demonstrations with the help of their own laboratory.

Zignoli and Castiglia give a survey on the cement and concrete industry's courses for operatives and forcmen. It is mentioned in the survey that in all European countries, the teaching programmes have common fundamental subjects.

It is stated in the conclusion of the paper that the planning of courses must have its own gradual progression, starting from the primary education to the more complicated one.

In other countries, too, and within other sectors of the building field, extensive experience of further training work has been acquired and some of those present at this congress were able to give interesting reports from their institutions.

According to Mathur, K6 peculiar problems exist in developing regions in the general preparation of information. This is due to great differences in social and economic conditions, climatic factors, technological development, human and material resources. If the problems of coordination of building activities and efforts to bring about developments in the building industry are not too big, research centres are able to follow up the research work in order to realize the benefits of research by undertaking follow-up action to ensure the application of results in practice. In big countries or other large circumstances, however, there is a need of a separate agency for "co-ordinating the development work by promoting knowledge and its application, to serve as a link between research centres and the building industry, attempting to bridge the gulf between research and its application. It would also act as a channel for feeding back". This co-ordinating agency has to work closely with building research and development organizations and with the building industry as the receiver of knowledge.

Specific aspects on product information

The task of coordinating the knowledge of functional requirements of buildings and building elements and the knowledge of the properties of elements and of the materials of which the elements are made, is being carried out in different countries through the combined action of several institutions.

The Congress papers within Group H give some examples here of the methods of action and of the different types of documents which are of most interest in this connection. The entire complex concerns to a high degree the question of information. Especially Blachère in H3 and Keys in H10 discuss the matter. Within CIB the work with product information and the co-operating of this information with the users' need of a qualified technical information is started in Working Commission W31, which has the name "Master list of properties of building materials and elements".

Keys states that "if architects, for instance, were convinced that this is in the best interests of building efficiency and economics, and would insist on the submission of properly evaluated check lists, this could then form the basis of such a re-assessment of methods of selection. This would compel manufacturers and servicers to look more closely at what they are offering and by research and testing improve quality and restore consumers confidence in the building products' market". Keys pleads for a reliable documentation of building materials based on these principles and mentions that the method outlined should be developed for decision making processing with the aid of electronic data processing. These arguments agree well with the discussion being carried on within CIB W31.

As the product information concerns a big part of the total information to the building practitioners, the improvement of this information is very important.

Statements made by the building materials manufacturers indicate that there would be no opposition to an adaption of their information for both traditional and non-traditional building to the needs of the users, if these needs could be defined. As mentioned earlier, increased industrialisation will probably entail increased integration between the building materials industry and the building industry. When working with "open systems" of construction methods, information from the producer should be well adapted for the building process. It is probable that most of the technical-commercial literature which is now thrown to the winds, in the future can be replaced by information which the user will find usable and suited to his needs.

Information directly connected with or adapted to the production process

The flow of information is a vital factor in the building process. This process requires information at different stages – information which consists not only of literature but also of data of different kinds and which is adapted to the production process.

Drawings constitute one of the most important elements of the flow of information. In the analyses and recommendations described by Tyrén and Åkerblad in B18, certain demands of interest to Group K are put forward.

In the building field, computers have begun to be used for statical calculations, for calculations and also for data processing, specifications, bills of quantities, CPM-network etc. Two papers deal with the theory of a central specification, viz. Bindslev C1 and Nielsen C14. The central specification becomes a framework for both the manual and mechanical guiding of the building process. According to Nielsen the central specification is a library of descriptive items covering all common and recommendable structures, methods of construction, finishes etc. used in ordinary building jobs. Each item is provided with a number for recording purposes (code number) and all the items are transferred to magnetic tape for electronic data processing.

If a "complete" description of the building was available it would be possible to fulfil the individual requirements by selecting, out of this complete description, the required parts. By applying these principles the text contained in the central specification will be related to product information documents and also to drawings and to information sheets on building details. This opens the perspective of coordination of all the facts to be reported at the various stages of the production process.

This coordination also calls for a systematic coordination by means of a coding system. The coordination can become very advanced as in Bindslev's paper, which describes an application of the SfB-system for drawings, specifications, bills of quantities, CPM-network, etc., or less advanced as in Ugander's paper C23 "Integrated data processing for builders and general contractors" outlining parallel applications for the parallel activities: quantity surveying cost estimating, network planning, cost control and cost analysis.

Industrialisation's accentuated need for information

The "open system" of industrial building implies the assembly of prefabricated catalogue products, which is pointed out i.a. by Blachère in F3. This requires a more comprehensive and specified presentation of data and other facts than earlier in order to facilitate a satisfactory definition of those products which could come into consideration for the user.

In A10 Sebestyen states that industrialisation of the construction industry needs an organisational cooperation between the building materials industry and the building industry for an increased exchange of experience and knowledge. According to Sebestyen "industrialisation proceeds not only through research by one organization but also by relying on an exchange of experience within and between countries and by adapting and perfecting the knowledge thus obtained. Development based on evidence from outside sources is of vital importance, particularly in smaller countries, where full-scale research cannot possibly be carried out in every field but available resources have to be devoted to those projects from which most profit is expected".

In the paper of Junttila, C24 is stated that a building firm must solve many problems when introducing a new production method. Types of matters to be solved and the questions to be answered by a firm are exemplified and the influence of the development of innovation on different functions in building activities are commented. The answer to these different questions requires that "the building firm itself should be very much interested both in building technique and production technique, in technical research, especially the utilization of research results, and also in performance schedules, performance organization, description of work, etc."

All these are factors which are guiding the next steps in the development of information. With regard to special problems for developing areas in connection with the industrialisation process, it is stated by Webb in his paper J11 that "the development of competitive industrialised systems very often does not favour interchange of information", and it is also his view that "there is, probably far more than in the case of traditional building, a need for international planning and exchange of information to ensure early availability of findings and to avoid costly duplication. CIB can play, and is playing, an important role here but it is necessary to ensure that this information is always presented in the context and form and at the level at which developing countries require it".

Information through building regulations

Building regulations constitute a form of information which produces a powerful, rapid effect and it should be utilized sensibly so that it might retain this effect. Christensen states in his paper D2 that with regard to the task of the authorities in respect of building regulations its character has changed because industrialisation creates new commercial conditions with greatly increased market regions. The authorities must draw up progressive regulations which provide the best possible conditions for industrial house planning. In this connection Christensen presents proposals for different principles of classification and sub-division of regulations and their contents and discusses the need for a simplified formulation of regulations, which facilitates the receiving of information through regulations. Christensen touches on - but does not mention - the wish put forward in various quarters to have the regulations systematically coordinated with other primary documents such as central specifications etc. and with the principles for codification, which are used for these documents.

General organizational problems

The questions of organization of information bodies are among others dealt with by Denton in B3 and Cembureau (The European Cement Association) in K2.

In his paper Denton surveys the problems facing the building industry in Great Britain in connection with planning and design for industrialisation and argues in favour of the formation of a national permanent agency for a regular exchange of experience and also for an International Building Agency to secure uniform approach and prevent duplication of efforts in the planning and design for industrialisation.

The British agency has already been set up as a private company (N.B.A.) on a non-profit-making basis initially financed from the Treasury and with the possibility of charging for its service.

Denton says that he feels that there is a real and urgent need for the establishing of a permanent International Building Agency whose purpose would be, among other things, to secure the proper and expedient organisation of a systematic exchange of information between nations. It is suggested that CIB could and should become the world's building information centre.

In Cembureau's paper, a description is given of the work being carried on within an international building materials organisation whose prime function is to provide an effective link between the cement and concrete associations.

Among the activities are mentioned international conferences, studies of topical, technical and architectural problems in connection with the use of cement and concrete. The organisation also effects an exchange of publications and publishes reports and bibliographical bulletins and is preparing an abstract service on the same main principles as applied by CIB.

An attempt at a complementary survey and subjects for discussion

The basic training

The new principles for planning and building and the rapid development of the methods used make it necessary to treat the basic training problems very seriously. In the schools and universities a foundation must be laid for the continuous training of the individuals in their practice, and this must be done so that it allows an elastic adaptation to future methods of design and construction. The basic training and a step by step arranged "post-graduate" training must be coordinated and dimensioned for the increasing number of technicians who will be needed in the future for the building industry. Good text-books are also necessary as well as technical aids as TV, tape-recorders etc. for "programmed training". In some countries efforts have been made to improve the basic training and the results of different methods and aids and a contact with research bodies will be of great interest. At present these problems however are not realized everywhere to be as important as they really are.

The problems of basic training, post-graduate training and the daily communication of knowledge to and between the practitioners must be solved together. A new generation of building practitioners grows very fast and the basic training of these gives in reality a rapid effect and also the training for a better communication technique. One important information is how to find and use information.

Documentation development work

Intensive work is being carried out in all parts of the world to improve the methods of information retrieval. The traditional aids provided i.a. by classification systems are being supplemented by special types of subject index in order to facilitate the retrieval, and different principles of coordinative indexing are being tested. The classification conference within FID/CR arranged in 1964 by Mølgaard-Hansen among others, presented a survey of the extensive work which lies ahead of us in order to manage the information retrieval problems also by help of data computers — also in the building sphere. When compiling thesauri and other aids the material available in ABC and SfB should be of great value. This development is followed within IBCC/CR and it should be in the interest of everybody to ensure that IBCC obtains the necessary resources.

Development in documentation and classification work is in progress within allied fields of activity such as soil mechanics and road building. The question whether it is important that housing areas be coordinated with adjacent fields of activities should be studied in good time. The CIB contacts with other international organizations can be a good base for an eventual coordination.

Information centres and their place in an information system

It has been evident that it is not possible for an individual or for a small or medium sized firm to operate a complete information function. Help is needed and is given by information functions of professional associations or by specific information centres. The rationalization of information as a total concept and of reference information documents (as well the general information documents as the project related information documents) calls for a new view of the information and documentation centres of the building industry, whether they are directly connected with research bodies or are separate instances, such as state bodies or consumer-cooperative or producer-cooperative bodies. As discussed in many papers and studies, that part of development work which concerns the practical application – of which information to practitioners is a part – should be extricated from a possible placing at research bodies and gathered at special agencies or centres. The situation from an economic standpoint has hitherto been one in which such centres have often had to be built up in some form collaboration with manufacturers of building materials and have had to deal with both information on building materials and products and other information, for which latter category economical resources have as a rule been far too limited. Centres have in some countries been built up through one or a small number of organizations, e.g. architects, engineers and building contractors organizations. Facing an increased degree of industrialisation it is clear to me and many others that the various categories of users must work together in creating and supporting such agencies or centres in this respect in a more intensive and a different way than they have done hitherto with the needs of the users as guiding principles for the future work. Examples from different countries, including the Scandinavian countries, show that this brings about a more powerful effect because, among other factors, the risk of duplicated effort is reduced.

By building up centres or agencies with the widest possible scope of activity the foundations can be laid for *a permanent information system* which should be part of an international network. The foundation for such a network has already been laid through the work carried on within CIB.

The future organization of an information system should be able to be built up advantageously by the users preferably on the basis of cooperation between different categories of users and be based on studies of the users' needs.

Cooperation: research-information

When planning central information activities the problems of the cooperation between research and information centres must be seriously considered. The communication of knowledge from research is a kind of a relay race and it is important that those holding the batons regard each other as equals. A chain is not stronger than its weakest link. To sharpen my statement I would like to say that information and documentation in their future progressive form cannot be regarded as a subordinate service for researchers who by virtue of their profession feel that they hold an exclusive position.

The discussion carried on hitherto between research and information (including documentation) in respect of mutual problems has often been coloured by uncertainty about the expressions and concepts employed. Personally, I believe that it is essential to regard information as a wide concept and not simply as a Public Relation concept or an editorial question and that information must be treated as one of the three major elements in the flow of the design and building process: information, energy and materials. Comments in the same direction are given by Blachère, Kunszt and Mazure in their papers for the CIB General Assembly 1965 concerning programming and management of building research. (See CIB Bulletin, No. 2–3, 1965).

Financing information work

The possibility of effecting improvements in the existing information system depends to the greatest extent on the amount of funds available and here a number of problems of principle arise.

From an economic point of view organizational questions are interesting and important. It can generally be stated that the responsible building information and documentation in most countries is not organized in an identical way. In many cases it is enmeshed in a situation where the interest of State research is to produce results from the research carried on with State funds, while the user of the information about these results cannot use it directly and has no resources to transfer and adopt the information satisfactorily from their points of view. The development of general building information and building documentation has in many instances had to be based on whatever grounds and means it has been possible to make available, and is in many cases started on a foundation formed in cooperation with the building materials industry.

I usually say that it is possible to obtain money for research on the one hand and for advertising or Public Relations work on the other, but only with difficulty for unbiased information. The institutions which have been working with this information have hitherto almost constantly had to face financial problems. That is a situation which must be changed, if the central information and documentation bodies shall give an effective contribution to the development of the further industrialisation of the building industry.

It is important to point out that the general attitude of granting authorities in the building field – as well as of some research bodies and of many of the practitioners offices – hitherto has been to regard the information as it primarily concerns the dissemination of research results as a problem of improving up-to-date information on the activity and results of individual research bodies, while reference information – for retrospective searching – in its entirety has up to now been paid only very little attention by them.

For the future economical planning we must realize that we are going through a period of transition in which among other things:

1) The professional resources of the book publishers often estimated on a short-term profitability basis, are inadequate for many purposes.

2) The executive bodies for a centralized, neutral information on building materials and products will probably come to a position where they are able to coordinate the

product information and transform and distribute it in a way which is practical for the user.

3) The State as financer of the research wants in a higher degree than at present the user to pay for the information about research results etc.

4) The maintaining of a rational information centre and responsible information activities are already calling for considerable investments and continuous acceptance of risk. Moreover, the handling of information which to a certain extent will be aided by the use of data computers can become so costly in many cases that only a limited number of types of question determined in advance will be permitted—the programmes worked out govern the questions and the questions beyond their scope may become too expensive for the user to pay for. This last point involves a complex of problems which also concerns the important question of principle of the free utilization of information.

The cooperation between ministeries for building or research, research councils and institutes, technical universities and schools, professional bodies, industry, information centres or agencies, etc. will in many countries be examined in order to create an efficient information machinery and to distribute responsibilities and duties.

Financing international activities has in many connections proved to be even more difficult to solve. It is probable that the major part of this international work has hitherto been carried out by means of a system whereby the work of the international committees is done by the committee's secretariat which is located at a national institution. It seems important that more funds should be made available for certain tasks of international importance within the field of building information and documentation.

Courses for advanced training

By R. P. Andrew (U.K.)

While enormous advances have been made in the construction industry during recent years, the pattern of training of those employed in the industry has changed little. The main emphasis in the educational field has been on increasing the number of students undergoing technical training, and only now is a serious look being given to the type of training which is needed. In the United Kingdom as in other countries the increasing mechanization and industrialization of the building process—together with its increasing complexity—has led to much less reliance on the craftsman, with corresponding changes in the technical knowledge required of personnel at all levels.

At the bottom end of the scale the operative receives little or no training; he picks up what he can on the site from being told what to do. The designer receives a basic training, but his detailed knowledge is picked up almost haphazardly, and the professional bodies themselves have done little to ensure that facilities are available to enable their members to further their training.

Even the employers—with exceptions, of course—have been slow to realize the value to themselves of systematic training schemes for their staff. In fairness this situation is not peculiar to the construction industry, but is true of industry generally, and indeed it has been left to the government to take action to remedy the situation. Industrial Training Boards are being set up, one of the first being for the construction industry, and these will decide on a levy which will be imposed on each firm within the industry. This levy will be used to ensure that the appropriate training is done. A firm itself running an acceptable training scheme will be able to offset the cost against the levy, so that in effect firms not themselves carrying out any training will help to bear the cost of training carried out by others. At what levels this training will be has yet to be announced, but at the time of writing (September 1964) it would appear likely that the training to be approved by the Construction Industry Board will be at a number of levels, and not confined solely to the young entrant into the industry.

In the author's opinion, this principle of training at all levels is of vital importance. It seems unnecessary to state that however good the design, the structure may fail if the steel is put in the wrong place in a reinforced concrete beam; and conversely no degree of precision in the execution of a job will correct a faulty design. But there is a long chain of responsibility from the drawing board to the finished structure, and at present the training of many of those in the chain leaves much to be desired. Far too much knowledge is still gained—both on the site and in the design office—by being passed on informally during the course of the day's work, and far too much is left to the individual to acquire as and when he can.

Basic training

As in other countries, the basic training of the civil and structural engineer in the United Kingdom is carried out in the Universities and the Colleges of Technology throughout the country. It is fairly general in character, and usually consists of three years full-time study; this is then followed by a period in practice, working under a qualified engineer, after which the student becomes a member of the appropriate Institution (of Civil or Structural Engineers) by passing the Institution's examination.

This basic qualification ensures a minimum standard of entry into the profession. Any further training, however, is a very hit and miss affair, and although various types of course do exist, most of these are of an ad hoc nature and there is no established pattern of further training.

University post-graduate courses

Since 1945 the Universities have done their best to establish post-graduate courses in various fields, but these courses have not been able to attract the students. The established pattern of University education is in multiples of a year, and so the post-graduate courses have almost invariably been of one (academic) year's duration (October to June). It is probably a gross over-simplification to say that these courses have failed because they are too long, but this must be the largest single factor. Intended for those who have already had some years practical experience after their initial training, most of the courses would not be running at all were it not for students who are prepared to pursue them immediately after their initial degree courses.

Courses in Colleges of Technology

The Colleges of Technology have been far more successful in their efforts in advanced training. These Colleges have gradually evolved from "night-schools", and although most of their work is now carried out during the day (either with full-time students or with students released from their work for one day per week), they nevertheless run a large number of advanced evening courses. Here there is no set pattern, and indeed most Colleges will arrange almost any course for which there is a demand. Traditionally these Colleges have always used large numbers of part-time lecturers from industry, and although with the increasing emphasis on full-time courses this emphasis has become less, nevertheless they almost automatically turn to industry for lecturers on their specialist evening courses. The usual pattern for these evening courses is a series of anything from five to twelve evening lectures, held weekly, although a few courses have been run in concentrated form, lasting two or three days. Each session usually lasts two hours, divided as appropriate between lecture and discussion. In some cases the whole series will be given by one lecturer, while in others each lecture may be given by a different specialist.

These courses have been very well supported, and have obviously been filling a much felt need. Their biggest drawback is that they are somewhat haphazard in occurrence. Being usually one evening a week, any one course can only serve a limited area, so that except in the very heavily populated centres any particular subject can only be covered occasionally. In other words an engineer based in a country area wishing to study further the subject of say shell roof design will be very lucky if he does find a course suited to his needs within reach. It should perhaps be added that the Colleges of Technology do not in general possess residential accommodation, which does have some bearing on the type of course they can run, and although this situation is changing in the Colleges of Advanced Technology (shortly to become Technological Universities), the residential accommodation will be primarily used for full-time students.

Short courses organized by the Cement and Concrete Association

It was with this background that in 1950 the Cement and Concrete Association started running intensive one-week residential training courses on various aspects of concrete construction. The success of these courses was immediate.

It is obvious that whereas employers are not anxious to send their staff on courses lasting one year, they are keen to send them on courses of one week's duration, and at present there are some 1300 people attending these courses each year.

The Cement and Concrete Association's Training Centre is situated at Wexham Springs, about 40 km from the centre of London, the estate being shared with its Research Station. This coexistence of research and training is a very valuable asset, and indeed research staff are able to present the results of their work directly to the user, feed-back to the research worker on the problems facing the engineer in practice. The residential character of the courses also encourages participants to discuss their own problems providing a valuable cross-fertilization of ideas and experience.

There is an increasing awareness of the value of this type of course, and it is anticipated that the demand will grow rapidly in the immediate future, no doubt accelerated by the work of the Industrial Training Boards.

K1

R. P. Andrew

Believing it has an important role to play in the training field, the Cement and Concrete Association is at the time of writing planning a considerable extension of its training facilities, to permit two courses to be run simultaneously. A new Training Centre will be opened in 1966, and the greatly improved facilities will enable a much greater range of courses to be offered. The new accommodation is also being planned to facilitate the running of courses of longer than one week's duration, as there is a demand for certain types of course which cannot adequately be dealt with within one week. Furthermore, in view of the present trends in the training field, the new Centre is being planned to allow for a further extension if this should prove desirable.

The training courses offered at present range from specialized courses on, for example, bridge design for engineers and industrialized housing for architects, down to courses for the concrete foreman and the ganger. Every effort is taken in planning these courses to ensure that they do meet the needs of the industry, and in the case of the courses for gangers the Association enjoys the closest collaboration of the Federation of Civil Engineering Contractors and the National Federation of Building Trades Employers, both in the planning and in the publicizing of the courses.

This wide diversity of level of courses offered reflects the Association's view of the importance of training *at all levels*, and the response of the gangers (with no previous training since they left school at 14 or 15) to these intensive courses has been most encouraging.

In view of the short time available, visits to construction sites are not normally included during the courses, it being felt that the time can more profitably be spent in the lecture room or in the laboratory.

Where possible, emphasis is laid on practical demonstrations, and for this purpose the Training Centre has its own laboratory, independent of the Research Station. The laboratory is equipped to carry out all the normal tests on the materials, to make up trial mixes and demonstrate the effects of varying the constituents, to cast, stress and test prestressed concrete beams, etc. It is thus possible not only to talk about a subject, but to demonstrate the salient points in the laboratory—a particularly important aspect of instruction when dealing with the practical man (the ganger and the foreman). Indeed, at this level some relief from the lecture-room is necessary, and practical demonstrations offer the ideal alternative.

Unfortunately the present facilities do not permit the courses to be split into small groups for individual experimental work, which would be more appropriate for many subjects at the engineer level. These facilities will be provided in the new accommodation, however, where as well as two main demonstration laboratories there will be a number of small laboratories for such work.

The pattern of the courses offered when the new accommodation becomes available is gradually being built up on the foundation of the experience to date. At the engineer level there will be a "general" course on concrete technology, covering the basic problems of making and placing concrete. It is also intended to introduce a rather longer course (of up to one month) on "design", intended for the young graduate early in his employment in a design office. During this period, it is felt, the young graduate could be taught much of what he at present acquires in his first year in the design office.

These basic courses will provide the background to more specialized courses on such subjects as concrete roads, mix design, precast concrete, lightweight concrete, ultimate load design, formwork, etc., which will, it is hoped, provide any engineer concerned with concrete construction with the possibility of furthering his knowledge.

In the new Training Centre, a "projects" course for both architects and engineers will be offered. This will be very much of an experiment, but if successful could prove of immense value to the industry. The intention is to gather together a number of experienced architects and engineers who would work in groups of three (one architect, one structural engineer and one contractor) on specific projects set for them. Formal lecture sessions will be kept to a minimum, but members of the staff will be available to give advice on specific problems. This intimate working together in small groups will, it is felt, help to give those attending the course an insight into the teamwork necessary to produce the ideal result.

Below the engineer level, the courses at present being run are nearly all of a general nature, covering the basic problems involved in the making and placing of concrete. Obviously much detail must be omitted in a course lasting for only one week, and one cannot expect staff of this level to continue with such an intensive course for a much longer period. Here again the answer would appear to be follow-up courses of a more specialized nature, following a similar pattern to that already established at the engineer level. This trend has in fact already begun, courses on road construction having already been held at the general foreman level. In this way each course will be complete in itself, so that individuals—or employers—may select the courses to suit their particular needs.

Up to the present, no examination has been set for the students at the end of the course; nor does the Association submit any report on the students to their employers. Every attempt is made to avoid a "school-room" atmosphere. The absence of examinations does not result in a lack of keenness in the students. It must be remembered that these are mature people, whose very presence on the courses infers an "interestedness", and who usually already have decided views on many of the subjects dealt with, resulting from their own experience. Such differences of view lead to lively discussion sessions—an important part of every course—and an experienced lecturer can often get the participants themselves to answer many of the questions raised. About half the lectures and demonstrations are given by members of the Association's research and advisory staff, most of the remainder being given by the small nucleus of three lecturers and a demonstrator on the Training Centre staff. The balance of the lectures are given by practising engineers and architects who act as guest lecturers.

The information activity of an international organisation in the building materials industry

Contribution from Cembureau, the European Cement Association

The world cement industry has made rapid strides during the post-war period, reflecting mainly the steady increase in construction activity in both the developed and the developing countries. The actual world production of cement has risen from approximately 180 to 400 million tons in the ten years since 1954. The five largest cement producing countries—the U.S.S.R., U.S.A., Japan, West Germany and Italy, together account for more than half of the total world output, the remainder being provided by about 90 other countries. Western Europe alone produces about a third of the world's cement.

At the same time, this increase in production has been marked by a number of technological advances which have given great scope for the improvement in the quality of the product manufactured.

Cembureau, the European Cement Association, is the international association of the cement industry covering sixteen West European countries. Its main function is to provide an effective link between the cement and concrete associations in these countries by ensuring that all experience gained in one country is promptly made available to other countries.

To provide the proper setting for Cembureau's technical information activities, it is necessary to outline the work of the national cement and concrete associations.

Information activity at national level

The national cement and concrete associations collect information within the cement industry of their country, and from all other appropriate sources, and disseminate it in the form of technical advice to architects, engineers, contractors, precast concrete manufacturers and all others engaged in using cement. They also provide information for the general public, making it receptive to new ideas affecting the use of cement in building and construction work, and stimulate interest in the industry in general.

All cement and concrete associations initiate research and development work on matters relating to the application of concrete. Some have their own laboratories; others provide funds for the support of research in private, academic government institutions, or sponsor research by applying a combination of both these methods.

The information gathered by the cement and concrete associations has to be processed for purposes of storage and dissemination, so that its retrieval becomes a routine operation. This makes an efficient documentation service based on a comprehensive technical library essential.

The education and training of cement users at all levels are important tasks. Training courses for foremen and engineers are organized, some of them forming part of the syllabus at colleges of technology. Lectures are arranged throughout the country and conferences are convened at major centres, serving as a forum for the exchange of experience among experts. Exhibitions are held, often in co-operation with professional institutions or public authorities.

Regular information for a much more numerous audience is disseminated in the form of periodical publications, monographs and pamphlets.

At the same time, close contact is maintained with newspapers, technical periodicals, radio and television, supplying them with news and providing on request suitably prepared material, including photographs and films. Interest is drawn to major construction schemes and important new techniques by means of study visits to sites or factories. The associations also provide a technical advisory service, often from branch offices located in different parts of the country, involving occasional visits to projects in progress. Enquirers needing guidance on literature dealing with their problems are encouraged to use the associations' libraries. Information on research is disseminated in a similar way, though through more specialized channels or media, such as monographs, research reports, proceedings of learned societies, congresses and symposia.

Information activity at international level

The information work of an international association complements that of the national associations by providing a means of linking equivalent activities within the various countries. A proliferation of the bilateral exchange of information between different countries has long been recognized as a wasteful procedure which often involves language problems, and the organization of the flow of information between cement and concrete associations in the sixteen member countries has therefore been made the responsibility of an international association. It is understood, however, that a direct exchange of books, booklets, trade literature and periodicals takes place. It is also natural for an association in one country to contact the similar body in another country to arrange for study visits of architects, engineers, precast concrete producers and other professionals. It is sometimes arranged for specialists to visit several countries to lecture on selected subjects.

Collecting information

The sphere of co-operation of Cembureau covers definite uses of cement and concrete such as roads or farm-building construction, while the largest field of cement consumption may be described for convenience as building and structural work. Activities on the research level consist of work related to the testing of cement and concrete and more recently to research on concrete. A direct exchange of information and views takes place round the table at meetings, in which a large number of delegates from all countries participate, arranged at fairly regular intervals of a year to eighteen months. These events are prepared with documents related to the topics to be discussed and are followed up afterwards by progress reports or final reports. Many subjects are, however, of a standing nature and may require committees, groups or rapporteurs to lead the work more or less continuously between meetings.

The building market is characterized in general by a shortage of labour, especially of skilled craftsmen, and to a certain extent of experienced engineers. Considerable efforts to industrialise building construction have been made in recent years and the quality and over-all economy of concrete element construction have been proved in several countries. A special committee of Cembureau has been assigned the task of studying concrete element construction and recommending action to stimulate the development of rational construction methods. A number of papers to the CIB Congress describe the advances made in concrete element construction in several types of buildings. A trend report on industrialised housing construction in Western Europe gives the proper setting of building dwelling-houses with concrete elements. Another paper concentrates on the use of concrete units for the construction of offices, public buildings and hospitals, while a further paper is concerned with school buildings. One author also outlines the use of elements for factories, sports halls and other large span buildings. Agriculture as a potential market for universal building elements is analysed by another author. The special design considerations of constructing in seismic areas is dealt with in a South European document. A contribution from France is concerned with joint research on new types of prefabrication with the establishment of regional working groups on concrete products.

The possibility of producing attractive concrete facing surfaces is another feature of precasting, although cast in situ surfaces are also of high standard as formwork material, and techniques have greatly improved, partly as a result of international co-operation. Conventional building methods have turned into industrialised methods owing to the developments in formwork, machinery, reinforcing techniques and the use of ready-mixed concrete, as described in one of the Congress papers.

The functional properties of concrete in housing such as sound insulation are under constant review. This subject is followed by an expert who in his capacity as a member of the ISO committee on acoustics has a particularly good knowledge of the best practice in acoustic design. The best methods of obtaining a sufficiently high standard of sound insulation will be compiled in a draft booklet for the use of member associations in their advisory work. Congress delegates will receive a report on the acoustic design of industrially produced dwelling houses. Another property which calls for attention is the thermal characteristics of concrete as used in walls and floors. The function of a building may change after a number of years. Thus a building intended for dwellings may be altered to be used for offices or shops and thus requires a flexible interior design from the outset. This aspect together with the initial and maintenance cost of buildings is being considered in a study of the total cost of concrete buildings during their service life. A special report to the congress incorporates considerations of a flexible design.

The redevelopment of towns implies a considerable field for concrete construction, and information on proposed plans or schemes in progress are circulated to the cement associations. Pictorial material for exhibitions is sometimes circulated between member countries.

The trend in European agriculture shows a rapid mechanization of work and the formation of larger farming units by the concentration of scattered land or by merging small farms together. These developments lead in turn to a need for the construction of flexible farm-buildings. Considerable attention is focused on constructions on the farm and nearly all members associations draw on the pool of information provided at meetings and on the reports by experts. A symposium arranged in 1962 on farm-building techniques fulfilled the function of summing up the latest developments in agricultural construction in Europe and the U.S.A.

Building codes often specify the testing of cement and concrete used in concrete construction. Fruitful co-operation between a Cembureau committee, RILEM and ISO has resulted in specifications for the testing of cement which have been adopted in the national specifications of several European and overseas countries. The growth of the ready-mixed concrete industry is a striking feature in concrete construction and it is natural that the cement industry is concerned with adequate testing methods of such concrete. Studies are also being carried out of properties of hardened concrete such as shrinkage and swelling and resistance to chemical attack, and more and more attention is being paid to appropriate testing techniques of concrete in practical construction. Methods of control in the industrialized production of buildings are described in a Congress paper and a companion paper deals with aspects of the quality control of ready-mixed concrete and the licensing of factories supplying this concrete.

Cembureau does not serve merely as a clearing-house for information supplied by affiliated bodies: for example, the secretariat gathers information from other sources which are not easily accessible to individual associations, or which may even be unknown to them. It also initiates and maintains in countries not adhering to Cembureau exchanges of publications and experience with organizations concerned with cement, such as cement producers, concrete research institutes, building research organizations, as well as individuals in appropriate organizations.

What has been said above concerns technical or research work. Every important industry must plan its future production capacity to meet increasing demand on the market. Cembureau regularly collects statistical data on cement production and consumption and, where possible, figures of the end-uses of cement as well as the volume of total construction. These statistics serve as an important basis for forecasting the future demand for cement. Any materials industry must be interested in various economic aspects which concern its clients such as rational transport of the building material and the efficiency of its products.

It is important for the construction trade to cater for the vocational training of workers, foremen, engineers and supervisors. The cement industry alone or in co-operation with trade associations runs concrete training courses for those categories engaged in the building process. Training is dealt with in two Congress papers.

Co-operation with international organisations

Other international organizations form an important sector among sources of information, and many contacts exist with those covering related fields of interest such as building materials and construction in general. Relations with such organizations take various forms: different types of membership have been arranged with some, while regular exchanges of information and publications are maintained with others. A number of Cembureau representatives serve on international commissions and sub-committees, and joint committees have been set up in particular cases. Cembureau is represented on committees of the International Federation of Prestressing (FIP) dealing with prefabrication, seismic structures, high-strength concrete, prestressed lightweight concrete and fire resistance. Cembureau is a supporting organization of CIB, and is represented on its Working Commission W 19 on Large Concrete Elements. The co-operation with RILEM has recently been extended with Cembureau representatives, the recently established RILEM working groups on the field testing of concrete and admixtures to concrete. It is a natural step to make known the advances in prefabrication by co-operating with BIBM, Bureau International du Béton Manufacturé, at its congresses. As an example of joint committees, – although not in the building field – one might mention the joint PIARC-Cembureau Committee on Prestressed Concrete Roads. A survey of these various contacts would show that Cembureau covers at international level most of the activities which are of importance for its work, and that the resulting information is disseminated widely among all types of cement users.

Processing and dissemination of information

The comprehensive and continuous collection of information from numerous sources by the Secretariat requires a documentation service which stores and retrieves documents efficiently, and which processes them to facilitate their dissemination in suitable forms.

A number of monthly bibliographical bulletins are issued. An accessions list includes a selection of titles of publications received. A bibliography of bibliographies is issued, as well as a bulletin listing translations, intended as a bibliographical tool to assist documentalists and librarians in tracing translations of literature published in Slavonic and other less accessible languages.

Other types of information, whether received from member associations or from outside sources, are disseminated by different methods. Many items of special interest such as important construction schemes, congresses, conferences, exhibitions, surveys and reports by other organizations are featured in newsletters issued at frequent intervals.

Topical photographs are obtained from national associations as well as from outside sources, and are highlighted by reproducing them in a monthly bulletin which serves as a continuous index to buildings and structures in the news.

From time to time experts are commissioned to write monographs on subjects on which up-to-date literature is scarce and these are published in printed form. The two latest publications deal with concrete railway sleepers and monorail structures in concrete.

In the field of research, data on activities in member countries are regularly supplied to the Secretariat which circulates to national associations tabulated information entered on cards in a loose-leaf file. All research undertaken or sponsored by any one association is thus recorded in a compilation which can be consulted and kept up-to-date by all other associations. Concrete research projects in the U.S.A. are compiled in lists by the American Concrete Institute and these will be published together with European lists and be made available through Cembureau to concrete research institutes and organizations in Western Europe.

Just as a properly organized documentation service is important for covering literature within a country, it is also desirable to establish an efficient routine for making this documentation available to associations in all other countries. To this end, the member associations agreed in 1963 that a direct exchange of abstracts of literature on cement and concrete technology and application should be started. The basic principle, in line with that governing the CIB abstracts exchange, is the coverage by each association of the literature in its own country, and the dissemination of this information on abstract cards to all participants in the exchange. The stage has now been reached when most national associations are making preparations for participation in the general exchange of abstracts.

Conclusion. The role of concrete in the development of industrialized building is given a proper setting in one of the congress papers. However, concrete or any other material cannot play a part on its own. It is integrated in the total building process, as is outlined in another Congress report on the coordination of planning, production, construction and financing.

It is natural that an international exchange of information will speed up the building process. Several aspects of international co-operation on information within the West European cement industry are described in this paper by outlining methods of collecting, processing and disseminating information. Experience has shown that this co-operation improves the potential of the cement and concrete associations to be of benefit to the consumers.

Dissemination of knowledge to busy professional men

By D. Fink (Denmark)

The world over, building as well as agriculture are carried on by enterprises geographically dispersed and in general relatively small and economically independent. The word enterprise covers building owners and consultants as well as all links in the building process, from the manufacturer of materials to the unskilled worker on the building site.

The parties in building, both in office, workshop, and on site, belong to various intellectual levels, characterised by different trainings and thereby influencing the editing and dissemination of professional knowledge.

For the professions and trades of building, more or less conservative educations have been organised, with the aim of preparing the individual man to give satisfaction in practical activity as known today. However, any education also ought to give a transverse professional orientation of the entire building industry and an insight into economic and social life.

Acquired knowledge and capability developed during an education do not last for a lifetime. It is asserted that the professional knowledge of technicians becomes obsolete at a rate of up to 10% annually. When we add to this a man's progressive mental rigidity as he gets older, the prospects of mankind seem sinister.

Every man should, regardless of his intelligence level, constantly try to renew himself in his profession and in life as well. However, it is understandable that amazingly few professional men in addition to exhausting work within their profession can manage, by reading, to keep up to date in their field. Considering all stages downwards from the highest levels of education, there are, with professional men, decreasing requirements for, and interest in, expanding their insight, and increasing requirements for data and "dodges" for direct application in everyday routine work.

The enterprise of building and the associations of professions and trades, however, take their own interest in, and generally also have an understanding of, their social obligations to the effect that the fundamental studies as well as continued post-graduate training enable their staffs to contribute to the solution of current tasks in their field. However, this cannot be achieved by specialisation only. Concurrently, more comprehensive information is needed.

Professional and trade organisations, certain social agencies as well as commercial enterprises, therefore try in various ways to renew and expand the knowledge of professionals, with the aim of maintaining and increasing their performance in order that they may constantly contribute to the progress of the enterprise and the society to which they belong.

As fundamental educations have a minimum curriculum to prepare those concerned for a start in certain professions or trades, any kind of post-graduate training is organised with the aim of giving the participants current supplementary or new knowledge for immediate application.

In order to make such post-graduate training effective, methods of psychology of selling are applied, and visual as well as audio-visual facilities are used. Concurrently with the presentation of new information, preconceived opinion and opposition to learning must constantly be fought.

Influence is organised on several fronts, such as:
in the home
at the place of work
at society meetings and arrangements
at arrangements of institutions
at arrangements of manufacturers and suppliers

The great majority of professional men, however, must be urged in various ways to renew and expand their knowledge and capability, or they must be advised by their employers that it is necessary that they keep abreast of developments within their field of activity.

In order for busy men to cope with such self-renewal, however, their intellectual receptivity and working methods must be developed.

Ways of disseminating professional knowledge

These are:
instruction and practice
lectures and discussions
talks and round table talks
advice and information
presentation and demonstration
study circles and self-tuition.

Documentation is an integral part of any dissemination of knowledge and is defined as methods and aids to render the contents of a document accessible to the potential user.

The acquisition of knowledge, and the maintenance and utilisation of such knowledge are practised by different people in different ways dependent upon whether they possess the auditive, haptic, motory, or visual types of imagination. Dissemination of knowledge should therefore be arranged and carried out with proper regard to several types of imagination.

All acquisition of knowledge which can take place at home or at the place of work is for the individual in principle easy to accomplish, but in practice it is difficult to assign the necessary time for concentration.

It is even more difficult for the individual to afford time for any arrangements outside his home and place of work which of course also makes it difficult for organisers to make such arrangements and get attendance. Especially, increasing time of travel between home and place of work and assembly halls, respectively, limits the attendance to arrangements, the value of which to the individual person nevertheless must be considered obvious. It is therefore apparent that, on the part of the organisers, there is increasing inclination to organise courses lasting several days and which are preferably held at another geographic locality than that of the domicile of the participant.

Arrangements for dissemination of professional knowledge

These are:
informative meetings and symposia
courses and seminars
congresses and conferences
exhibitions and fairs
study visits and study tours

Characteristic of all these arrangements is the use of the spoken word. The acquisition by the participants and the audience, respectively, of the spoken word, however, is dependent upon the art of the lecturer to vary between expressive presentation which is impressive, in order to stimulate the receptivity of the audience, and informative presentation which, according to the nature of the matter, must be a relatively monotonous presentation of information. The presentation of practically any subject, however, requires support of illustrations, graphical representation, and tables and possibly models and samples.

According to the qualifications and number of the audience, a large variety of visual and audio-visual facilities are available. Most of these will be commonly known, and the latest ones will be put into use or demonstrated during this conference.

The knowledge accumulated throughout the world, taken down in unprinted notes and reports as well as in publications, is of limited value until utilised for problem solving which, as far as the building professions and trades are concerned, preferably applies to practical activities, e.g. production. As few professional men, however, have surplus working capacity and other qualifications for self-tuition, the knowledge at any time relevant and current to the potential user must be disseminated by means of the spoken word at meetings and other arrangements.

Methods for the dissemination of knowledge are in rapid development, and there are exciting innovations imminent with regard to fundamental as well as post-graduate training.

The latest inventions of teaching machines, audio-visual and other facilities have not yet been realised nor have the final experiments on this subject yet been undertaken.

Methods of transmitting and receiving information on building

By S. Janiszkiewicz (Poland)

The report gives ways by which informative material is collected in the Polish building industry and how it is transmitted to its users, mainly designers and contractors. The organization of the information service in Poland is linked to state administration and is supervised by the Ministry of Building*.

The Technical and Economic Building Information Centre not only carries on activities appertaining to information but also fills the role of coördinator of the entire information service network of scientific research centres, federations, enterprises and designing studios.

Directing information under such circumstances is facilitated because by way of properly collected informative material, it can exert its influence on the trends of technical development, disseminate new methods of execution, new building materials etc.

Preparation of informative material

An analysis of the production plan and of the plan for technical development constitutes the first task lying at the foundation of all preparation of informative material.

The analysis should in consequence indicate which of the tasks given in the plans mentioned above will require, before they begin to be implemented, informative material to be collected, indispensable to an efficient and correct execution as regards its quality—one which will conform to the standards in force, to the quota units and technical conditions.

Such an analysis should in principle include all the production tasks. Technical services of federations and enterprises should give their attention, in making their analyses, not only to new and difficult processes, but also to those which are traditional but on a massive scale, and which because of their mass, require special care both on the part of the federation and on the part of the enterprise. For this reason a list of such tasks must be drawn up on the basis of production plans and plans for the technical development of the supervised units in the federation for its own needs as issuing from its function as production and technical supervisors over enterprises. Such tasks will be under the particular care of the federations for which informative material is to be collected, which will be indispensable for a proper fulfillment of their duties as supervisors and which will be needed to perfect and raise the qualifications of their own personnel.

Projects to be undertaken by enterprises should be indicated, and informative material should be collected before work on them is begun. This will concern in the first place new technologies, new methods of execution, the use of new building materials, new machines etc., as well as those undertakings where known technological processes will be used but which will require special care because of their complicated character or because they may be executed under specific conditions (periods when the temperature is low, special conditions for making foundations etc.).

Scope and kind of information

The scope of collecting the material will depend on the level of the principal groups of its recipients. If the recipient is of the assignment level (in federations and enterprises), the scope will be extensive, covering the whole of the task to be implemented and will become narrower as the responsibility of particular positions taking part in the implementation of the tasks becomes smaller. Informative material should be prepared so that it will be differentiated according to the groups mentioned above in two aspects.

Education will be the first of such aspects, whereas the function fulfilled will be the second. The task is difficult because basic informative material is not so differentiated. For this reason, the task of the information service collecting material for the respective groups of recipients mentioned is to prepare it in such a form that it would be most easily available to such groups. Before beginning to implement a definite task, the federations and enterprises should prepare by way of their information and technical services, sets of informative material according to definite groups of recipients.

Collection of informative material; an outline scheme of their preparation

As mentioned above, a detailed analysis of technological, organizational and economic problems pertaining to the implementation of a task should precede the collection of informative material. The results of such an analysis should indicate the informative material that should be collected in order to become familiar with the task to be implemented, to organize it properly and to execute it properly under definite conditions and in a definite time.

Such material will be:

- The orders and other obligatory legal acts such as: standards, quota units, instructions, legal regulations,
- classification as to theme with documentary analyses of technical literature on the implementation of the task discussed,
- data pertaining to experiences gained by other units which had implemented similar tasks and with which direct contact can be maintained to discuss such experiences, etc.

The duty of collecting material, as regards federations, belongs to the Information Centre in agreement with the technical board of directors. Material should be collected in the enterprises by the respective technical departments in agreement with the managers of buildings erected.

Utilization of material

Proper utilization of the informative material collected constitutes the basis for taking proper decisions and for the proper execution of tasks on all levels of their implementation. This is the most difficult problem in the entire cycle of elaboration, collection, transmission and utilization of information. The informative material can be excellently prepared but if, however, it will not be properly received and utilized, the entire work of the information service will become ineffective. The problem concerning the reception and utilization of information by its potential recipients becomes the more difficult because it is composed, especially on the level of its direct executors, of a number of factors, sociological, psychological, physiological in nature and of such factors defined as material incentives. Material incentives are the consequences of a correct performance of the task. They are not the cause but the result, as regards quality, of a good and punctual implementation of production plans. Well prepared information received well by the recipients gives a guarantee for putting such incentives into action.

Factors of the first kind result from the social consciousness of the working crew. Hence, it is the duty of the managers of the federations and enterprises to present to the social awareness of the technical personnel and the working crew, the aims, needs and role of the implemented task in the national economy.

The physiological factor, good physical fitness and increased output requirements depends in a large measure on creating a well organized work for the crew and proper conditions of work and recreation.

When preparing the way in which information is to be utilized all these factors should be cleverly used. They depend on an adept approach of the technical personnel to the crew, on their tactfulness, on the confidence the crew has in the personnel and on their personal moral assets. Utilization of information must take place in a planned way. This will include a number of consultations and conferences at the level of the federation when informative material needed in the implementation of production tasks defined by the plan will be transmitted to workers of the federation and to those workers of the enterprise responsible for definite tasks.

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* The Ministry of Building supervises the building-assembly and specialist federations, which in turn supervise the contractor enterprises.

Such material must be elaborated in written form. An employee of the federation (the manager of the Information Centre) should be designated by the board of directors of the federation as the one responsible for the elaboration of the material and for transmitting it to those interested. Informative material should be talked over and discussed. Such conferences by their very nature would be educative in character and it would be recommended that they be conducted as a seminar.

Such conferences could if necessary, be supplemented by exhibitons, films or excursions to the building site, where tasks similar to those discussed are in the process of implementation. The manner in which information is to be transmitted on the level of enterprises should be educative in nature. Informative material and the groups of its recipients should be differentiated as depending on the level of training and the function filled in the federation.

Experience with information sheets on building details

By H. Kristiansen (Norway)

The need for transferred information

The tremendous growth of technical literature in building research makes it impossible for those concerned with building practice, to keep their knowledge up to date. To reduce this problem there are various series of digests which present news, research results and principles for planning and building in a way that makes it possible to cover the field more quickly. Thus the information reaches half way to practice.

The next step, to transfer and apply this new knowledge to existing practice, demands more again. It demands time and experience and is rarely achieved other than by the very few firms which have a development section of sufficient size within their staff.

For all other designers and contractors there is a strong need for this kind of information which gives new knowledge transformed into design and specification ready for use in designing and on the building site itself.

Existing loose leaf information sheets

There are several kinds of information sheets on building details, and it might be of use to group them into three broad categories:

Digests

Most digests presenting information on building deal with principles and conclusions of research work. They also give advice. But very often the problems they are handling are seen from a more theoretical point of view.

Information sheets on products

This technical and economic information on products should enable architects and builders to choose between a number of materials and products. A master list of properties of products, which this kind of information should provide, is prepared by a CIB Working Commission (W 31) in CIB Report No. 3.

Information sheets on constructions and building details

There are several types of information sheets on building details. Some of them show examples of details or constructions of existing buildings and without any further explanation. Others explain the principles and show important details.

This paper deals with experiences of information sheets issued in Finland (1) for more than 20 years and in Norway (2) for about 8 years. The sheets may be defined as:
Loose leaf information sheets dealing with new knowledge transformed and applied into design and specifications ready for practical use.

The Finnish and the Norwegian information sheets have much the same frame and are divided into three main sections:

Introductory The introductory section deals with the following topics:

- The object and the scope of the sheet in question
- Defects and faults of execution, products, materials etc. often occurring in connection with the topic treated and which should be prevented when making up the drawings, specifications etc.
- Survey of all general and specific aspects which ought to be taken into consideration when the details of work are to be indicated on drawings and specifications.
- General information on the sheet and on the products, materials and executions recommended in it.
- Reference to other Architectural Data Sheets, National Standards, Building Codes and Regulations connected with the topic treated.

Materials. The section is called "Materials" and shall set out the requirements needed for the products and materials to ensure a high standard of execution and a high quality in the finished building. Generally, this section includes references to existing relevant National Standards. The materials are individually described with the symbols of the SfB-system for building products. Information should be given on the quantities of products and materials needed for the work in question. Names of firms and specific products should be avoided.

Execution. This should set out the requirements needed to ensure a high standard of execution and a high quality in the finished building. The description of the work should follow the order of operations which is usual in the building process and should be as close as possible to the usual style of working descriptions. The description should be accompanied by ample illustrations.

Whenever suitable, reference should also be made to other publications. These references should refer only to publications which are easily comprehensible and accessible for the group(s) of builders who are intended to benefit from the sheet in question.

From the editors' point of view the above mentioned series have been very successful. A very high percentage of architects, civil engineers in the building trades and of contractors are subscribers and thus the series have become effective tools of information.

Purpose, character and recipients of data sheets

The purposes vary according to the interests of the editors, and the following list does not attempt to give a definitive ranking:

- To spread research results
- To spread and encourage the adoption of the results of new research from own and other research bodies is a main problem for research institutions.
- To encourage standardization
- Interpreted information of high quality on constructions and details issued by recognized authority and adopted by the users will serve as a standard even if it is not a formal standard.
- To spread information on good practice. In most countries the practice differs in different parts. Information sheets may be of great help in the endeavour of getting good practice from one district adopted by the others.
- To facilitate planning. The work of planning becomes more and more complicated and time consuming. "Standard" details will solve problems and save time for the designers.
- To facilitate the work on the building site. "Standard" details will save time. They will be well known by the workers and, therefore, raise productivity and quality.

The character of data sheets. In spite of the close connection between the editors in the countries mentioned above, their data sheets differ in character. Perhaps the differences explain some typical traits of how data sheets have their specific forms.

The institution which the editor represents and the editor himself will—consciously or unconsciously—tend to rank the list of purposes mentioned above, depending on their interests.

A research institute may see as the most important task, to present new research results and to get them adopted as soon as possible. As a result of this the choices of items may seem disconnected. The collection of these loose leaves will not be as a complete handbook answering all common problems. The leaves may be of temporary validity because they deal with topics which are in the process of development.

A standardisation body may be more concerned about trying to present "best current practice". Attempting both to influence existing practice and also to keep a certain connection with tradition demands a process which may take time and possibly risks loosing the attraction of innovation.

A third institution might try to make a collection as complete as possible (dealing with all common problems) and provide information of long term validity. By such ambitious and respectable attempts one will always run a great risk to be overtaken by developments and the demand for more information.

Influence of the author

As well as the editors and the bodies they represent, the authors themselves influence the character of the data sheets. The choice of authors will, therefore, to a certain extent be a decisive influence on the specific form of information sheets.

Influence of national conditions

There are several reasons why the same problem and information must be handled differently in different countries such as:

Climate and resources. The design of specific details and constructions for practical use has to be related to a particular climate. The materials and products at hand will differ depending on the national resources.
The information must relate to these actual conditions.

Laws and regulations. There is to day more or less a lack of correlation in laws and regulations between one country and another, and the information must of course be in accordance with the existing regulations.

Tradition and workmanship. Breaking traditions demands intense information activity to get a correct new practice, and should as far as possible be avoided. Both the inheritances of knowledge and the traditions of quality of workmanship differ from one country to another. Information on building practice has to start at the appropriate national level.

Existing information. Existing regular information through journals, handbooks, standards, standard specifications, catalogues and data sheets from the producers of building materials etc. have to be considered so that the information in building practice fits into the national pattern.

Categories of recipients and categories of information. Effective information should give a precise answer to a clear question. As the points of view of an architect, civil engineer and a contractor are not quite the same, one should give different information for these different categories. The different education of the recipients should also be taken into consideration.

The extent to which an institution can provide a wide range of differentiated information must be related to the resources of the institution. Thus in small countries it is not possible to differentiate the information to a very great degree. For example in the Scandinavian countries you will not find data sheets intended for every single category of recipients. To bridge the lack of possibility of giving an accurate answer to each category of recipients, and to make the information sheets an effective tool, there is a need for the recipients to have an understanding of the background and reasons for a certain performance. This should, therefore, be explained in the information sheets.

To sum up, information sheets on building details and constructions should explain the reasons why the design and performance has its specific requirements. In design and specification, they should show precisely how new knowledge combined with best current practice may be interpreted and applied to constructions and details ready for use by the practitioners.

Some conditions for success

Quality and regularity

To stimulate interest and to extend its use, the information should answer to actual problems. Constant high quality is necessary to maintain confidence in the information.

The preparation of information sheets is not a one man job. To secure high quality the information should have its origin in a broad milieu which has relations with research, with standardisation and with practical work on building sites. This, possibly, can only be managed by a balanced composition of the staff.

A certain quantity is also needed so that, as far as possible, each recipient finds an answer to his actual problems. This kind of information should be issued regularly, and it is very important before starting to be sure of having the capacity and resources to fulfil the work for a lengthy period.

Editing

The frame of the data sheets is of great importance. The layout should be logical and well integrated in text, figures and design. A data sheet should not contain too much: Perhaps one to three pages of material. It should not deal with more than one problem. It should give a complete and clear answer on a well defined topic to those it is meant for. The information should be flexible in a way that makes it possible to apply it to different situations. Text and drawings should be presented in a way familiar to the recipient. The language should be plain and unacademic. Too much information is written in complex style and language though it is shown that even people with a higher education prefer information to be simply written.

Impartiality

The editorial body should be independent with sufficient professional standing and with the best possible contacts and relations with the construction industry. The information should be based on knowledge derived from objective research and practical experience. All references to individual firms and use of proper names on products or methods should be avoided.

Terminology

Success in disseminating this kind of information will confer a status which demands a high degree of responsibililty. The information will penetrate to all levels in the building industry. The terminology used will set an example and should be carefully formulated.

Renewal

Series of loose leaf information sheets on accurate, specific details may be prejudicial and against the purpose if they are not kept up to date. Obsolete information is a barrier to progress and must be removed or replaced. The problem of keeping material up-to-date might be overlooked at the start, but it will increase proportionately to the number of sheets. The loose leaf system is mostly chosen to ease this problem, and the routine for the renewal should, therefore, be planned at the start of any series.

The possibilities of international collaboration

It has already been mentioned that the main point in this kind of information is to keep in close contact to the existing national building practice. The climate and other conditions also limit the use of design from one country to another. Within these limits there should still be possibilities for some exchange of information especially on favourable performances which easily can be adopted in other countries. More possible would be the exchange of basic material, i.e. the information which is not printed and remains in the possession of the editor, and on which the information sheet is based.

Last but not least, an exchange of experience on general information and communication problems on this field could be most valuable. In international collaboration there has been a great deal of work on the classification and systematizing of information. These investigations have been very useful. But perhaps it is now time for a discussion of the real content of information, how it should be presented and how it is adopted. The development of a basic understanding of the mechanism in communications would enable us to ensure that the research results will be of benefit to the community.

In this field there are basic problems specific for the building industry and for research bodies. In raising these problems and attempting to solve them, there will be need for international collaboration and exchange of experience.

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Promoting building knowledge and its application in Asia and the Far East

By G. C. Mathur (India)

The task of promoting building knowledge and its application is characterised by developments in several fields of activity connected with building. As compared to industrially advanced countries, the accomplishment of the task in the Ecafe (Economic Commission for Asia and the Far East) region poses several peculiar problems owing to great differences in social and economic conditions, climatic factors, technological development, human and material resources. The two main aspects of the problem could be identified as follows:

- promotion and application of knowledge as regards improvements in indigenous building materials, traditional construction techniques, manual building methods, planning and designing of buildings to suit the climate and socio-economic conditions of the region.
- collection, study and adaption of modern advances in building knowledge acquired by the advanced countries to build economically, speedily and efficiently.

Though much would have to be achieved by the countries of the Ecafe individually and collectively, international co-operation and assistance to the Ecafe countries would be of great value in this field.

The programme. In the programme for promoting building knowledge and its application, stress is squarely to be laid on building research and application of its results. It is not the intention in this paper to discuss the role of building research. However as it plays an important part in assisting promotion of building knowledge and its application some discussion of the pattern, programme and organisation of research in the Ecafe countries, has been inevitable. The three main steps that are required to initiate efforts for promoting building knowledge and its application are:

- promotion of building knowledge through research. To create more knowledge to solve local building problems and the problems which are involved in applying knowledge;
- development works. To co-ordinate and integrate building research and to promote application of its results.
- implementation. To transform building knowledge and results of research into actual practice.

Promotion of building knowledge through research

Research facilities. Facilities for research in building are generally inadequate in the Ecafe region. As a result many building problems exist and there are gaps in building knowledge which have to be bridged prior to promotion and application of such knowledge. Many countries of Ecafe have yet to take an initiative in organising national and local centres for building research and for co-ordinating the efforts for the benefit of the industry. In India, research and co-ordination work are receiving increasing attention. The Central Building Research Institute at Roorkee was set up in 1947 and is the premier national laboratory. The National Buildings Organisation was established in 1954 to co-ordinate building research and to promote application of results. Local centres for building research for tackling problems of indigenous character have also been established by the Public Works Department in different States of the Indian Union. To tackle building problems peculiar to the Ecafe region and to disseminate building knowledge in a concerted manner, under the auspices of the United Nations Economic Commission for Asia and the Far East, two Regional Housing Centres have been established. One Centre is located at New Delhi (India) for hot-arid regions (N.B.O.) and the other is at Bandung (Indonesia) for the hot-humid regions. The activities of the Regional Housing Centre, New Delhi (India) (N.B.O.) for promoting building knowledge and its application have been separately described at the end. Such effort at international level and work done by agencies like the International Council of Building Research Studies and Documentation at Rotterdam (CIB) and a specialised U.N. agency to deal with housing and building are highly useful in channelling international co-operation and assistance for the advancement of building knowledge and its application.

Co-operative Research. The building industry should also give due place of importance to research to promote its development. Perhaps a stage has not been raeched when the individual industries could afford to set up research units of their own. However, research on co-operative basis could be sponsored or organised by the respective building materials manufactures' Associations in Ecafe countries.

Industry Oriented Research. Building research is of practical importance and as such industry-oriented research should receive greater attention. The programme of research should be evolved to fulfil the requirements of the building industry, which will enable full exploitation of the results by the industry.

Indigenous Problems. Improvement in the use of cheap, locally available but non-durable materials like certain types of soils used for building mud walls, grasses and leaves which are used for covering the roof, reeds, bamboos and local timber that are used in many ways in building —should receive special attention. The use of these materials is widely prevalent in the Ecafe region but these materials possess certain inherent defects which have to be offset by evolving improved building methods.

The predominently tropical climate of the region also presents several building problems like control of heat to promote thermal comfort in hot-arid climates, water-proofing of rooves and damp-proofing of floors and walls in wet climates, termite proofing and resistance to decay, fire-proofing and earth quake resistance in certain regions.

Modern advances. Side by side, the advances made in the industrially developed countries have to be studied and such research work undertaken which would assist in adapting the techniques to suit the indigenous requirements and local conditions.

Research Follow-up. Building research centres are intended primarily for research work; however, to realise the benefits of research it is necessary to undertake follow-up action to ensure the application of results in practice. This would mean extending research activities to include in its scope laboratory and field trials for achieving practical bias, extension of knowledge through demonstration and pilot plant production, dissemination of knowledge and technical assistance in field work. It may not be feasible for research centres to accomplish this without impairing research. Nonetheless in the Ecafe countries, to a certain degree, research has to undertake the responsibility of promoting building knowledge and its application.

Development Work

Co-ordination of building activities and efforts to bring about developments in the building industry call for adequate research background and appreciation of the problems involved. Where the problem is not big, research centres may equip themselves and contribute to follow-up action. But in big countries a separate agency for co-ordinating the development work is warranted to concern itself mainly with the task of promoting knowledge and its application, to serve as a link between research centres and the building industry, attempting to bridge the gulf between research and its application. It would also act as a channel for feeding-back. Such activities are composed of research co-ordination work on the one hand and promotion of application of results on the other hand.

Research Co-ordination. It involves co-ordination and integration of building research by:

- Co-ordination and integration of research programme;
- Identifying practical building problems of the industry;
- Initiating the problems for investigation;
- Farming out research schemes;
- Sponsored research work —providing financial, technical or expert guidance;
- Studying and evaluating results of research and
- Presentation of the results of research.

To these ends the co-ordinating agency works in close collaboration with building research and development organisations.

Promoting application of results. It entails the following action:

- Field trials;
- Large-scale experimental construction or pilot plant production;
- Wide dissemination of building knowledge in readily intelligible form;
- Extension through demonstration and displays;
- Transformation of results of research into actual practice and
- Surveys to ascertain the extent of implementation.

To achieve these the co-ordinating agency works in close liaison with the building industry and prepares them as receiving ends for adopting the results of research in practice.

Information service. Another important development work is to collect and collate building knowledge acquired through research in the advanced countries. It evaluates the knowledge so obtained, to the building industry. It answers enquiries by studying available knowledge and information.

Implementation

Application of results of research in actual practice is an exacting task. The progress is achieved rather slowly. It calls for concerted action to overcome many hurdles. Therefore a proper approach to bring about implementation is of great significance. Some important actions in this direction, in conformity with the conditions in the Ecafe region, are highlighted here.

Laboratory and field trials. Full-scale laboratory trials are helpful in ascertaining certain problems in the application of results of research. Such trials, under controlled conditions, provide necessary data to meet the practical requirements. However, such trials do not account for the actual field conditions. Field trials are also necessary to appreciate the practical field problems and possible variations which may have to be encountered. This would help in further perfecting the techniques. To carry out laboratory and field trials the building industry should provide facilities and extend its co-operation to the research centres. Due to large variations in local conditions in the Ecafe region adequate trials are essential to promote application of results. Display and actual demonstration as means extending new ideas and techniques are of particular significance in the Ecafe region. They convert 'know-how' into 'show-how'. This also offers an opportunity to provide for training. As such the laboratory and field-scale trials would provide an opportunity for clarifying and extending the ideas and techniques. It may, however, be necessary to organise demonstration projects to extend the ideas and techniques.

Experimental construction and actual practice. It is still found to be necessary to undertake large-scale experimental construction or pilot plant production to establish the utility of new ideas, materials and techniques, to enquire into the possibilities of repetitive use and possible variations and thus to transform ideas and results of research into actual practice. Such projects would also provide a cover for unforeseen eventualities of risks which might be involved, create confidence and demand, offer an opportunity to obtain sufficient data for modifying the techniques, if necessary, to satisfactorily suit performance called for. This would greatly assist in transforming the results of research into practice. Provision for undertaking experimental construction should be kept in the building budget and funds for setting up pilot plants should be provided liberally. In promoting building knowledge and its application experimental projects on a large enough scale would create the desired impact.

Promoting self-help effort. By and large, building activity in the Ecafe region, particularly in the rural areas, is carried through by self-help. As such building knowledge is required to be promoted in order to meet the requirements of ordinary builders. The requirements in this respect are much different than in advanced countries where building activity is undertaken mostly by well-organised public agencies and private co-operatives and knowledge is required to suit the needs of certain specialised groups of people. Therefore in the Ecafe region stress is to be laid on an extensive programme of dissemination of building knowledge at the individual level and on simpler and popular presentation of knowledge. Moreover, as the vast majority of the rural population is unable to read and write, it is imperative that audiovisual techniques should be adopted.

Technical assistance. As the economical level in the Ecafe region is rather low the peoples have to be enthused in adopting improvements through technical and financial assistance, which, therefore, should be provided for in the dissemination programme.

Implementation survey. The extent to which results of research are absorbed by the industry should be checked and studied periodically. The causes which prevent or retard the application of results of research should be identified and a proper approach to overcome these hindrances should be developed.

The work of regional housing centres

The National Buildings Organisation which is also the Regional Housing Centre of the United Nations for hot-arid regions of Ecafe was established at New Delhi, India, in 1956 as an agency to co-ordinate and promote building knowledge and its application.

Research co-ordination. The activities as enumerated under the heading development work, are pursued by the Centre. It has sponsored several research projects, co-ordinated research activity, evaluated results of research with a view to their application Special problems of the building industry in the Ecafe region have received its attention.

Service to building industry. The Centre provides an information service to the building industry. Useful information also from abroad is circulated to the building industry, through library service, screening of films, publication of building trade directory and bibliographies, through the issuing of abstracts and digests and via an enquiry service.

Dissemination. The Centre arranges for dissemination of building knowledge and results of research by bringing out publications to suit the requirements of people of different levels such as research workers, field engineers and architects, technicians working on the job, building materials manufacturers and builders, ordinary people interested in building and the rural people. Popular publications on technical subjects in regional languages are also published. Lectures and training courses are organised; symposia and seminars are held; films and other audiovisual materials are produced and exhibited; lectures and radio programmes are broadcast; articles and press notes are issued for publication in daily newspapers, popular periodicals and technical journals.

Contact and liaison. Liaison officers to the Centre have been appointed by the member countries of the Ecafe and the State Public Works Department in India. Close contact and collaboration with building research and development organisations have been established. The Centre has made agreements for exchange of information and results of research over some 210 research institutions in India and foreign countries. The Centre provides a forum for those in the public service, engineers, architects, manufacturers and builders to find solution of their problems. Above all, under the aegis of the United Nations and the International Council for Building Research Studies and Documentation it serves as a link in the chain of an international movement for promoting building knowledge and its results.

Regional Housing Centre, Bandung (Indonesia). The Centre at Bandung is catering specially for the requirements of hot and humid regions of Ecafe. It is also engaged in advancing building knowledge and bringing about its application.

Conclusions: National and local research centres should be set up to promote building knowledge specially in the matter of bridging the gap in knowledge as regards improved utilisation of indigenous resources and tropical building problems. Research on co-operative basis may be organised by the building industry to solve the problems involved in the application of results of research. The work of collection, study and dissemination of modern building knowledge acquired from advanced countries should receive greater attention. Industry-oriented research should receive specific attention and the results should be presented in simple and intelligible form. Research centres should not confine attention to research but may also engage in taking follow-up action. When the task is great a separate co-ordinating agency may be created. Effective liaison should be established by Ecafe countries to support and to carry forward the work done by the Regional Housing Centres.

A practical approach to the dissemination of knowledge (implementation of results) should be developed e.g. by undertaking of field trials, demonstration work, pilot-plant production, experimental construction on large enough scale and dissemination of building knowledge particularly by audiovisual means. Adequate technical and financial assistance should be made available especially for promoting and organising self-help effort.

K 7

V. Zignoli and C. Castiglia

Vocational training of workers and foremen in the concrete construction industries

By V. Zignoli and C. Castiglia (Italy)

The fundamental importance of technical training of young men in any type of industry is well known. This importance has been examined by European organizations which recognize the need of more skilled workers in the production field. Therefore, it is particularly important that a specific examination of the European situation regarding the technical training of qualified building workers and foremen should be undertaken, particularly in view of the creation of a European labour market. The following study has been faced with serious difficulties, due to the lack of documentation and of statistics on the subject. While in the field of traditional industries, especially metallurgy, we have information which has been recorded with an excellent formulation, in the building field it appears there is insufficient co-ordination on a subjective interest.

Anyway it has been very interesting to find on the one hand a certain amount of secrecy from some of the people interviewed, and an absolute and conscious confidence of some other people, who recognized that a common experience and co-operation could give many advantages.

Aims of training

The necessity of studying the methods which have been used for training is deduced from the interest of forming more completely the working unit. The worker must be able to have a more complete professional life and he must have a wide technical knowledge to participate consciously in the work of the building firm. Continuous technical progress necessitates the new generation being qualified and being able to face up to progress. The higher mechanization which any modern building firm tries to reach would be useless if training could not allow the workers to exploit its operation. This principle is true for workers, but much more for foremen.

The trend of professional training of building workers and foremen has been modified in the past years. These changes have followed, of course, the changes of the work market and of the employment politics which have been adjusted to economic needs.

Technical evolution has been equally fast in each European country. In each case it brought a large increase of qualified workers, requiring from the workers, most of whom are not qualified, a fast adaption to the new trend. The specific possibility of the building industry to absorb unqualified labour gives rise to many serious problems. There is hesitation in facing the political problem involved, caused by an increase of qualified workers, while increased technical progress reduces opportunities for employment. This is particularly true in underdeveloped and depressed countries. However, it is necessary to keep in mind, as experience has largely demonstrated, that technical progress can only give rise to a quantity of work which is superior to that which preceded it.

Research

All over Europe, technical training is generally given by vocational schools or firms. At this point an immediate question arises: "Must professional training be hinged on schools or on firms?"

If we refer to the aim we wish to achieve, there is no real distinction. Rather we think that the higher interest consists in co-ordinating the two. From the point of view of costs schools are financed directly or indirectly by firms and as far as teaching programs are concerned firms indicate and direct a certain plan of courses. Generally in Europe training is fully organized by firms with an organic system of regulations. On the other hand in France, there is a Central State Service which is organized in a scientific way, on a very vast scale and which is based on already established directions. The firm intervenes only to give a help to the State initiatives and the apprenticeship in firms is considered as an integral or substitutive part of the school duty. Sometimes costs are borne by those attending the courses.

Programs

Systematic and radial staff training is much more evident in the case of training of foremen whose functions of staff management, work scheduling, preparation and control of the working stages, require a greater and greater responsibility. As far as the programs are concerned, in all European countries, the teaching programs have common fundamental subjects:

- Properties of concrete
- Proportion of cement
- Methods of casting
- Additives of concrete
- Winter castings, heating methods
- Reinforcements
- Building machinery
- Formwork
- Joints
- Mixtures
- Vibration
- Technical drawing
- Hygienics

and laboratory demonstration tests concerning:

- Quality control
- Laying of wires and cables
- Inert moisture
- Prestressed concrete
- Static testing.

The basis of teaching is common both for workers and foremen, but foremen are also given information which will enrich their knowledge and will prepare them to carry on their tasks, and to develop everybody's spiritual and intellectual endowments. As regards foremen the courses aim to take advantage of their natural aptitudes for command, but for workers comparative responsibilities are, of course, much more restricted.

Courses

With regard to the length of the courses, we must make a clear distinction between a full time term and a part time one. Young people and aspirant foremen usually attend the first one, the second one is attended by workers.

Part time courses

In Sweden these courses last 4 or 6 weeks and they are organized by the Swedish Cement Association. They are evening courses of 70 hours in all of which 50 are dedicated to lectures and 20 to demonstrations. In Norway much the same conditions apply and for the foundation of these courses a Concrete Instruction Council has been created by the Norwegian Cement Association. In these two countries experience has taught that after a working day, evening courses are quite heavy, so that many people prefer correspondence courses. The reason for this preference may be seen from the psychological point of view, that it is a person's own will which keeps him in touch with the school.

Correspondence courses have been founded in Belgium, but they have not had a great success, although everybody agrees on their importance.

In England there is a general trend towards seasonal courses lasting four or six weeks.

A Sunday school which has been started in Cremona, Italy, seems very interesting and successful both for results and attendance. In Italy, where specialization courses last at least six months there are also some courses directed by ENAOLI (Scuola Edilizia Lamaro della Enaoli) for the workers' orphans.

In Italy there are 247 Building Institutes, where about half of the time is dedicated to technical teaching on concrete. These courses are attended by young men with some experience, who did not end their course of study and who desire to cease being laborers and to become qualified workers. The courses last six months and successful candidates obtain a qualification diploma, (bricklayers, reinforced-concrete bars workers, cement layers and so on).

Italian Training Institutes are attended by young people after normal school and their courses last three years. These normal schools require eleven years of study; young men end the courses at the Technical Institutes at 18 years old and obtain the qualification of building foremen. The courses are not well attended because the qualification has not much value. Young men who can continue their studies prefer to attend a school for geometers (138 state schools and 40 private schools) which have 1744 classes and about 40,000 students and where people are prepared for general building construction and especially for reinforced concrete building. These schools give a diploma by which a person can start an activity as building foreman and practise a real profession with some limitations concerning reinforced concrete projects, but with good possibilities to work as assistant to the chief building yard engineers.

Among the other Training Institutes, there is in Rome a very well known and highly appreciated one, the Scuola Edilizia Lamaro della ENAOLI, run and subsidized by the "Institute of Cavalieri del Lavoro".

In Italy, the *Evening Schools recognized by the State*, are often annexed to some Superior Institutes (as the Giannelli School of the Engineering faculty of Rome). They are attended by qualified or specialized workers who aim to become building foremen. In the main, schools for workers and foremen specializing in concrete have not developed greatly in Italy due to the fact that young people are not attracted to the work because of its seasonal nature and the discomfort of work on building-sites. Those who wish to become qualified workers and to reach the position of foreman prefer working in comfortable factories without the risk of seasonal unemployment.

Vocational training in France is divided into complete courses and part time ones. Two precise distinctions must be made regarding age and regarding different degrees. People without a basic education or people who have to be educated professionally by specialisation, attend first grade courses. For specialisation, in order to become highly qualified, there is a second grade course. There is also a great need of training for adults, who have a problem which is essentially relative to the capability of acquiring a higher qualification or to the adaptation to new jobs.

This conception of "polyvalency" has been essentially developed in France and has interested Belgium, much more than any other country; in fact in this country it is easier to change a job, if we consider that 80% of workers work in small firms where the staff consists of 20 people.

In England only, technical teaching for concrete is completed with some lessons concerning the use of concrete in road construction.

Full time courses

These courses are attended preferably by students younger than fifteen and they may last from five to six months or to three years (Italy and France). There are forty hours a week of study and the State is almost completely in charge of expenses. Only occasionally do the students give their personal contribution. In part time courses, the students themselves bear the cost of the course.

In Italy an interesting idea is being studied by the Defence Office, of including some specialized courses on concrete during military service.

As regards age, for unspecialized workers in Belgium, the minimum age at which a man may become foreman is 23, and he must have at least 5 years practice on the site. This idea is not shared by Germany, where more than anywhere else, you may find, in a specialized field, someone who did not have former experience at all. Hence the reason for the unproportioned increase of the number of foremen to the number of workers which increased from 1953 to 1962 in the ratio of 1/29 to 1/21 between foremen and workers (an increase of about 50%). On the other hand it is necessary to have a reasonably wide choice to create a supply that will be able to satisfy the possible changes of work demands. Moreover, we have to keep in mind retirement which must take place at different ages with the purpose of avoiding that a large number of collaborators of about the same age, could prevent some industrious but older people gaining promotion.

Conclusions. Building firms after the war have been structurally transformed both for the higher increase of investments and for the attainment of complete and full employment; all this requires an accurate planning of the factors interested in the operating cycle. Planning is especially required to meet the possible demands. It is also necessary to co-ordinate the information that must come from parties concerned. This information must first of all consider the forecasts of the work necessities.

In the schools the planning of courses must have its own gradual progression starting from the primary education to the more complicated one. Then it is necessary to unify teaching programs, stressing present subjects like prestressed concrete, and bringing in subjects that have been wrongly under-emphasized (e.g. hygienics), or have not been studied at all (e.g. accidents).

It is necessary to consider and study more organically the evening, correspondence or Sunday schools.

Finally, it is necessary to promote meetings not only among the teachers and lecturers, but even more among the apprentices of different schools.