BUILDING RESEARCH WORLD WIDE

Proceedings of the Eighth CIB Triennial Congress, Oslo, June 1980

Volume 1a

Key-note papers, invited papers and submitted papers

Edited by

Norwegian Building Research Institute

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PREFACE

This volume contains key-note papers, invited papers and submitted papers for the Eighth Triennial Congress of the International Council for Building Research, Studies and Documentation (CIB) held in Oslo in June 1980.
Key-note papers are written by authors who are requested to review the field indicated through the subject title.
Invited papers are written by authors known to have special knowledge on one or more subjects within the field.
Submitted papers are written by authors who have responded to our general request for papers within the framework of this congress.
We appreciate the quantity and quality of the papers. Some fields get a first general documentation through this congress.
We wish to thank the authors for their loyalty to the instructions for preparation of papers. This has enabled us to get the papers printed within relatively short time limits.
We have taken care not willfully to undertake any alterations in the manuscripts. We, therefore, hope that the papers are reproduced exactly according to the wishes of the authors.
The preprinted papers appear in these two volumes. There may be a third, small volume of some delayed papers which will be available at the congress. Finally there will be a fourth volume containing speeches and discussions at the congress. Participants will get all these volumes.

Ce volume contient les communications de base, les exposés demandés et les exposés soumis pour le 8ème Congrès triennal du Conseil International de la Recherche du Bâtiment, Etudes et Documentation (CIB), tenu à Oslo en juin 1980.
Les communications de base sont écrites par des auteurs auxquels on a demandé de résumer le domaine que le titre indique.
Les exposés demandés sont écrits par des auteurs connus pour leur connaissance spécifique d'un ou plusieurs sujets dans le domaine concerné.
Les exposés soumis sont écrits par des auteurs qui ont répondu à notre demande générale d'exposés dans le cadre de ce Congrès.
Nous apprécions la quantité et la qualité de ces exposés. La documentation générale concernant certains domaines apparaît pour la première fois à l'occasion de ce Congrès.
Nous tenons à remercier les auteurs d'avoir suivi fidèlement les instructions pour la préparation de ces exposés. Cela nous a permis de les faire imprimer dans un délai relativement court.
Nous avons pris soin de ne pas altérer volontairement les manuscrits. Nous espérons donc que les exposés sont reproduits exactement selon les souhaits des auteurs.
Les exposés préimprimés apparaissent dans ces deux volumes. Il se peut qu'il y ait un troisième petit volume, qui sera disponible pendant le Congrès, contenant les exposés arrivés en retard. Enfin, un quatrième volume, contenant les discours et discussions tenus au Congrès, sera remis à tous les participants.

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Local materials

Ressources pour la construction, matériaux disponibles en particulier dans les pays en voie de développement. Matériaux locaux

DEVELOPMENT OF LOCALLY PRODUCED BUILDING MATERIALS IN DEVELOPING COUNTRIES

Albert Kartahardja, Civil Engineer. Director of the Directorate of Building Research, Indonesia.

Summary

Governments of developing countries must pay adequate attention to the development of the building materials industry which plays a major role in contributing to the success of building programmes and it is essential to encourage the use of local rather than imported building materials. It is therefore recommended that priority should be given to the development of non-traditional and non-conventional building materials based on locally available and indigenous raw materials and resources including agricultural and industrial waste products. The development and establishment of small-scale and labour-intensive industrial manufacturing units should also be encouraged and supported in order to increase productivity and to improve quality. For that appropriate technologies for producing building materials should be developed utilising indigenous raw materials and resources.

Résumé

Les gouvernements des pays en voie de developpement doivent favoriser les activités de l'industrie des matériaux de construction, lesquelles peuvent accomplir avec succés les programmes de construction indispensables. L'encouragement de l'usage des matériaux locaux est recommandé et préférable à l'usage des matériaux importés. Pour atteindre le but, il est souhaité de developper l'emploi des produits non-traditionels et non-conventionels fabriqués à base de matériaux bruts disponibles avec des caractéristiques remarquables ou à base de rejets de l'industrie et de l'agriculture.

La création des etablissements d'une grandeur limiteé et à base de main d'oeuvre intensive, doit être encourageé afin d'augmenter la production et d'améliorer la qualité en utilisant des resources et des produits bruts indigènes.

Introduction

1. It is universally recognized that success of any building programme depends on the availability of building materials of the right type in the required quantities at the proper time.

In many developing countries, the large-scale construction that goes with industrialization makes heavy demands on construction materials while the building materials industry, which is in the process of development, is not able yet to meet the demands satisfactorily. It is therefore no exaggeration to state that all development plans will be imperilled if no adequate attention is given to the development of the building materials industry.

2. A comprehensive policy for co-ordinated efforts in the development of the building materials industry based on long-term plans for the development of the construction industry, is therefore necessary. The present policy in many developing countries reflects a direct involvement of the Government in the development of the building materials industries.

Accordingly, different measures should be introduced, such as:

- long-term loans at low interest to establish or expand the production of key building materials;
- increased import duties of building materials and components which can be substituted by nationally produced commodities;
- provision of subsidies and assistance for the establishment of workshops for the production of building elements and components and for the purchase of machinery and equipment, and
- the promotion of research and development of «new», i.e. non-traditional and non-conventional, building materials and construction techniques.

3. It is estimated that in a developing country, 50–70% of the total construction cost of a building is for building materials. Therefore, since the import of building materials and components compared with imports of other materials and commodities can consume a disproportionate share of foreign exchange, the establishment and development of local or domestic indigenous building materials industries is therefore a matter of urgency and importance to increase the national production of building materials.

Indigenous building materials

4. Most of the indigenous building materials in the tropical zone are derived basically either from the soil or from organic products.

In all countries with a sufficiently high forest area per capita (about 0.5 Ha more), timber, bamboo and other organic materials can be considered as the natural indigenous and predominant building materials. Where the forest area falls below this limit, in-organic materials are utilized more and more.

Data and information on building materials commonly in use in the world reveal that raw material resources and their effective industrial exploitation are very unevenly distributed among countries.

Timber, bamboo, clay, lime-stone, aggregates, pozzolana and sand are examples of raw materials found in not many countries and some countries have to import them from the few countries with an export surplus.

5. Some countries have to rely heavily on imports of building materials and in some cases these imports accounted for 14 to 40 per cent of the construction cost of a building. Even if imported materials formed a small share of construction costs in absolute values, the quantum of foreign exchange would easily amount to unacceptable

levels if no planned action were taken to replace imports and to develop an efficient domestic building materials industry based on locally available indigenous raw materials.

Therefore, more emphasis is placed on the need for surveys of natural resources. However, priority is often given to surveys to locate valuable raw materials which could be exported while little attention is given to surveys of raw materials for construction.

When cement is introduced into a country, it tends progressively to replace other materials, owing to its versitality, ease of handling and durability, although the technology of production is relatively sophisticated. The establishment of a cement industry may promote the setting up of subsidiary industries manufacturing cement products such as asbestos cement sheets, concrete blocks and panels, cement floor tiles, concrete sewer pipes, etc. In countries where portland cement is exported and natural pozzolana is found, pozzolana-portland cement or pozzolana-lime cement is produced as a cheaper alternative for blocks and mortars.

Since first class timber species are export commodities, it is important to promote the use of the second and third class timber species for building and especially for housing construction. To extend the life time and durability of those timber species, seasoning and chemical treatment (preservation) is recommended.

Bamboo grows naturally in almost every country in the tropical zone and is used as a building material extensively in Indonesia. Bamboo is used in many different ways in the construction of the walls, the roof and the floor of a house.

Lime is a traditional material which is still being used in developing countries as a component for mortars and plasters and also for whitewashing. Lime can also be used for the manufacture of pozzalana lime blocks, for soil stabilisation and other lime based building materials such as sand-lime bricks and lime cellular concrete. [1]

Building materials industry

6. The building materials industry is closely connected with the construction industry. The objective of both industries in developing countries is to provide the facilities necessary for the economic development and well-being of the people. The share of the gross national product (GNP) contributed by the building materials sector, including transport, increases rapidly with economic development, from about 5 per cent for the developing countries to nearly 13 per cent of the GNP for the most advanced countries. The annual per capita expenditure on building materials, including their transport to building sites, may be estimated at about $6 in countries at an early stage of development (with an average per capita GNP of $127) while in the next group of countries (with an average per capita GNP of $315) the corresponding annual expenditure of GNP on building materials may be estimated at about $23. In the most advanced countries, no less than $104 per capita is estimated to be used annually for the purchase and transport of building materials. [2]

7. Available data indicate that developing countries still produce only a small proportion of the world output of building materials e.g. Europe, Northern America and the Soviet Union manufacture ± 70% of the worlds's cement and their combined share of world production of sawn soft wood is ± 80 % [2]

Recent statistics also demonstrate the efforts of many developing countries to extend the national production of building materials in order to develop and speed up construction and to reduce the foreign exchange bill. However, the bulky nature of certain building materials, for example concrete blocks, makes it necessary to locate these industries near the points of utilization. This has the effect of limiting the marketing and widespread use of such materials.

These difficulties can be solved by dividing the production process; for example, cement clinker is produced near the deposits of clay and limestone and transported for grinding to a plant near the markets. This technique is recommended for developing countries, where there are considerable distances between the sources of raw materials and the centres of population. Clay bricks and roofing tiles, and lime can also be produced in this way by locating the kilns near the markets.

8. In developing countries, imported building materials represent a significant percentage of total imports. In Africa, Asia and Latin America, the value of imported building materials ranges from 5 to 8 per cent of the total value of imports. In addition, those imports may account for a large percentage of the building materials used. Many countries of Africa import from 50 to 60 per cent of the building materials used. Similarly, imported building materials account for, on average, 30 per cent of the construction costs of the Asian region. [2]

For developing countries, metal products are the largest group of imports, followed by timber, cement, sheet glass, sanitary and electrical equipment, paints and hardware. It is therefore recommended that priority is given to the development of non-traditional and non-conventional building materials based on local resources such as stone, pozzolana, shale, lime, bamboo and timber, as well as agricultural and industrial waste products. The establishment of small-scale industrial manufacturing units such as small sawmills and small non-traditional brick and roofing tile or block plants should be encouraged and promoted. Specially, the feasibility of small-scale production of pozzolana portland cement and pozzolana-lime cement should be studied in those countries where natural pozzolana is found.

Countries with adequate resources of coke, anthracite or petroleum coke, whose consumption of cement is low (30 000 to 60 000 tons per year) should consider small-scale production of portland cement and for that the use of the shaft kiln process. [2]

9. The importance of adapting the technologies of produc-

ing building materials to local conditions is essential, as the exact nature and quality of raw materials varies in different countries. It would be neither logical nor economical to import processes that depend on imported raw materials when alternative processes could utilize locally available indigenous raw materials.
A technological process based on local indigenous raw materials and resources is preferable to a process for which the main raw materials and machines have to be imported.
In developing countries labour-intensive technologies have to be developed to overcome among others the problem of unemployment. For that reason it is often appropriate, although not economical, to convert large-scale capitalintensive plants from industrialised countries into small-scale labour-intensive plants to be more suitable for developing countries. For example, appropriate technology has to be developed in Indonesia to change a Lime Kiln producing 100 tons of lime per day into a kiln producing only 10 tons per day. The same has to be done also for a 40 ton Particle Board Plant, Brick Extruders, Concrete Block Machines, etc.
In most developing countries of the Asian region the major share of building materials used in housing construction is produced in small cottage industries which lack technology and ability to produce the required quantity of quality-controlled products.
In other words, the bulk of building materials used, particularly in the construction on low-cost houses, consists of local materials produced by traditional methods. Therefore, the small-scale building materials industries must be improved as a matter of urgency by providing assistance to increase production and improve the quality in order to get more durable and better finished products for relatively low cost.
10. The important difficulties and obstacles which limit production of local building materials in developing countries are:
a. lack of capital needed to improve and increase production;
b. low level and unsteady demand for building materials resulting from the very limited purchasing power of the population and the fluctuation of constructing programmes;
c. scarcity of managerial skills required for efficient operation of small scale industries;
d. marketing procedures that are detrimental to both consumer and producer and only yield good profits to dealers and middlemen;
e. disorganized system of transportation of building materials, substantially increasing their cost when they are delivered to the buildingsite.

Many developing countries also suffer from gradual disappearance of traditional craftmanship. This results in the decline of the quality of traditional building materials, such as bricks and lime, produced in several countries. Thus, all of these difficulties combined contribute to a very small percentage of building materials that are produced by the developing countries in relation to the world's total output.
For these reasons Governments of developing countries should increase their active role in supporting the development of the small-scale building materials industries by a.o.:
- establishing pilot plants to introduce the production of non-traditional and non-conventional building materials and components;
- setting up demonstration plants to demonstrate improvements and new technologies or techniques in the processing of local indigenous raw materials;
- organising training in both the technical as well as the managerial aspects of small-scale building materials industries; and
- promoting and giving support to research activities on the production of building materials and components utilising local raw materials and resources.

Besides that, developing countries should also consider regional sharing of markets for building materials. Only a few developing countries have adopted a comprehensive policy for co-ordinated efforts in the development of the domestic building materials industries. Long-term targets for these industries and long-term programming of construction activities should be based on surveys of raw materials suitable for the production of building materials and on research in building materials.

Research in building materials

11. Research and development, and technical information are dominant factors in economic development. In more developed countries, their importance is well illustrated by the rapid increase in the amount of money spent on research and technical information within the past decade. In the majority of more developed countries, the annual expenditure on research and development ranges from 1 to 3 per cent of the gross national product. In connection with this it is worth noting that whereas in some industries from 5 to 10 per cent of production is devoted to research and development, in the sphere of housing, building, planning and civil engineering the figure remains between 0.2 and 0.3 per cent. However, research in these fields has also developed increasingly in recent years and has been expanded to investigate complex problems related to socio-economic, technical, organizational and environmental aspects of human settlements. Recent research findings in the fields of data-processing, systems analysis, operational research, automation and computer technology are applicable to housing, building and planning.
12. The institutional framework of research organizations depends upon the economic structure of a country. There are basic similarities, however, in the way research institutes are organized and function.
Research institutes may function:
a. as an integral part of a government department or as a semi-autonomous institution linked to a governmental agency;
b. within a university or as a semi-autonomous body linked to a university;

c. as an incorporated, private, non-profit-making organization;
d. as a technical arm of an industrial establishment or an industrial association.

In the majority of more developed countries, several specialized research institutions exist and each is concerned with a particular building materials field. In addition, these countries have a national body (or special bodies) for the formulation of research policies and co-ordination of research activities at the national level. CIB-Secretariat has data available on research organizations in Europe and North America whose activities are closely related to the development of building materials.

The need for systematic collaboration at regional and interregional levels is being increasingly recognized and attempts are being made to undertake and encourage bilateral and multilateral international collaboration, particularly in the new field of building materials.

13. In recent years, efforts have been made in developing countries towards setting up new or upgrading existing research facilities. Some countries have set up research programmes covering a wide range of building materials and others have made or are in the process of making a modest beginning with a few selected problems and questions. Relatively greater progress can be discerned in the research in building materials. Most research institutes formulate their research programmes annually and some are also preparing long-term programmes. These research programmes are usually based on problems faced by government agencies and are seeking answers to needs of builders and producers of building materials.

14. The practical application and implementation of the research results is the ultimate goal of research. Thorough documentation and systematic dissemination of useful research information (through data sheets, periodicals and special publications, etc.) are integral parts of research activities. However, most of the information is often disseminated in such a way that it does not reach those who need it, nor does it reach those for whom it is intended. Moreover, the research information is often received in a form which makes its use difficult. One of the prime difficulties is that institutions established for the purpose of research do not communicate well with users; a practical system for disseminating information is still lacking.

15. In most developing countries research and development of building materials is geared towards reduced costs of building materials which account for as much as 60 per cent of the total construction cost, and towards the improvement of the quality of those materials. As a particular requirement, maximum use of local indigenous resources and building materials and the improvement of their properties is specifically sought.

Other fields covered by building research include the environmental impact and social aspects of the building materials industry in many developing countries, standardization is not yet fully applied. The eventual adoption of international building standards by these developing countries would require thorough research on the applicability of those imported standards to local building materials that are used in the region, taking into full account national customs and traditions.

16. In the developing countries building materials industries are at very early stages, and research activities in this field have concentrated on design, development and promotion of simple machines and tools for the purpose of encouraging and assisting entrepreneurs in setting up small-scale building materials industries. The main problems which building research faces in most developing countries are:

a. low priority in national programmes;
b. lack of scientists;
c. difficulties in obtaining funds and research equipment;
d. lack of co-ordination.

17. Low priority accorded to research in national programmes originates in the preference given by most Governments to economically, quick-yielding projects which would substantially improve the prevailing low standards of living of their populations. Moreover, in the field of building research, Governments tend to sponsor only pilot projects, which are often based on imported technologies that would in a relatively short time provide the country with some of the necessary building materials and components.

The lack of scientists can be attributed to the fact that many developing countries have only recently become independent. Education in several of these countries is expensive as well as not compulsory; therefore, only a small portion of the indigenous population has been able to acquire higher education. Moreover, a large number of this already small segment of educated individuals has emigrated to «brain-drain» recipient countries. In addition, combined with the tendency of Governments to favour economical quick-yielding projects, most of the available national scientists are not given the opportunity to participate in scientific research activities. This results in the loss of their skill and defections to other more favoured fields.

Finally, existing educational institutions are capable of producing only a limited number of building scientists. This indirectly limits building research capability in most developing countries despite the fact that it is generally acknowledged to be most essential and that activities in this field should be increased.

18. The urgency felt by Governments to reduce the acute housing shortage, particularly in the urban areas, is understandable. The problem, however, remains unsolved because the scarce available resources are not sufficient to cope with the needs, and research does not provide immediate solutions to improve the situation. This generates a vicious circle: on the one hand, Governments are eager to solve the housing problem; on the other hand they are reluctant to support the necessary research which eventually might assist them in reducing the housing deficit. With regard to this, a clear policy is required from the Governments.

The importance of research has already been recognised by the developed countries. At present they allocate be-

tween 2% to 4% of their GNP for scientific research activities.
Developing countries, however, allocate less than 1% of their GNP for research and development activities, and less than 0.1% for building research activities. UNESCO recommends that allocations for research activities in all nations be increased by 1% of the country's GNP. This implies that the minimum budget for building research activities should be 0.1% of the country's GNP. [3]

Conclusion

19. The success of the National Development Plans and construction programmes of a country depends on the availability of building materials and the proper development of the building materials industry.
Governments should pay proper attention to the problems, difficulties and obstacles faced by the building materials industry.
Taking into consideration the availability of local indigenous raw materials and resources, Governments of developing countries should adopt a sound comprehensive policy for the development of domestic building materials industries.
Simultaneously with the development of the building materials industry, priority should be given to research and development in the field of building materials. Investigations into the rational utilization of existing indigenous raw materials and resources and research and development of non-conventional and non-traditional building materials, should be promoted by the Governments of developing countries and supported by international organizations.

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Extending the lifespan of traditional houses
Examples from Tanzania

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Summary:
Problems of rapid decay and unhealthy conditions constitute a serious problem with houses in rural Tanzania. Lack of financial and technical resourses leave only one possibility; to find means to improve traditional houses by utilizing local building materials better and to introduce technical solutions and methods which lend themselves to self-help efforts. This paper describes four examples of improved constructions: mud and pole house, improved solid mud house, burnt clay brick house and house build with soil-cement blocks.

Résumé
Les problèmes de détérioration rapide et de conditions insalubres constituent un problème sérieux pour les habitations rurales en Tanzanie. Le manque de ressources financières et techniques ne laissent qu'une possibilité: trouver des moyens pour améliorer les habitations traditionnelles en utilisant mieux les matériaux locaux de construction et introduire des solutions et méthodes techniques qui mènent les Tanzaniens á faire des efforts pour s'aider eux-mêmes. Le document décrit quatre exemples de construction améliorées: habitation en terre et paille, habitation en terre séchée solide, habitation en brique d'argile cuite et habitation construite en blocs de ciment-terre.

Introduction

In tropical Africa the main problem in the provision of adequate housing is similar to that of elsewhere; a shortage of resourses in relation to human needs. Tropical Africa is, however, fortunate in that the wast majority of its population still live in rural areas where housing requirements are more easily satisfied than in urban areas.

The experience of the authors are mainly drawn from rural areas in Tanzania. In these areas neither the people nor the governement can afford to use expencive building materials. Traditional materials will therefore still find major use in the forseeable future.

In Tanzania with a population of approximately 18 mill. (1978) more than 80 % of the houses in rural areas are made of mud-and-pole walls with grass roof thatching. These houses lack foundations and proper ventilation, which especially during the rainy season create damp and unhealthy living conditions. The lifespan of such traditional houses is 5 - 10 years, depending on local conditions, maintanance, etc. Because of the rapid decay, more than 500 000 houses have to be rebuilt each year. A concrete block house could well have a lifespan of more than 50 years. To build such a house (60 m^2) using a local craftsman would cost US $ 6 000,- ex. finishes and consume approximately 4 tons of cement.

If 50 000 houses or 1/10 of the number which has to be rebuilt each year, are built in this way it will consume 200 000 tons of cement and cost US $ 300 mill. Tanzania has neither the financial nor the technical resources to handle even this task in a short time.

The only possible way left is to find means to improve the traditional houses by utilizing local building materials better and to introduce technical solutions which can extend the lifespan of such houses to at least 15 - 25 years and to an acceptable cost. The building materials have to be provided from the immediate surroundings and building the house must be the task for the houseowner alone or in cooperation with neighbours.

Local conditions e.g. living patterns, climate and available material resources vary considerably from one part of the country to the other. In dealing with improved housebuilding one must not forget that the traditional houses through generations have been emminently ajusted to climatic conditions; from hot humid at the coast to arid hot at day, cool at night on the inland plateau. Another advantage with traditional constructions, which must not be forgotten, is that they are easy to repair and renew and that such work does not include any capital expenditure on the part of the owner.

Common for almost all rural houses in Tanzania is that mud or soil is used in some way or another. Traditionally this excellent building material is applied in mud-and-pole structures (the poles constitute a framework in which the mud is placed) and in solid mud walls. More recently burnt bricks and soil-cement has been introduced. In the following, four examples of improved constructions with soil or mud are given.

Example 1.
Improved mud and pole house

The majority of the mud and pole houses built in Tanzania rarely have foundations. This is one of the main reasons for the short lifespan of such houses. Fig. 1.1. shows how the poles in such a wall gradually are getting destroyed because of the decaying process from the wet surroundings or from termite attacks. The best way to improve such a wall is to build it with a proper foundation. See fig. 1.2. The first step is to dig a trench, e.g. 30 - 40 cm deep and 30 cm wide, and cast a 10 - 15 cm footing of a durable material, for example soil-cement (mix 10:1) or sand-cement (mix 8:1). The footing must harden for at least one day. The poles are then erected and kept in a vertical position while the foundation wall made of the same material as the footing is cast. It is important that the foundation wall has a height which is at least 15 cm above ground level. This is to reduce the washing out effect of splashing water from the ground and by driving rain. Fig. 1.3. shows how the wall will look just before the mud is placed between the poles.

Fig. 1.4. shows the final house with courrugated iron sheets as a roofing material. It is interesting to observe the wall finnish. Small stones are pressed into the mud plaster. This is not only done from a decoration point of view, but also to prevent driving rain from washing out the mud.

If the house-owner wants to plaster the house with a permanent plaster of soil-cement or sand-cement, the stones will make good connections to the existing mud-wall. This house is further improved by casting a soil-cement floor slab, 5 cm thick, on the top of a drainage layer (coarse sand and stones). The floor slab should be at least 10 cm higher than the ground outside and should be finished with a cement slurry. The cost of such an improved house (60 m^2) will be, when doors and windows are excluded:

Cement: Foundation and floor	US $ 92,-
Roof: Corrugated iron	" " 270,-
Rafters, nails etc.	" " 38,-
	US $ 400,-

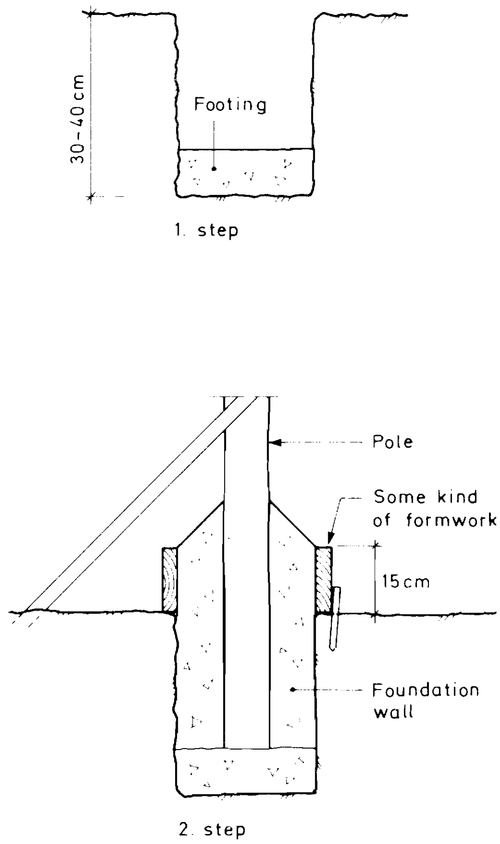

Fig. 1.2. Foundation for mud and pole wall.

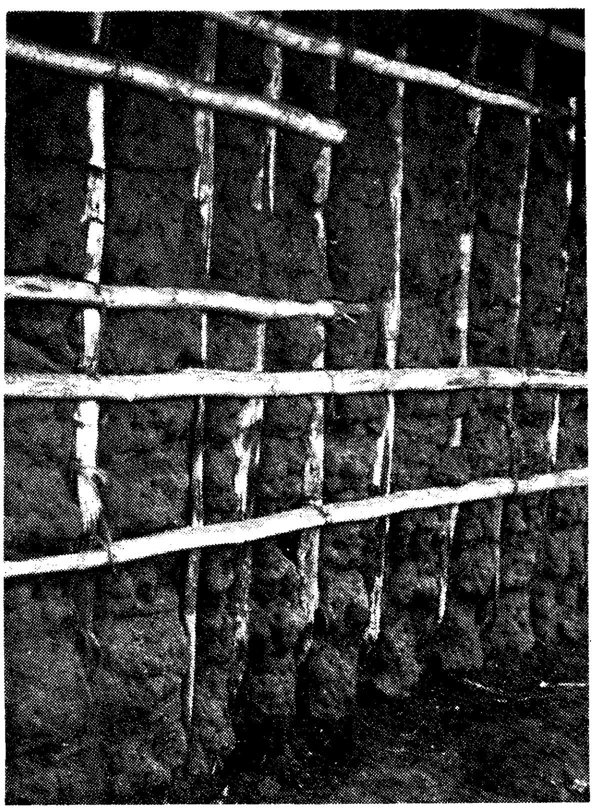

Fig. 1.1. Eroded mud and pole wall

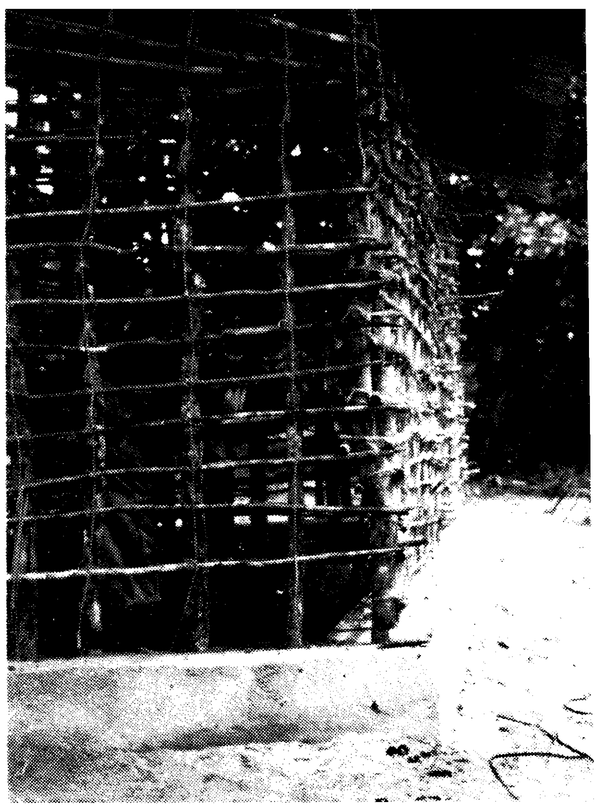

Fig. 1.3. Pole framework on proper foundation.

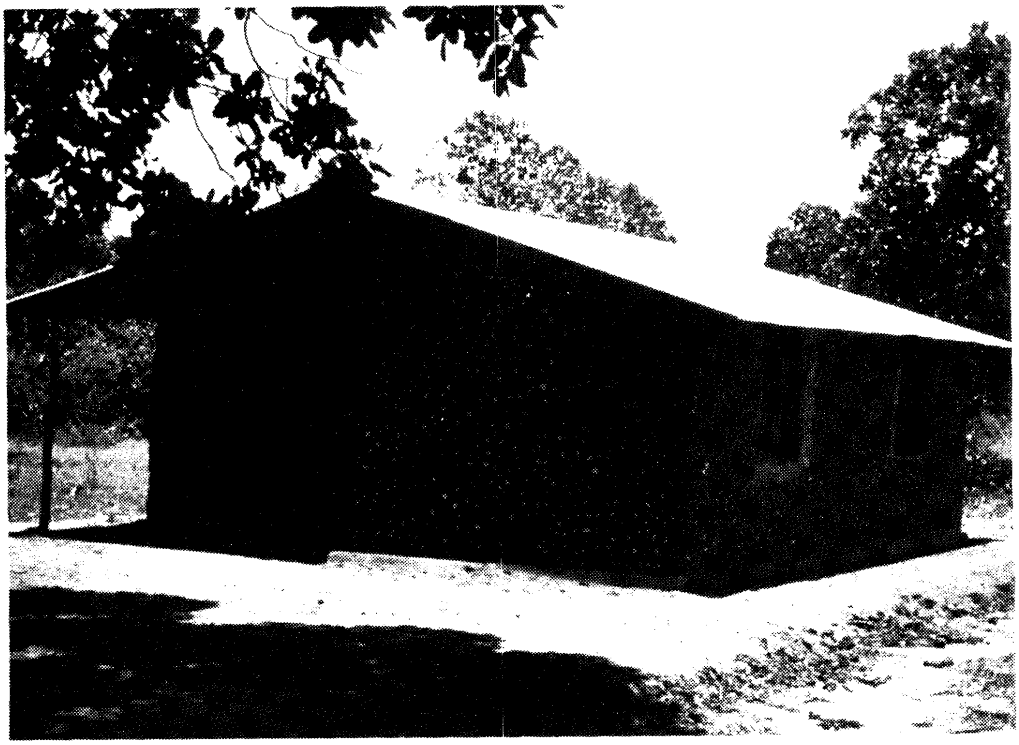

Fig. 1.4. Mud and pole house.

Example 2.

Improved solid mud-house

The traditional way of building a solid mud house is to place layers of soil on top of each other, and let one layer dry out before the next one is added. The failures and reasons for detoriation of such a wall construction are mainly that they have no foundation, that the wall is cracking, that surface water is permitted to undermine the walls and that the wall itself is washed away by driving rain. See fig. 2.1 and 2.2.

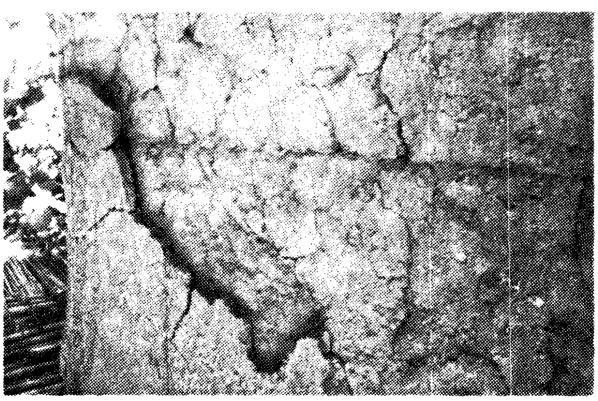

Fig. 2.1. Erosion of monolithic wall due to rain.

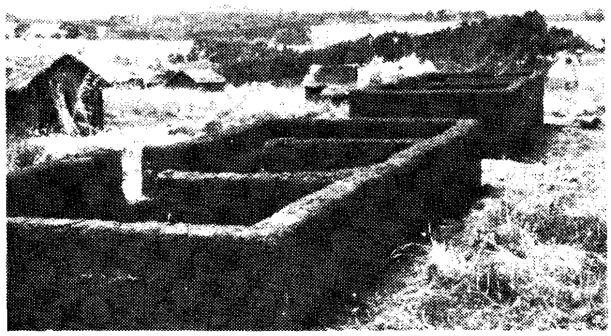

Fig. 2.2. Monolithic mud walls under construction.

Note large cracks due to schrinkage.

The wall construction can be improved by introducing new building techniques. First, the wall must be erected on a proper foundation, similar to what is described in example 1, but without the poles. By using a formwork for the wall-construction (see fig. 2.3.) the soil will become better compacted when tamping it. This will give a stronger wall and less cracks will occur because a dryer soil can be used.

The wall construction can be even further improved by introducing load bearing pillars made of tamped soil-cement and in between ordinary tamped soil (see fig. 2.5.).

The formwork both for the pillars and the wall sections can be demoulded immediately after they have been filled. In this way the height of one section can be built for all the pillars and infill walls in one day. Fig. 2.6. shows in detail how one pillar is filled with a rather dry soil-cement and compacted with a tamper. The mud wall is plastered outside and inside with a soil-cement plaster. The floor is levelled with a 5 cm soil-cement screed.

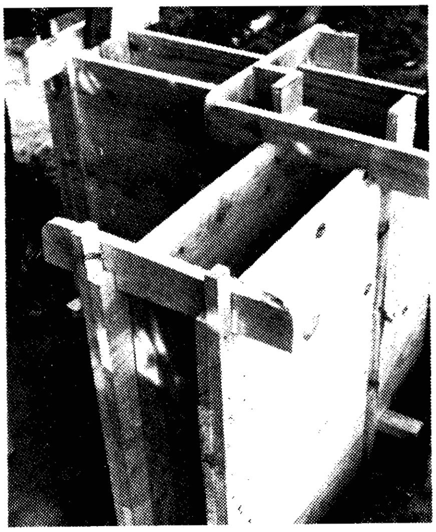

Fig. 2.3. Formwork - section of corner.

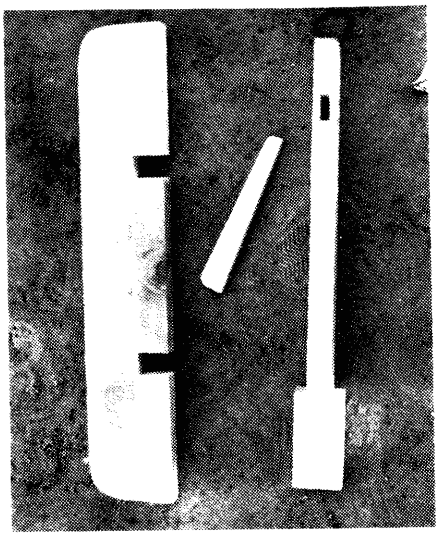

Fig. 2.4. Spacer for the top of the formwork and wooden stick with wedge.

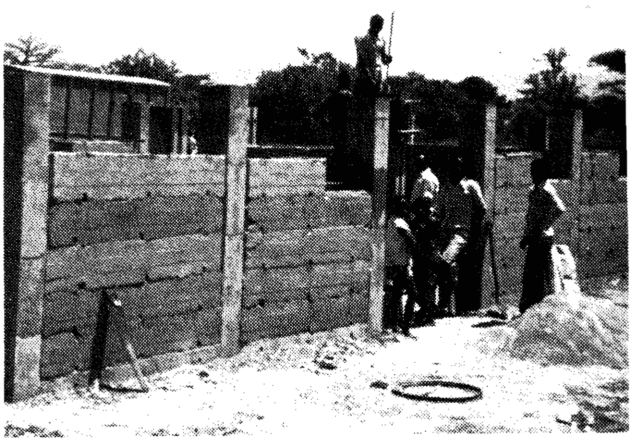

Fig. 2.5. House with load bearing pillars under construction.

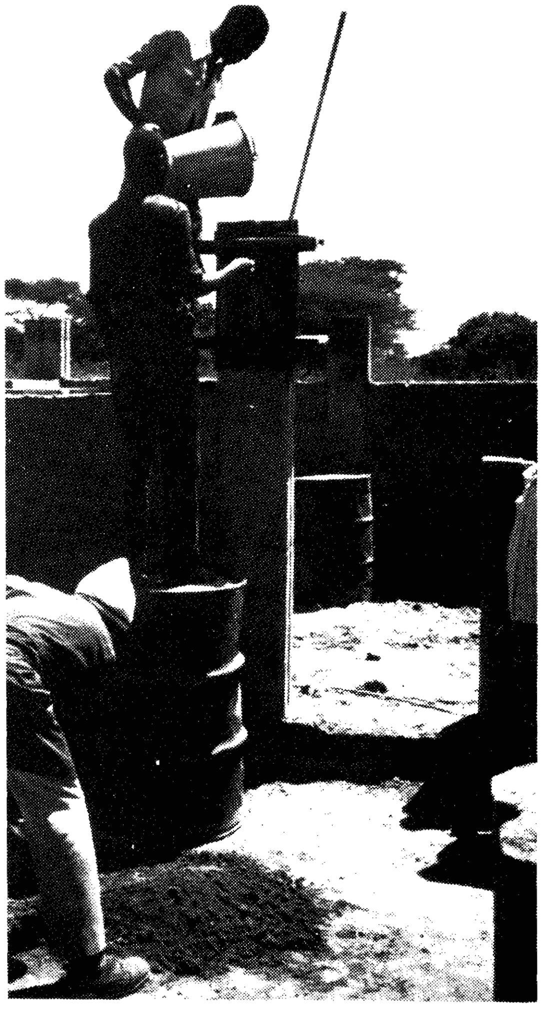

Fig. 2.6. Casting a soil-cement pillar.

Example 3.

House built with handmade burnt bricks

The advantage of using burnt clay bricks for improved housebuilding in a country like Tanzania is that the bricks can be produced from purely local materials, and with little or no investment. Lime and/or cement mortar can with few problems be substituted with joints of mud.

A soil suitable for burning can be found in many places all over the country. A limiting factor to a wider use of bricks is the supply of firewood which in many areas is scarce. To avoid deforestation it is therefore important to encourage local production of bricks only in places where firewood is abundant. The simplest way to produce bricks are to mould them directly on the ground and burn them in a field kiln. Fig. 3.1. and 3.2.

Fig. 3.1. Production of hand made burnt clay bricks.

Fig. 3.2. Typical kiln for burning bricks in the field.

The quality of bricks produced in this way vary a great deal, from very good to poor. Dimensions are inaccurate and surfaces are rough, but they still represent a huge improvement on the traditional materials. If firewood is available, the self-help builder only need to invest his own labour to produce a building material which can be used for foundation, wall, floor and even in some cases roofing.

If the building is to be constructed entirely from bricks, the foundation is merely a prolongation of the wall with a footing at the bottom. It is important that the footing and the foundation have a proper bonding as the mortar for economic reasons in most cases will be a soil mixed with just enough water to make it workable. The footing is made 1½ stone or at least 35 cm wide.

The foundation wall is finished not less than 15 cm above ground. To prevent moisture from rising up through the wall, the top of the foundation is levelled off with a high cement content mortar. Fig. 3.3.

Fig. 3.3. Foundation and wall.

Walls are made 1-brick thick for stability and with a simple bonding. Distance between cross-walls shall not exceed 4,5 m unless the wall is stiffened in some other way. Mud mortar is used on condition that joints are made as thin as possible. Lintels above door and windowopenings are made of sawn hardwood, preferably of a specie that is resistant to termites. In some areas, washing out of mud joints is a problem. To prevent this the joints can be scraped out to a depth of about 5 mm and then pointed with a cement/soil or lime/soil mortar. This is usually not necessary above 60 cm from the ground. Fig. 3.4. shows examples of brick wall construction.

Fig. 3.4. House constructed from burnt clay bricks. Mud is used as jointing mortar.

Bricks can also be used for flooring. Even if laid with butt joints on a bed of sand and with cracks filled with sand, such a floor is a substantial improvement compared with the traditional dust floor. The best burnt bricks with the smallest deformities should be selected for the floor. To prevent flooding and rising water the bed of sand should be 10 - 15 cm thick, see fig. 3.5.

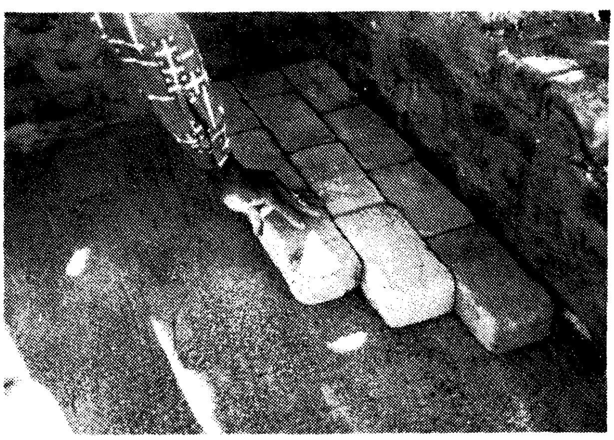

Fig. 3.5. Placing bricks as floor.

There are examples where roofing slates of burnt clay have been produced on a self-helped bases. There are however, two reasons why this type of roofing have a limited interest only.

- The slates are more difficult to produce with necessary accuracy than ordinary bricks and require a better clay.
- The slates require a more accurate roof-structure than most other roofing materials; e.g. corrugated metal sheets. The slates also requires sawn battens. The only capital expenditure counted for in a "brick house" is therefore in this case corrugated iron sheets.

Example 4.

House built with soil-cement blocks

Throughout Tanzania soil-cement blocks are considered as an alternative building material in sand deficient areas where bushpoles are difficult to obtain and where technical assistance can be provided. Such blocks provide walls, foundations and floors with a durability and appearance approaching that of concrete. Blocks are made from the soil found at the building site, in most cases using less cement than needed for concrete blocks.

Table 4.1. shows the minimum cement content for some soils. Cement and soil is mixed thorougly in the dry state. Water is then added until a relatively dry mix is achieved.

Table 4.1. Cement contents by weight of dry soil

Combined clay and silt content	Internal walls	External walls	Foundations	Floors
10 %	7 %	7 %	7 %	15 %
10 - 25 %	5 %	7 %	7%	10 %
25 - 40 %	5 %	10 %	10 %	10 %

Production of blocks can take place at several levels of mechanisation. The self-builder can do all operations by hand using a wooden mould for compaction (fig. 4.1.). A building cooperative could rent or buy a compaction machine such as the Cinva-Ram. Hand production give almost the same quality as produced with the cinva-Ram.

Actual construction is carried out much the same way as for the brick house described in example 3. The footing is, however, made by tamping soil-cement directly into the foundation trench. Fig. 4.3. and 4.4.

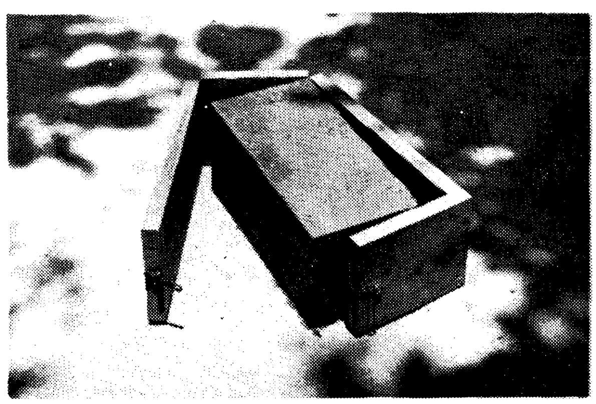

Fig. 4.1. Block made in simple mould.

Fig. 4.2. Blockmaking with Conva-Ram.

Fig. 4.4. Construction of Soil-cement block house.

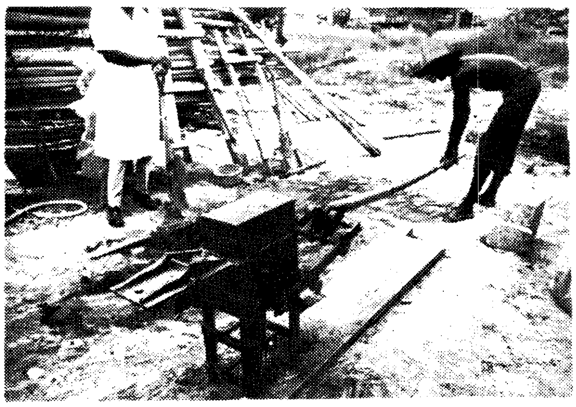

Fig. 4.3. Soil-cement footing being compacted.

Development of Building Materials and Low-Cost Housing in Indonesia

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1. Introduction.

1.1 The Objective.

The provision of adequate housing for the population is one of the Indonesian Government's main objectives. It has been realized that a necessary prerequisite for boosting housing construction is rapid development of the building materials industries.

Besides providing the necessary materials for housing construction, the development of building materials industries supports the general industrial development of the country. The special character of most building materials industries (the products are heavy and cheap and production is consequently scattered over the country so as to be near the local markets) leads to development in rural areas more than most other industries. In addition, the products can be produced from local raw materials and by labour intensive methods. Development of the building materials industries can thus efficiently support the Government's policy for development of rural areas.

It is further realized, that rapid development of building materials industries and housing construction in urban as well as in rural areas will contribute substantially to the achievement of balanced economic growth with more equal distribution of income, and will thus support the Government's general development policy.

1.2 The Magnitude.

It is currently estimated, that out of a population of about 135 million, some 10 million people are still without a home of their own. This corresponds to around 2 million housing units. If housing should be provided for the homeless, let's say within a five year period, this would mean the construction of some 400,000 housing units annually. The housing problem is more acute in urban areas than in rural districts where non-home owners traditionally live in with relatives. In these areas, however, most existing housing is of sub-standard quality, and should gradually be improved.

Besides the current shortage of housing units the estimated increase in population of 2% per year will result in an annual population increase of 2,7 million corresponding to some 540,000 new housing units per year.

It is thus reasonable to estimate the total housing need to at least 1 million housing units per year.

One million low-cost houses of a popular 45 m^2 standard type would consume 7,000 mill. clay bricks against the current total production of some 2,400 mill. bricks, and 2,000 mill. roofing tiles against the current total production of some 420 mill. tiles. Around 12 mill. m^3 lime will be consumed against the current total production of less than 5 mill. m^3. There is an even more acute shortage of materials for window glass, nails, hinges etc.

1.3 The Policy.

A main theme in the development policy of the Indonesian Government is the endeavour to distribute the fruits of development to all sectors of society. In the field of building materials and housing this brings the problem of rural development into focus.

It is generally recognized that the distribution of development results to the rural population has been dropping dangerously behind the urban development. The fact remains, that the dramatic impact of the rapid population growth and the migration from rural to urban areas has resulted in overcrowding, insanitary living conditions, frustrating traffic congestion and slum and squatter settlements in the big cities. Thus the most obvious problem of physical planning and development lies in the populous urban cities and towns. There is, however, the less obvious but extremely vital problem of planning and development in the rural villages of the country, where the way of life still depends on agricultural and industrial activities carried out according to simple and traditional production techniques. Approximately 80 per cent of the Indonesian population live in rural areas. Here, the overcrowding is not as intense as in the urban areas, but the condition is aggravated by the lack of variety of employment, chronic underemployment, unsatisfactory sanitary conditions and shortage or absence of educational facilities.

It is on this basis that the Indonesian Government has decided to emphasize and expand its development programmes for the rural areas. Several activities have been initiated to make rural living more attractive. Housing and support for small scale industries are along with agricultural improvements among the foremost activities to have been initiated.

The most obvious role of housing in the achievement of economic goals is connected with the basic desire of the people to own a house which therefore makes housing a strong incentive for saving and domestic capital formation. Housing is, furthermore, the largest client of the construction and building materials industries. Assistance in the improvement of rural housing will thus benefit the development of these small scale industries.

Any efforts in industrial development will have to take this policy into account. Development of building materials and housing in Indonesia is therefore not a simple question of supply and demand.

2. Building Materials Production.

2.1 The Industry.

The building materials industries in Indonesia are dominated by small scale family enterprises distributed all over the country, with a main concentration on Java. These industries contribute substantially to the income of the population outside the urban areas. Their production methods are labour intensive and require low capital investment. The products are mostly sub-standard and barely adequate for the construction of simple dwellings. Larger, "modern" industries are only found in the portland cement and steel field. A few "modern" brick and roofing tiles factories exist near Jakarta, but they are operated with great difficulty due to their high capital investment and the high technical and managerial requirements. The building materials industries in Indonesia are therefore basically a traditional back-bone in the rural economy.

Improvements are urgently needed both quantitatively and qualitatively. The main techno-economic problems in the small scale industries may be identified as follows:

- Inefficiency of production methods;
- Insufficiency of technical and managerial skills;
- Unorganized and costly marketing;
- Inadequate financing facilities;
- Scarcity of fuel and electricity.

It should be noted that Indonesia faces no problem in provision of basic raw materials and a basic labour force.

Due to the weakness of the small scale industries and their socio-economic value for giving work opportunities to the poorest sector of the population, the industrial policies concentrate on supporting and developing these industries.

Two ministries are directly engaged in the development of building materials for housing. The Ministry of Industry assists the building materials industries through its research institutes (The Ceramic Research Institute and the Materials Testing Institute, both in Bandung) and through special project activities for "Guidance to Small Scale Industries" (BIPIK). These activities comprise assistance to improvement in production techniques and procuring of simple machinery, assistance in improving technical and managerial skills and assistance in the formation of cooperatives for production and marketing.

The Ministry of Public Works is engaged in research and development through its Directorate of Building Research in Bandung, and in information and demonstration activities in building materials and housing through its network of "Building Information Centres" (BIC) covering the 27 provinces of the country. These centres train rural instructors and give courses to private groups engaged in construction activities. Several demonstration plants located in development centres throughout the country introduce new or improved technologies and materials, and pilot housing projects demonstrate their proper use in housing. The Ministry of Public Works is also engaged in the formulation of standards and holds technical seminars and training courses for professionals, students and Government officials.

2.2 Research and Development.

The ultimate aims of research and development of building materials in Indonesia are:

- to speed up the construction of buildings and houses;
- to improve the quality of buildings and houses; and
- to reduce the cost of building and maintenance.

An important overall policy guideline for this development is the requirement of using local, labour intensive solutions. Apart from cement and steel, building materials can be produced on a small scale and by labour intensive methods. The Indonesian Government maintains this requirement strongly and possibly wisely. If larger and more efficient plants were allowed to replace the traditional small family enterprises with their widespread distribution penetrating even the most remote areas, an important means of obtaining cash by these often part time producers would vanish and thereby endanger social stability.

This, however, places researchers in a difficult position. In most cases they will have to re-discover or re-design small scale production processes and machinery which are no longer available in the industrialized countries. The increase in fuel costs makes this task even more complicated, as fuel efficiency usually decreases sharply with the size of the plant. The special environmental conditions in Indonesia also invite the development of new processes and materials.

Since 1974, the Indonesian Government has, with the assistance of UNIDO, been engaged in a large scale project for the development of the domestic building materials industries. More than 15 different fields are covered by this project. The activities of the project are carried out within three Government research institutes: The Directorate of Building Research of the Ministry of Public Works, and the Ceramic Research Institute and the Materials Testing Institute both of the Ministry of Industry. The three institutes are situated in Bandung. Each of the 15 fields of activity in the project is carried out by a joint Indonesian-UNIDO team. A typical team consists of: one Indonesian senior expert, two or three younger Indonesian engineers or architects, one UNIDO senior expert and one UNIDO associate expert. The UNIDO senior expert in most cases only joins the team for three month annual visits to act as resource person and initiater of new programmes. The rest of the team works continously. By this arrangement the staff of the research institutes directly benefit from the experience of the foreign experts, and are from the beginning given full responsibility for the work which they will later have to continue alone. The main objectives of the project, which covers a six years period (1975-1981), is thus to strengthen the national institutes in their endeavour to assist the building materials and housing construction industries, and to participate in this work by suggesting and initiating relevant research and development programmes.

Technologies adapted to local conditions are developed in various fields including:

- Highly fuel efficient labour intensive clay brick and roofing tile factory producing 5-6 mill. bricks/year and requiring an investment of less than US $ 1 mill.
- Efficient indigenous technology trench kiln for medium size production of clay brick and roofing tiles.
- Highly fuel efficient lime kiln producing 10 tons/day of high quality lime and requiring an investment of US $ 60,000.
- Efficient indigenous technology lime kiln producing 6 tons/day of good quality lime and requiring an investment of US $ 20,000.
- A range of appropriate technology production units for pozzolana-lime alternative cement varying in output from 40 tons/day (US $ 600,000) to 200 tons/day (US $ 1,65 mill.).
- Small scale production units for pozzolana-lime blocks.
- Several solutions for the improvement of less than efficient existing up-draft brick and roofing tiles kilns.

And in the near future technologies will be available for:

- Small scale particle board factory (40 tons/day).
- Extremely small scale soil-lime block units with hand operated presses,

as well as small scale solutions in several other fields. The technical solutions are presented in reports or in actual demonstration units, and techno-economic as well as financial feasibility studies are being prepared to facilitate the selection and implementation of the most viable solutions for different conditions.

It may be seen from the above examples that the technologies developed cover a wide range of sizes. The larger units, although they utilize locally available machinery and labour intensive technology, require relatively large investments which makes them possible near larger and fast growing cities or for cooperatives formed by traditional small scale producers. Several solutions, however, are of a size which makes them directly suitable for individual enterprises.

The activities in the development of the building materials production technology are being continued, and are gradually including efforts to rationalize the traditional construction procedures utilizing new and better materials and methods.

As several countries in the South East Asian region share the same problems in provision of building materials for low-cost housing, the UNIDO project in Indonesia may be useful as a model for development work in these countries and some of its results may be directly applicable. In line with this the Indonesian Government arranged an exposition and workshop in August 1977 for small scale building materials industries for rural development in cooperation with ESCAP and the UNIDO project and with participants from several countries in the region. By such arrangements exchange of technologies now available in the countries may be initiated, and duplication of research avoided.

3. Low-Cost Housing.

3.1 The Housing Construction.

3.1.1 The Domestic Construction Industry.

The domestic construction industry in Indonesia covers a wide range of firms, comprising traditional, small firms working locally in a single area and using traditional labour intensive construction methods, as well as modern companies operating in several regions and in command of advanced technologies in building construction and in civil engineering works. The further development of the capacity and efficiency of the construction industry to meet the country's increasing demand for construction is generally hampered by lack of adequate long term planning and administrative coordination of the construction activities. In addition there is a general shortage of skilled technical and managerial manpower at all levels and in all sectors of the industry, including a shortage of skilled workers in factories and on building sites.

The modern sector of the domestic construction industry in Indonesia has already grown far beyond the early phases of development envisaged in most developing countries. In facing competition from foreign firms, the modern sector is especially handicapped by the lack of national technical codes and standards, inadequate contracting procedures, high interest rates on working capital, shortage of equipment, etc.

The traditional sector of the domestic construction industry is lagging dangerously behind the modern sector in obtaining its share of the total construction activity. Its share has steadily declined in recent years. The Government policy is, in view of the potential social danger this implies, to give high priority to the strengthening of this weak sector, which is especially hampered by irregular competition and inadequate business administration.

The Indonesian Government is currently engaged in the formulation of a comprehensive development programme for the domestic construction industry in cooperation with foreign aid agencies.

3.1.2 Government Construction Programmes.

3.1.2.1 Urban Programmes.

The Direcrorate General of Housing, Building, Planning and Urban Development (CIPTA KARYA) of the Ministry of Public Works is responsible for Government construction programmes in the housing field. Rural and urban housing improvement projects are managed by its Directorate of Housing, water supply and sanitation projects by its Directorate of Sanitary Engineering.

Housing.

During the REPELITA II * period the National Housing Corporation (PERUMNAS) under the Ministry of Public Works established 73,000 low-cost housing and site-and-services units in 17 cities. The cost of low-cost housing units varies from US $ 1,600 to 4,200 whereas the cost of site-and-services plots varies from US $ 700 to 1,600. The units are sold to selected low- and medium income groups under specially favourable conditions which implies a 65 % Government subsidy. The monthly installments charged to the occupants have been as low as US $ 5 per site-and-services plot and US $ 6.50 for low-cost houses.

This programme will be expanded during REPELITA III to cover a total of 150,000 housing and site-and-services units in approximately 100 cities throughout the country.

Water Supply and Sanitation.

In the field of urban water supply and sanitation the Government provides drinking water, establishes waste disposal systems and prevents and controls environmental pollution.

The programme was carried out in less than 100 cities during REPELITA II. During the REPELITA III period the programmes for water supply will be expanded to cover 150 smaller, 40 medium sized and 10 larger cities. Sewerage and waste disposal systems will be provided in 10 larger and 40 medium sized cities.

Urban Kampung Improvement Projects (KIP).

The Urban Kampung Improvement Programme (where the term Kampung refers to village units in urban slum or squatter areas) has been executed for several years in various slum kampungs in the heart of the city of Jakarta and in several other major cities. Development components include improvement of roads, school building, bridges, drainage and flood control systems, public latrines and water supplies.

The Kampung Improvement Programme is a comprehensive approach. The main attempt to change the kampung environment is not merely through physical infrastructures and kampung beautification. The scope of the relief is also to pay attention to the improvement of social welfare activities, creation of employment opportunities, informal kampung organizations, cooperative movements, education and training programmes and to pay attention to the attitudes and changes on the part of the kampung people themselves.

During the REPELITA III period the Kampung Improvement Projects will,with the assistance from foreign aid agencies (IBRD, ADB, UNEP and others), be expanded to cover a total of 15,000 Ha with 3,5 million people in 200 towns. The cost is estimated to US $ 72 million (US $ 4,800 per Ha).

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* The Five Years National Development Plans (REPELITA) cover following periods:
REPELITA II : from April 1974 to March 1979
REPELITA III : from April 1979 to March 1984.

3.1.2.2 Rural Housing Improvement Projects.

The rural Housing Improvement Projects are scheduled at present to provide assistance in the upgrading of housing and general facilities in 6,000 rural villages during the REPALITA III period. In this unique programme the difficulties experienced in disseminating building research results in such a way that they reach those who need them in a form which makes their use direct applicable, are the main concern of the Government.

A programme for the training of young technical instructors to be stationed for a longer or shorter period in the kampungs, the provision of simple tools, block presses etc to be introduced, demonstrated and given to the villages, and the erection of demonstration houses in cooperation with the villagers has been found most suitable. The efficient training of young technical instructors in new appropriate technologies is the key activity to the success of this programme.

Besides other activities for rural development in other Ministries, the programme of the Ministry of Public Works comprises, as mentioned, assistance to 6,000 rural villages during REPELITA III. Each programme is budgeted to an estimated cost of US $ 9,600 (5,600 $ for housing, 2,400 $ for sanitation and 1,600 $ for access roads). These funds are intended to act as seed capital. With the assistance of rural improvement instructors development of home industries will be emphasized, firstly providing materials for the improvement of the village itself, later giving possibilities for "export" of building materials to neighbour areas or more prosperous villages. Of the 6,000 villages 1,000 will be selected from the lowest income group (swadaya), 3,000 from the medium income group (swakarya) and 2,000 from the more prosperous group (swasembada).

3.1.3 Private Construction.

It is currently estimated that the organized private construction sector will provide some 290,000 housing units during the REPELITA III period to supplement the Government programmes. No estimate exists for additional individual house construction.

The Government housing projects (PERUMNAS) together with the estimated private real estate development will thus provide only 10 % of the actual need. The remaining 900,000 housing units per year is thus a matter for individual and informal activities.

3.2 Research and Development.

Research and development on housing in Indonesia, which is carried out by the Directorate of Building Research of the Ministry of Public Works, concentrates on alleviating following problems:

In the urban areas:

- Insufficient supply of adequate amounts of the appropriate type and quality of materials at the right time, and at a price that the majority of the population can afford to pay.

- Scarcity of reasonably priced land for housing schemes.
- Inadequate financing facilities.
- Inefficiency in the building process.

In the rural areas:

- The poverty of the population.
- Their fatalistic acceptance of status quo.
- The low quality of locally produced building materials.
- The insufficiency of construction skills.

As in the case of building materials, the overall policy guidelines prescribe the development of local, labour intensive methods.

Over more than a decade several prototype houses have been developed. The design optimizes the utilization of available building materials and components under the prevailing environmental conditions. No visitor to Indonesia will forget the extensive utilization of clay roofing tiles which on the one hand represents the product of hundreds of small scale family enterprises, and on the other represents the most adequate protection against the country's heavy rainfall. Elegant and simple solutions to cross ventilation arrangements are now used in all new low-cost housing. Ten centimeter thick brick- or hollow block wall constructions with corner reinforcements of concrete give a durable, earthquake resistant loadbearing frame for the house. Even cost saving unplastered masonry work has been introduced.

The Government projects, which set the standard for low-cost housing, considers a total squaremeter price of US $ 35 to 50 adequate, and low-cost houses are commonly one family dwellings of 45 m^2 size. To cater for the lowest income group 18 m^2 core house solutions are available. In such projects only the basic toilet, kitchen and minimal sleeping and living room of healthy and durable quality is provided. The owner will then, when means permit, expand the core house with additional rooms erected with cheaper materials such as bamboo matting.

The recently rocketing prices for land near major cities has caused the Government to give up its steady "one family - one house - one garden" policy. Development of 4 storey walk-up flats is now included in the programmes.

The development of adequate financing facilities is lagging behind, but progress is in sight, especially since the appointment of a new junior minister for housing within the Ministry of Public Works.

To boost the development of the building materials industries and housing construction steps have been taken to prepare an overall coordination of building activities and materials production. In a country composed of 27 different regions, each at a different development stage with different environments and raw materials resources, this is a major task to be undertaken in the comming years. The UNIDO project is currently assisting the Government in preliminary "Housing Capacity Studies" in major development regions. Such studies will be tools for the Government in detailing its development programmes for housing in relation to the development of building materials industries.

Research and development activities in housing construction techniques concentrate on improvements and rationalization of conventional techniques, including wood-working and masonry craftmansship, site planning and management, introduction of modular coordination, formulation of standards and codes, etc. The UNIDO project has recently assisted the Government in evaluating the feasibility and suitability of introducing prefabrication in housing construction. Although prefabrication will undoubtly be feasible in the future, based on studies of the local conditions, it has been recommended that a transition phase should be considered for which the phrase: "Rationalized Construction Method (RCM)" has been coined. This phase should concentrate on improvements in conventional techniques. It has been shown that the construction output with better planning and skills can be doubled at no apparent extra cost. Introduction of industrialized building and prefabrication at this stage of development would according to the study be doomed to failure. The unsteady and unpredictable market conditions and the insufficient skilled manpower available are singled out as the main reasons.

Such efforts as the above mentioned "RCM" and the introduction of modular coordination are regarded as elements in a "National Housing System". Such a system, giving detailed technical guidelines and solutions in relation to local conditions,will be a main target for research and development activities in the nearest future. In view of this UNIDO is currently planning a "Low-Cost Housing" project as the second phase of its technical assistance to the Indonesian Government in the building materials and housing field.

4. The Crucial Problem: Training.

The two previous chapters have briefly described activities in Indonesia for development of building materials and low-cost housing. Development in these fields is closely related. Without appropriate materials no housing project will succeed. Several of the obstacles to development are of similar nature, and they may each present their problem.

If, however, a common basic problem should be singled out as the major problem, it is the author's opinion, based on his experiences in participating in the challenging activities in Indonesia, that this problem is: Training, training and more training !

Excellent education facilities exist in Indonesia. Many of the author's Indonesian colleagues are certainly experts of an international standard. But there are far too few experienced engineers and architects to undertake the tremendous task set for them.

Although there is an aboundance of dedicated and well working labourers, their skills are far from adequate. Foreign aid agencies are assisting the Government in upgrading and intensifying the vocational training facilities in Indonesia, but realizing the magnitude of the job to be done, one sometimes gets a feeling of despair: The huge work force is there, it is going to be employed in the development activities, and it has not yet mastered the precision, the speed and the steadiness of workmanship needed for successful industrial development.

The question of education is certainly a key problem which is forcefully attacked by the Government, and improvements may come, although slowly. One may only hope that the development of strict discipline in the performance of routine operations, which is a condition for successful industrial development and which somehow seems foreign to the Indonesian nature, may be possible without destroying the joie-de-vivre, which is so characteristic of the Indonesian worker, and without which development will lose its real meaning.

Abstract

The paper describes current activities for development of building materials industries and low-cost housing construction in Indonesia.

The Government policy favouring development of small scale enterprises is described and analysed, and it is shown that housing and building materials play a vital role in the socio-economic structure of the country, which calls for great care in the development activities.

The paper outlines the strategies for the development, describes current industrial activities, and presents the progress and future programmes for research and development on building materials and housing in Indonesia.

Abstrait

Le bulletin précise les activités actuelles du développement des industries des matériaux de construction et des habitations sociales en Indonesie.

Le project du Gouvernement, qui encourage le développement des solutions à base de moyens limités, à été précisé et analysé, et il est prouvé que l'immobilier et des materiaux de construction sont d'une importance vitale pour l'économie et la structure sociale du pays, auxquels beaucoup d'attention doit être apportée en cours du développement.

Le bulletin détaille les stratégies de développement, précise l'activité de l'industrie actuelle, présente les progrès, les futures programmes de recherche, le développement des activités de logement ainsi que des matériaux de construction.

The quantification of steel and concrete product use, by sector, in the Irish construction industry

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Summary

This paper describes surveys carried out by An Foras Forbartha (The National Institute for Physical Planning and Construction Research) in Ireland, during 1978, in order to quantify the consumption of structural steel, reinforcing steel and concrete products, by end use sector.

Sommaire

Cette communication résume les résultats des enquêtes faites par An Foras Forbartha (L'Institut National pour la Planification Physique et Recherche du Bâtiment) en Irelande pendant l'année 1978. Le but des enquêtes était de mésurer la consomption d'acier de structure, d'acier d'armature et des produits de béton par les consommateurs par secteur.

1. Introduction

National statistics do not provide detailed information on the resources used in the various sectors of the Irish construction industry, yet this information is a prerequisite for rational planning in the industry and is an important ingredient in any analysis of construction activity.

This paper describes surveys carried out by An Foras Forbartha (The National Institute for Physical Planning and Construction Research) during 1978 in order to quantify the consumption of steel (structural and reinforcing) and concrete products by end use sector in Ireland.

2. Methodology

It was considered initially that the first requirement was to establish total consumption figures for a past year and thereafter to apportion these totals to a number of defined sectors of the construction industry. 1977 was chosen as the study year and the eleven sectors are described in Appendix I.

However, it became evident at a very early stage that a uniform methodology would not be appropriate for collecting consumption data relating to both steel and concrete products.

There are a number of fundamental differences between the structures of the Irish concrete and steel industries and these affect the manner in which consumption information is stored and more importantly, the manner by which this information can be accessed.

Ireland, whilst self-sufficient in concrete products, is heavily dependent on imports for steel. In addition, whereas concrete product end use is entirely confined to within the construction industry, a very substantial proportion of steel has application outside the industry. Thus, although steel import statistics would provide quantities which, when added to the known output of Ireland's only steel producer, would yield total steel quantities for any one year, nevertheless a reasonable basis for allocation to the construction industry was not apparent.

There was also a further difficulty in that the levels of steel stocks may vary substantially from year to year and this could distort the consumption pattern if an output method (i.e. on the basis of works' deliveries statistics) was employed. Concrete products, on the other hand, have a relatively short inventory period and would not be subject to such distortions. An input method (i.e. survey at consumer level) did not seem to be a good prospect for steel either, because of the difficulty involved in relating any survey figures to an unknown total.

It was accordingly decided that an output method would be utilised for concrete products and that, in the case of steel, consumption coefficients would be established for the various sectors.

The methodologies employed were as follows:

2.1 Steel products

2.2 Concrete products

2.1 Steel products

A survey of the main structural design practitioners and quantity surveying offices was undertaken in order to determine cost coefficients for both structural and reinforcing steels in each of the chosen sectors. The survey data sheet is shown in Appendix II.

The historical output of these sectors is published annually by the Department of the Environment in their "Review and Outlook for the Construction Industry" series.

However, these output figures include professional fees, whereas the coefficients relate to building costs only. Accordingly, the output figures were modified to reflect an estimated professional fee cost of 12½ per cent.

The coefficients were applied to the modified output figures and the ensuing sectoral valuations were then converted to tonnages of product.

2.2 Concrete products

The distribution of cement, in both bulk and bagged forms was traced. All bulk cement concrete product manufacturers in the country were circularised with survey documents requesting the following information:

- the tonnages of each product manufactured during 1977
- the appropriate average cement contents
- estimated consumption by each sector.

The survey data sheet which lists both the sectors and the products is shown in Appendix III.

Some concrete products (tiles, wood wool, asbestos cement, pipes, bricks, structural units) involve a small and known number of manufacturers. The survey provided sufficient information to enable the consumption of these products to be quantified directly.

Sector / Product	Housing	Industry & Semi-State Bodies	Agriculture	Education	Commercial Development	Sanitary Services	Public Buildings	Hospitals	Telecommunications	Roads	Other
Structural steel	.01	10.78	6.00	3.91	1.94	0.50	1.19	1.61	4.73	0.25	2.00
Reinforcing steel	.37	3.77	5.00	4.03	6.57	4.13	5.46	5.21	6.36	2.73	3.52

Table I. Consumption coefficients. Estimated percentage cost of steel (supply and fix) by sector - 1977

Sector	Estimated Building Cost	Structural Steel		Tonnes	Reinforcing Steel		Tonnes
		Coefficient	Cost £M		Coefficient	Cost £M	
housing	271.35	.01	0.027	67	.37	1.004	3,043
Industry and Semi-State Bodies	87.77	10.78	9.462	23,655	3.77	3.309	10,027
Agriculture	49.78	6.00	2.987	7,468	5.00	2.489	7,542
Education	31.23	3.91	1.221	3,053	4.03	1.259	3,815
Commercial Development	31.76	1.94	0.616	1,540	6.57	2.087	6,324
Sanitary Services	17.88	0.50	0.089	222	4.13	0.738	2,236
Public Buildings	7.73	1.19	0.092	230	5.46	0.422	1,279
Hospitals	10.40	1.61	0.167	417	5.21	0.542	1,643
Telecommunications	8.60	4.73	0.407	1,018	6.36	0.547	1,658
Roads	56.89	0.25	0.142	355	2.73	1.553	4,706
Other	106.75	2.00	2.135	5,338	3.52	3.757	11,385
Total	680.14		17.345	43,363		17.707	53,658

Table II. Estimated structural and reinforcing steel consumption - 1977

The reciprocal of the response rate was applied to the balance of the products in order to compile total estimated tonnages, individually and by sector.

Information relating to the distribution of bagged cement was made available to An Foras Forbartha by Cement Roadstone Holdings Ltd., the only manufacturer of cement in Ireland.

This information included the distribution pattern for bagged cement during 1977 and also the findings of end use surveys carried out during 1976 and 1979 with the assistance of merchants and cooperatives throughout the country.

Sectoral consumption percentages for 1977 were estimated by linear interpolation between the 1976 and 1979 findings, and these percentages were applied to the total tonnage of bagged cement consumed during 1977.

3. Survey findings

3.1 Steel products

3.2 Concrete products

3.1 Steel products

In all, sixty design practitioner offices and thirty-one quantity surveying practices were circularised with the survey documents, accompanied by an explanatory letter. Thirty six replies were received and this information was supplemented by cost data already available at An Foras Forbartha with respect to steel, in order to produce the set of coefficients shown in Table I.

In Table II the coefficients are applied to building costs for both structural and reinforcing steel in order to provide sectoral and total costs. Average conversion costs of £400/tonne and £330/tonne respectively for structural and reinforcing steel, were abstracted from cost data already available at An Foras Forbartha and were used to arrive at tonnages consumed by product and by sector.

3.2 Concrete products

The distribution pattern of cement sales for 1977 is shown in Figure I.

It was assumed that bulk cement delivered to manufacturers was entirely used to produce manufactured products and that bagged cement was used for site-mixed concrete, plaster and mortar.

There were 124 companies engaged in concrete product manufacturing from bulk cement during 1977. Seventeen of the largest manufacturers were approached directly and their cooperation was sought in compiling the survey data. Survey documents accompanied by an explanatory letter were mailed to the remainder.

Many respondents commented on a particular area of difficulty encountered in filling out the survey form, namely that although they had recorded their total consumption by product, it was not possible, in many

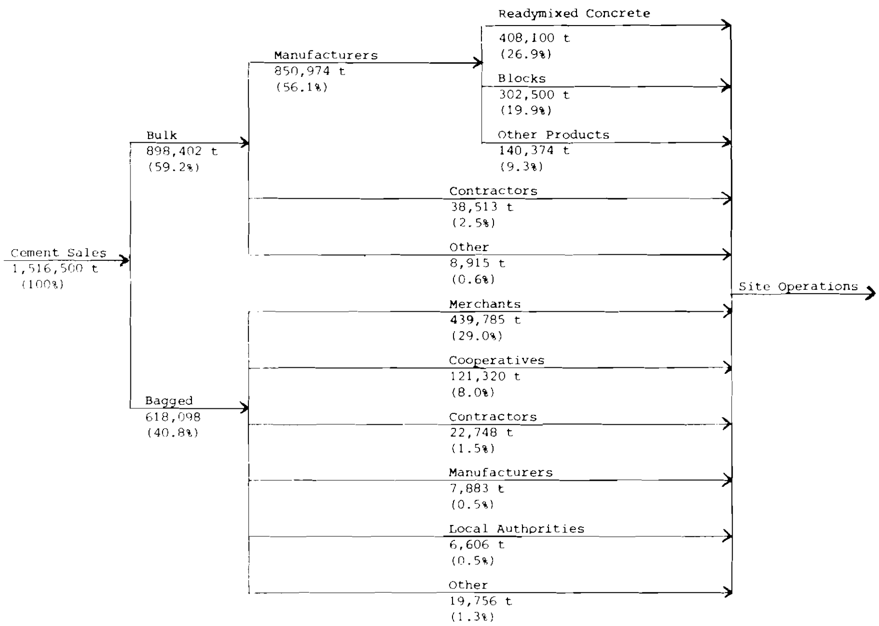

Figure I. Distribution pattern of cement sales - 1977

'000 Tonnes

Category / Sector	Readymixed Concrete	Blocks	Bricks	Slabs and Kerbs	Pipes	Lintels Sills Fencings Copings	Structural Units	Total
Housing	1,267.6	2,193.5	35.3	23.0	7.8	34.0	12.0	3,573.2
Industry	471.7	228.5	8.2	2.7	8.3	6.5	25.5	751.4
Agriculture	798.1	501.1	0.2	3.7	26.7	3.5	19.5	1,352.8
Education	206.3	105.9	7.9	1.1	-	1.0	8.0	330.2
Commercial development	231.3	108.2	6.2	3.7	0.6	1.5	20.5	372.0
Sanitary services	58.8	3.0	-	-	50.6	-	1.0	113.4
Public buildings	155.0	19.5	3.9	1.6	1.1	1.0	-	182.1
Hospitals	31.1	23.5	3.9	0.5	0.6	-	-	59.6
Telecommunications	30.3	4.0	-	-	1.1	-	-	35.4
Roads	320.1	24.6	0.2	7.5	13.3	1.0	-	366.7
Other	173.3	148.9	-	3.2	0.5	0.5	1.5	327.9
Total	3,743.6	3,360.7	65.8	47.0	110.6	49.0	88.0	7,464.7

Table III. Estimated output for manufactured concrete products - 1977

instances, to identify the actual consumption sector from their historical records.

This difficulty was overcome through consultation with their respective sales representatives, so that the returned survey forms represented a joint contribution of historical record, extended where necessary by the specialist knowledge of their sales staff.

The returned survey data sheets were analysed in accordance with the methodology outlined in Section 2.2 and the estimated output for manufactured concrete products is shown in Table III.

Sectoral bagged cement consumption tonnages were estimated in accordance with the methodology described in Section 2.2.

An Foras Forbartha carried out a detailed survey of housing construction during 1977, and amongst its findings concluded that mortar and plaster accounted for nine per cent of the total cement consumed by housing during the year. This was equivalent to about twenty per cent of the bagged cement delivered to housing sites. It is assumed that this same relationship should apply to all of the other sectors except agriculture, which has a particularly high utilisation of site-mixed concrete from bagged cement. It is estimated that ten per cent of the agricultural sector's bagged cement is used for mortar and plaster. It is further assumed that site-mixed concrete had an average cement content of ten per cent. Table IV shows bagged cement use:

'000 Tonnes

	Bagged Cement - Total	Cement - Mortar and Plaster	Cement - Site mixed Concrete	Site mixed Concrete
Housing	288.0	57.6	230.4	2304
Industry	39.6	7.9	31.7	317
Agriculture	190.4	19.0	171.4	1714
Commercial development	16.7	3.3	13.4	134
Other	83.4	16.7	66.7	667
Total	618.1	104.5	513.6	5136

Table IV. Estimated utilisation of bagged cement by sector - 1977

'000 Tonnes

Sector	Bulk Cement		Bagged Cement	Total	Percentage of Total	Construction Output Distribution %
	Manufacturers	Other				
Housing	389.5	21.7	288.0	699.2	46.1	45.0
Industry	88.5	4.9	39.6	133.0	8.8	14.1
Agriculture	146.3	8.2	190.4	344.9	22.7	8.6
Commercial Development	42.3	2.4	16.7	61.4	4.1	5.1
Other	184.4	10.2	83.4	278.0	18.3	27.2
Total	851.0	*47.4	618.1	1516.5	100.0	100.0

* Sectoral distribution assumed to be the same as for manufacturers.

Table V. Estimated total cement consumption by sector - 1977

Table V summarises total cement consumption by the main sectors and compares sectoral distribution with that of construction output.

4. Conclusion

The various resources used in the construction industry tend to have unique characteristics and any study aimed at quantifying the consumption of a particular resource should have due regard to the manner in which information peculiar to that resource is stored and how it can be accessed. These considerations will largely determine the most appropriate method for compiling consumption data.

There are three main general approaches that may be employed towards this end, viz. input, output and coefficient methods.

An analysis of information availability in relation to steel and concrete products in Ireland led to the conclusion that a uniform methodology would not be feasible for both groups of products but rather that a coefficient method should be used for steel (structural and reinforcing) and an output method for concrete products.

Appendix I - Details of composition of various sectors

Housing

Local authority and private housing, conversions, reconstruction, maintenance and water and sewerage installation.

Industry and semi-state bodies

Manufacturing and non-manufacturing industry and semi-state bodies.

Agriculture

Farm buildings (but not houses), related constructional works and water supplies.

Education

Primary, secondary, comprehensive, community and vocational schools, regional technical colleges, universities, training colleges, residential homes and special schools.

Commercial development

New office and shop development and extensions, alterations and conversions.

Sanitary services

Public water supply and sewerage schemes excluding work done in respect of which grants are paid for individual and group installations as these are included in housing sector.

Public buildings

Prisons, Garda stations, courthouses, post offices, etc.

Hospitals

Hospitals, nursing homes, mental institutions.

Telecommunications

Telephone exchanges and digging of trenches for cabling and duct laying.

Roads

Roads and bridges

Other

Includes

(a) Tourist development -
hotels, holiday accommodation and resort development

(b) Ports and harbours

(c) Airport development

(d) Places of worship

(e) Environmental services -
swimming pools, local authority libraries, itinerant resettlement, fire stations, local authority accommodation, sanitary conveniences and some harbour work.

(f) Other

APPENDIX II

SURVEY DATA SHEET

Estimated proportional cost of steel (supply and fix) by sector

Sector / Product	Housing	Industry and Semi-State Bodies	Agriculture	Education	Commercial Development	Sanitary Services	Public Buildings	Hospitals	Telecommunications	Roads	Other
Structural steel											
Reinforcing steel											

APPENDIX III

SURVEY DATA SHEET

CONCRETE PRODUCT SALES (TONNAGE) 1977

Sector / Category	Housing	Industry and Semi-State Bodies	Agriculture	Education	Commercial Development	Sanitary Services	Public Buildings	Hospitals	Telecommunications	Roads	Other	Total Tonnage	Average Cement Content %
Readymixed concrete													
Blocks													
Bricks													
Slabs and Kerbs													
Pipes													
Roof tiles													
Lintels, sills, fencing, copings													
Structural units													
Other (specify)													

The properties and testing of lime-pozzolana mixtures

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Summary

A method of testing suitable for the rapid evaluation of pozzolanas in the field is described. Good correlation is obtained with the results of medium-term strength tests over a variety of types of pozzolana. The test is simpler and cheaper to perform than comparable methods of test offered in existing national standards.

Le but de notre communication est de presenter une methode pour l'evaluation rapide, sur le terrain, de la qualite des pozzolanes. Une bonne correlation est obtenue avec les resultats de tests de force au moyen age sur une variete de types de pozzolanes. La methode que nous proposons est plus economique et moins onereuse que les tests semblables faits actuellement pour les standards nationaux.

Introduction

In recent years there has been a revival of interest in the potential of lime-pozzolana mixtures as alternative cementing materials in less developed countries. There are two main reasons for this interest. First, the high capital cost and large scale of cement plants has meant that indigenous supply of Portland cement has in many countries been unable to meet the demand, and there is a need to develop the use of locally produced substitutes. Secondly, the scarcity of resources of all sorts has forced a reconsideration of the possible value of waste or underutilized materials, some of which have been found to have pozzolanic properties.

In India, for example, where the gap between demand and supply of Portland cement has been steadily widening, there has been an increase in the use of burnt clay pozzolana, or surkhi, in lime-pozzolana mortars. The surkhi is usually produced from waste bricks and tiles, and although the traditional material is coarsely ground, there have been a number of attempts to improve the technology and produce a standardised product.

The disposal of rice husk ash frequently presents a problem in rice-growing areas. Recent work in India has demonstrated the potential of rice husk ash as a pozzolana, and a masonry cement known as ASHMOH cement has been developed. A number of pilot plants to manufacture this and similar materials have now been established.

In volcanic areas such as Indonesia and the African rift valley, very substantial deposits of volcanic ash occur, which are frequently found to have excellent pozzolanic properties. In Indonesia, a coarse volcanic ash is used in the manufacture of lime-trass building blocks which are commonly used in the large cities. A project to make use of the ash deposits in the Arusha region of Tanzania in a similar way has been started. A review of such developments has recently been published [1].

Because such industries tend to be small in scale, to cater to a local market, and to use a technology which is very much simpler and cheaper to establish than that for Portland cement production, they can be economically competitive with Portland cement, even when a high level of production efficiency is not achieved. Consequently the use of lime-pozzolana mixtures can be expected to increase.

However, the increased use of pozzolanas, whether with lime or with Portland cement, requires that reliable testing procedures be developed. Three different types of test need to be distinguished:

1. Tests for rapid evaluation of alternative materials for use as pozzolanas.
2. Tests for quality control on production of pozzolana or lime-pozzolana mixture.
3. Tests to form the basis of standards for the use of pozzolanas either in lime-pozzolana mixtures or in Portland-pozzolana mixtures in buildings or building products.

Because pozzolanas are never used on their own, but always in conjunction with other materials, it can be argued that there is little value in defining standards either for the chemical or physical properties of pozzolanas as such; but rather that all standards should be performance standards relating to the desired properties of the mixture in the use for which it is intended. Thus different standards would be needed for lime-pozzolana mortars and plasters; lime-pozzolana concretes; building blocks or precast products made from lime-pozzolana mixtures using accelerated curing techniques; and for Portland-pozzolana cements for general building use. Provided that these products can satisfy such performance specifications, no additional limitations on the precise nature or properties of the pozzolana need be specified.

However, where a variety of different raw materials is to be investigated for use as pozzolanas, it is important that appropriate test methods for this investigation should be developed. Even though no particular limits need to be placed on the results of these tests, the test methods themselves must be carefully standardised so that clear comparisons can be made, and also so that there can be useful correlations between the performance in such tests and the end use for which the pozzolana is intended. Such tests, which may be called field tests or rapid evaluation tests, do not need to be the basis of legal commitments between suppliers and users, or designed to be performed in national laboratories. Rather they should be designed specifically for use in unsophisticated laboratories which could quickly be established anywhere. The essential characteristics of such tests are that they should make use of simple equipment, they should be cheap to perform, and they should give rapid results.

This paper is concerned with the development of such a test, designed initially for use in a field laboratory in Tanzania in an area where a large deposit of volcanic pozzolana is found. The effect on the test results of some of the main variables in the test is examined, and correlation is attempted between the results of short-term tests and the medium-term strengths of a range of different materials. Some comments are made on the suitability of the tests suggested in existing national standards for field evaluation.

Elements of test

It was for a long time hoped that it might be possible to develop simple chemical tests by which the activity of a pozzolana could be determined. However, only limited success was achieved by any such test, and then only when testing materials of similar chemical composition and structure [2]. Unfortunately, the properties measured were not entirely related to the development of compressive strength in lime-pozzolana mixtures, or other desirable properties.

Thus it is today generally agreed that a strength test on a lime-pozzolana mortar is the most suitable method of evaluating the activity of a pozzolana: cube compressive strength is commonly used as the measure of strength since it is relatively easy to determine. Unfortunately, however, tests to determine strength involve a considerable number of separate operations, each involving several variables, and each needing to be standardised. The most important are:

- size of specimen
- curing regime
- type of lime, and lime-pozzolana ratio
- type of aggregate, and aggregate-cement ratio
- water content and mixing procedure
- casting and compaction procedure
- method of performing compression test.

Each of these will be briefly considered.

Size of specimen

For cheapness of equipment, ease of compression testing and for simplicity of transport, smaller test specimens have great advantages. In this test 25mm cubes have been used. These were cast in gang-moulds which proved very easy to construct. The repeatability of results was high, but cube results tended to be higher than with larger cubes: this however is not important in a test whose purpose is comparison and quality control.

Curing regime

To enable results to be obtained quickly, it was decided that a form of accelerated curing should be used: in this the test follows the earlier suggestions of Lea [3] and also the American and Indian standards. Many lime-pozzolana mixtures develop their full strength at ambient temperatures over a much longer period than does Portland cement, but the rate of strength development is very sensitive to temperature. Thus strength developed after a short period of curing at an elevated temperature has been found to be a useful guide to medium and long-term strength development. The curing regime used in this case involved 48 hours under water at 50°C, starting 2 days after casting; followed by a further 3 days immersion at 20°C until testing at 7 days. A 7-day test without curing at elevated temperature was also performed. Fig. 1 shows the effect on strength development of altering the length of the period of curing at elevated temperature for a Tanzanian volcanic pozzolana. In this case, after 2 days, approximately 75% of the maximum potential strength has been reached.

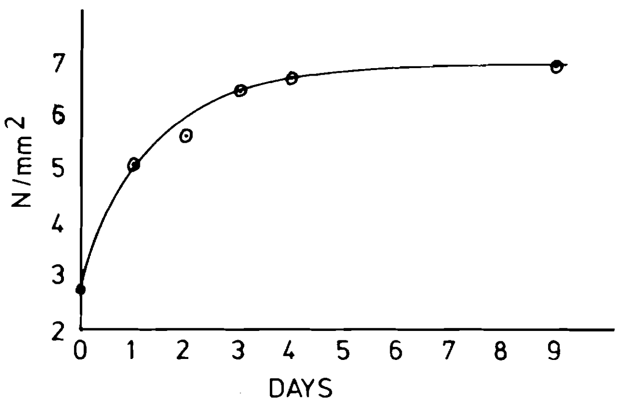

Fig. 1. Compressive strength as a function of duration of curing at elevated temperatures.

Lime and lime-pozzolana ratio

The lime used was a high-calcium hydrated lime satisfying BS 890. Unfortunately in many countries available commercial building limes are of poor quality and suitable lime may have to be imported. A lime-pozzolana ratio of 1:2 was used. Ideally, the lime content should be just sufficient for all the pozzolana to react fully. Fig. 2 shows, for a Tanzanian pozzolana, the effect on 7-day and accelerated strength of variation in the lime-pozzolana ratio. The optimum strength occurs in this case with a pozzolana:lime ratio between 2.5 and 4: a somewhat higher than optimum lime content was used to ensure adequate mixing of the lime.

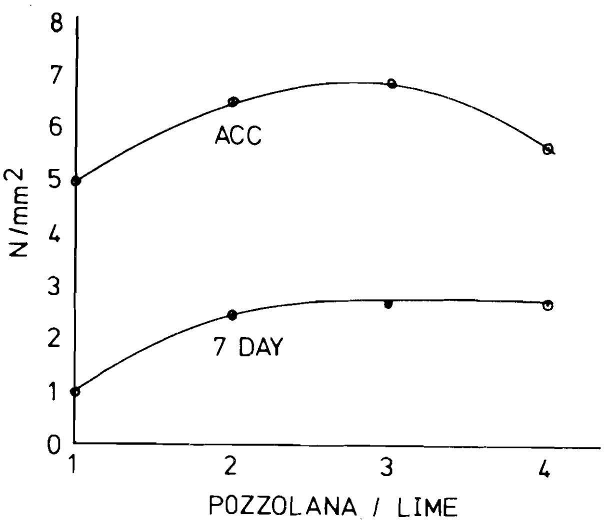

Fig. 2. Effect of varying lime-pozzolana ratio on compressive strength.

Aggregate and aggregate-cement ratio

To reduce the water content as far as possible, a graded sand was used, satisfying BS 4551. An aggregate-cement ratio of 3 was used as is commonly specified for mortar testing. The effect of aggregate-cement ratio on 7-day and accelerated strengths is shown in Fig. 3. The mixes are all of the same workability, as defined below; a richer mix will have a lower water-cement ratio and thus a higher strength.

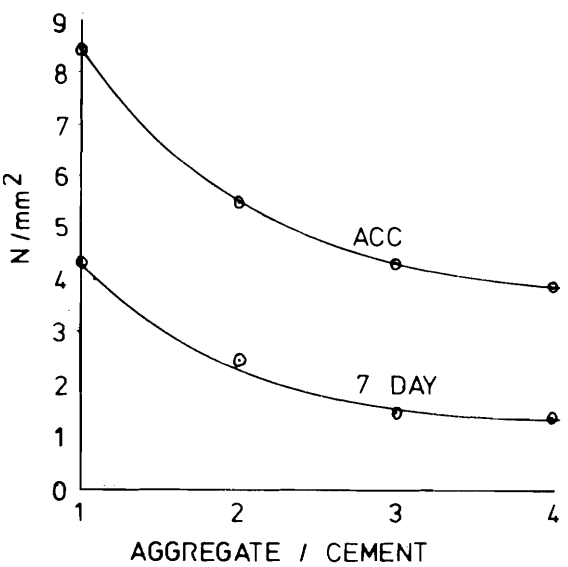

Fig. 3. Effect of varying aggregate-cement ratio on compressive strength.

Water content

The use of a fixed water content when testing a variety of types of pozzolana produces mixes of different workabilities, and can result in mixing and compaction variations sufficient to invalidate comparisons between materials. Certain workability-related effects also need to be eliminated. Fig. 4 shows, for a Tanzanian pozzolana, the difference between accelerated and 7-day test results over a range of water contents, and clearly indicates an unexpected reduction in the rate of gain of accelerated strength at low water-cement ratios. The effect is possibly related to thermal stresses between solid particles, and the degree of particle interaction will be related to workability. To avoid these problems, the tests were carried out at constant workability, defined by a flow test. The recommendations of ASTM C593 4 were adopted both as to the type

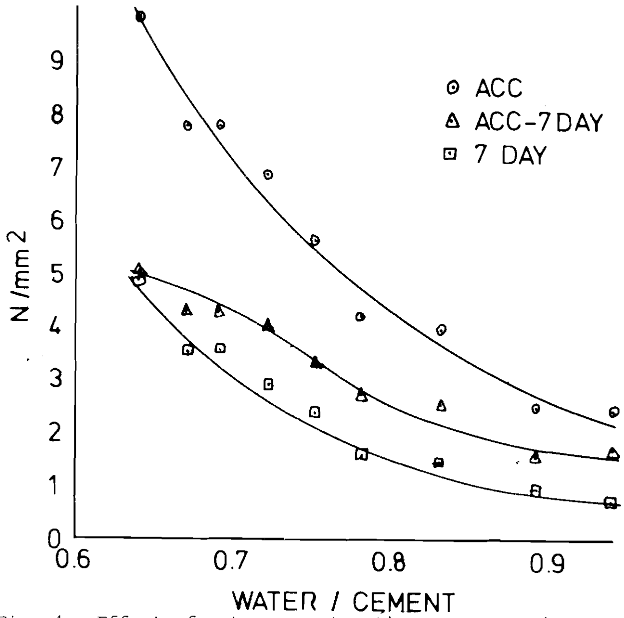

Fig. 4. Effect of water-cement ratio on compressive strength

of flow table and the determination of water content. The specified flow is far removed from that at which the thermal effects occur. Water-cement ratios over the range of pozzolanas tested varied from 0.56 to 0.92.

Other aspects of the test procedure

The mixing procedures adopted are set out in Table 1: a domestic paddle-mixer was used.

Dry mix lime and pozzolana	2 min
Add estimated water content and mix	2 min
Add sand and mix	1 min
Clean sides of mixing bowl and mix	1 min
Add any additional water needed and mix	0.5 min

Table 1. Mixing procedure

Moulds were filled in three layers, each layer tamped 30 times with a 1 cm^2 rod, and the surface levelled with a trowel. Compression testing in the laboratory was carried out on a strain-controlled testing machine at a constant strain rate of 1mm per minute: at least three cubes were crushed for each plotted point. For use in the field, a hand portable compression testing machine has been designed; field tests with this machine in Tanzania have recently been completed.

Comparative tests on pozzolanas

Seven pozzolanas of varying origin were selected. Three were burnt clays, two were artificial materials (a ground sintered p.f.a. aggregate and a silica gel), and two were volcanic ashes from Tanzania and Rwanda. A number of different samples of the Tanzanian ash were taken to obtain an indication of variation within the deposit. To attempt to correlate between the results of the accelerated test and medium term strengths (of most practical importance with lime-pozzolana mortar mixtures), a set of specimens was tested after 9 weeks curing at 20°C. Typical results are given in Table 2.

The highest strength, both in the accelerated test and after 9 weeks, was obtained with the silica gel,

Pozzolana Type and Treatment	Compressive Strengths N/mm² 7 day	Accelerated	9 weeks
Blue Gault Clay (Calcined 800°C, ground)	2.97	10.56	10.97
China Clay (Calcined 800°C, ground)	0.96	7.39	5.84
Burnt Clay (Indian Surkhi, ground)	0.58	2.36	3.43
Sintered Fly Ash (Ground)	0.26	1.03	2.34
Silica Gel (Untreated)	13.5	13.9	15.9
Volcanic Ash Rwanda (ground)	0.20	0.36	0.94
Volcanic Ash Tanzania (untreated B3)	2.36	6.24	5.73
Volcanic Ash Tanzania (untreated P2)	2.19	5.27	4.45
Volcanic Ash Tanzania (untreated P3)	1.62	4.47	3.64

Table 2. Compressive strengths of various lime-pozzolana mortars: typical results.

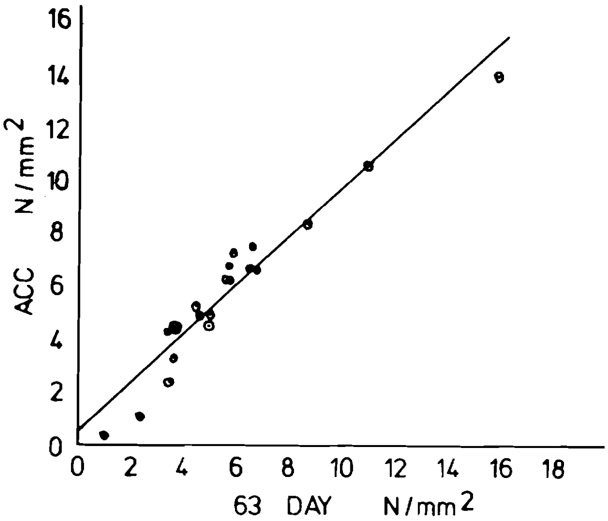

Fig. 5. Relationship between accelerated and 9-week compressive strength (all samples). Correlation coefficient = 0.96.

presumably on account of its very high internal surface area. This however is not a practical pozzolana. The burnt clay pozzolana using the Blue Gault clay also gave excellent strengths. All the other materials were found to have some useful pozzolanic activity except the Rwanda volcanic ash. There was a considerable spread of results from the Tanzanian volcanic ash, the reasons for which are still being investigated.

Fig. 5 shows the correlation between the accelerated strength and the 9-week strength over all 21 samples tested. The correlation coefficient is 0.96 indicating that the accelerated test is indeed useful in predicting medium-term performance for this range of pozzolana. When the group of 14 samples all from the Tanzanian volcanic ash are considered alone, the correlation coefficient unexpectedly falls slightly to 0.94.

Standard	Type of Pozzolana	Specimen size mm³	Max Design (by weight) Lime:Pozz:Sand	Determination of Water Content	Curing	Strength Requirements
ASTM C593	Any	50	1 : 2 :8.22	Flow Method Flow: 65-75% 10 blows in 6 sec	7 days 54°C 23°C Until test	7 days 4.1 MPa 28 days 4.1 MPa
IS 1727/1344	Burnt Clay Pozzolana	50	1 : 2M* :9	Flow Method Flow: 110±5% 10 blows in 6 sec	2 days 27°C 8 days 50°C	50 kg/mm²
IS 4098	Lime Pozzolana Mixture	50	1 : 3+	Flow Method Flow 110±5% 10 blows in 6 sec	7 days 27°C 21 days 27°C	LP 40 LP 20 LP 7 7 day 20 10 3 28 day 40 20 7 (kg/mm²)
DIN 51043	Trass	160x40x40	1 : 4 :7.5	Constant 0.45 x (trass + lime)	28 days 20°C	28 days 5N/mm²

* M = Specific Gravity of Pozzolana / Specific Gravity of Lime

\+ (lime+pozzolana):sand

Table 3. Provisions of standards concerning compressive strength tests on lime pozzolana mixtures.

An alternative measure of pozzolanic activity which has been proposed is Lea's 'activity index' [3] which is defined as

Activity Index = Accelerated Strength - 7 day strength.

Although devised for the purpose of evaluating pozzolanas for use in Portland-pozzolana cements, its use has been suggested for predicting longer-term performance of lime-pozzolana mixture. However, the correlation coefficient between the Activity Index and the 9-week strength over all 21 samples was only 0.77, indicating that the accelerated strength is clearly superior to the Activity Index as a measure of medium-term strength development. Long-term tests are still in progress.

National standards

Table 3 summarizes the provisions for compressive strength determination in a number of national standards for pozzolanas, those of India [5,6,7], Germany [8] and the United States [4]. Considerable variation is revealed in the methods of mix design, the curing regimes and the strength requirements. To some extent, this is a reflection of the different materials considered and the different end-use envisaged. The German standard refers only to trass, a single well-defined pozzolana which is also subject to limitations in chemical composition and fineness: thus the water content can reasonably be defined as a fixed proportion of the trass+lime content, and a single 28-day strength specified, which no doubt correlates well with longer-term strengths. Such a standard would not be suitable for use with a wide variety of pozzolanas of different type and origin.

Both the American and Indian standard (ASTM C593, IS 1727) are applicable to a wide range of pozzolanas: the mix design procedures are similar, except that the Indian standard specifies a constant volumetric relation-ship between the lime and pozzolana. Curing regimes are also very similar, each involving a substantial period of curing at elevated temperature (7 days at $54^{\circ}C$ in the American, 8 days at $50^{\circ}C$ in the Indian). The strength requirements are, however, rather different. The American standard specifies a minimum strength of 4.1 MPa, which should not fall after a further 21 days curing at $23^{\circ}C$. The Indian standards include different sets of requirements for different types of pozzolana, that for burnt clay (IS 1344) requiring a minimum strength after test (the 'lime reactivity') of 5 N/mm^2. Indian standards also, however, specify a further set of tests for lime-pozzolana mixtures (IS 4098) for use in mortars, defining three grades of lime-pozzolana mixture according to the 28-day strength attained after curing at ambient temperatures. It is suggested, but not required, that for 28 day strengths of 40, 20 and 7 kg/cm^2, lime reactivity values of 80, 60 and 40 kg/cm^2 respectively will be required. This standard is thus more akin to the type of end-use performance standard envisaged earlier, whereas ASTM C593 and IS 1727 are better suited for evaluation and quality control of pozzolanas.

The main advantages of the test proposed over these latter two standards is that by using smaller specimens the cost of the test and the quantity of material required for testing is considerably reduced, while by reducing the period of curing at elevated temperature an estimate of the strength attainable over a realistic time span seems to be obtained. This last point however needs to be further investigated with a wide range of pozzolanas.

A further advantage is that field testing of specimens using a hand-portable compression-testing machine becomes possible.

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The utilization of local materials in the development of block construction

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China is a developing socialist country. With the raising of the people's living standard, there is an ever increasing demand for residential buildings. As we are rather weak in building materials and technology, it is difficult for us at present to carry out construction on a highly industrialized level. So it is very important for us to find a way of our own that will best suit China's present economic conditions as well as the level of our technology and management. After many years of practice, we have found out that small size block construction is one of the most suitable ways in the development of residential buildings.

The production of blocks must be adapted to local characteristics, utilizing as much as possible the materials and industrial wastes that each particular place has to offer. Though we have a shortage in steel, cement and lumber, we have abundant resource of local materials and industrial wastes, and they are made full use of in the renovation of wall materials in many places in China. For example, in Sichuan Province, there is a great abundance in sand and pebbles in the rivers there. This kind of natural grading pebbles is used to produce concrete blocks by adding an appropriate amount of cement and lime. Guangxi Province is rich in sand and stone, hence the development of small size cement mortar hollow blocks. In many industrial cities, great advancement has been made in the utilization of industrial wastes for wall materials, the most commonly used being fly ash, colliary shale and slags. This is a good measure in enviromental protection as well as in the saving of energy and soil.

In construction departments in Shanghai, research work on fly ash blocks began in 1958, and ever since 1963 this kind of block has been used as wall materials in five-storey residential buildings. The fly ash blocks produced by the Shanghai Silicate Product Factory are composed of fly ash, lime, gypsum and cinder, the first three being used as cementing materials while the fourth as lightweight aggregate. The process of production follows the procedure of mixing, casting, vibratory moulding and steam-curing. There are four sizes, ranging from 28 x 38 x 19cm to 88 x 38 x 19cm, weighing 32 to 102 kg. each. The mix proportion is as follows:

Fly ash	31-33%
Lime	10-12%
Gypsum	2%
Cinder	55%
Effective calcium oxide in cementing material	
in winter	20-22%
in summer	17-19%
Water	30-32%

The physical and mechanical properties of fly ash blocks as proved by tests are as follows:

Density (dry state)	1300-1550kg/m3
Compressive strength	100-200kg/cm2
Water absorption	24-28%
Coefficient of thermal conductivity	0.4-0.5kcal/m hr °C
Shrinkage	0.6-0.7 mm/m

The blocks are steam cured under atmospheric pressure instead of high pressure. Autoclaves, therefore, are not used, and the process of production, as a result, is much simplified. So long as the mix proportion and curing system are strictly controlled, the quality of blocks can be fully guaranteed. Steam curing is the main stage during which the strength of the fly ash blocks develops. In order to gain better results, in the initial curing stage, the blocks are kept standing in the curing chambers for a certain period before temperature is raised slowly. If not enough time is allowed for standing and the raising of temperature, heaving and loosening will take place on the surface of the blocks, which will seriously affect the frost resistance of the blocks, and consequently cause difficulties in construction.

Laboratory tests and site applications prove that the main factor which affects the durability of the fly ash blocks is the carbonation by the carbondioxide in the atmosphere. As the hydrates in the cementing material can be decomposed by the carbon dioxide in the atmosphere, the amount of active calcium oxide used in the blocks is of crucial importance in the resistance of carbon dioxide in the atmosphere. Increasing the content of active calcium oxide may improve the carbonation stability. When the active calcium oxide content in the cementing material is 15%, the strength of the blocks after carbonation is generally 60-70% of that before carbonation. If the active calcium oxide is lower than 15%, the strength after carbonation will be much lower. Investigation made on block construction shows that carbonation action is unavoidable. After the completion of carbonation, the strength becomes stable. Therefore, in structural design, the properties of the blocks after carbonation should be taken as the basis for calculation.

The production of blocks needs no complicated equipments, therefore great profits and quick returns can be gained with small investments. Even the block-making machine, the main equipment needed in the production of hollow blocks, is easy to manufacture and maintain.

The GY-7 small hollow block machine made in Guangzhou weighs 2.? tons and is hydraulically operated and vibratory moulding, with a working pressure of 45kg/cm2. It can make 5 blocks each time and 2,000 blocks each shift. In some places, very simple small size block machines have been proved successful. Such machines weigh no more than several hundred kilograms, and can make more than 500 blocks each shift with a crew of three to four. The amount of blocks produced by one such machine in one year can satisfy the need of 10,000m2 of residential buildings.

Recently, a kind of circuit production line for medium size hollow blocks has been developed in Hangzhou, which links up the processes of moulding, conveying, curing and stripping in a systematic way. From the data given by the Capital Construction Committee of Zhejiang Province, the annual output of this production line is 42,000m3 which is enough for wall materials for 150,000 m2 of residential buildings.

High efficiency and speed in construction is possible and no heavy equipments are needed.

Medium size blocks are mostly 118 x 48 x 20cm in size and weigh no more than 350 kg each, and are therefore easy to handle. Simple hoist towers are generally used for vertical transportation, and mini-cranes and derricks can be used for the handling and erection of blocks. The labour required for each square meter of wall is 46% less as compared with traditional 24cm thick brick walls.

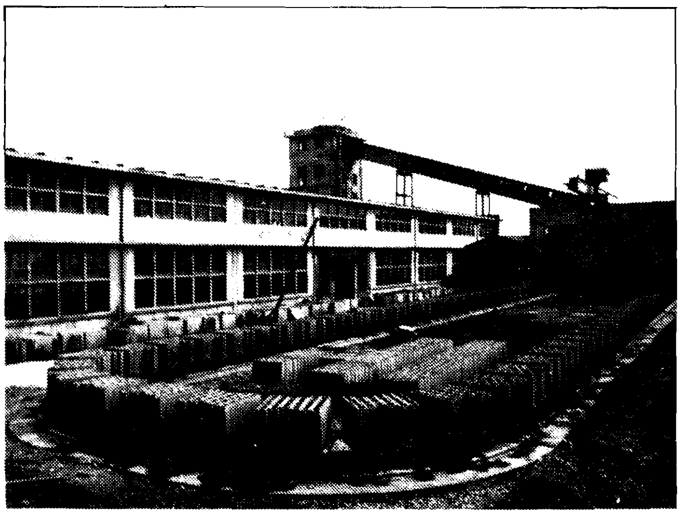
Small blocks are generally 39 x 19 x 19 cm in size, and weigh 3 to 18 kg. each. They are laid in about the same way as bricks and the equipments used for the two kinds of constructions are the same. The only difference is that blocks are heavier than bricks and the workers may feel unaccustomed at the beginning. But after they have mastered the skill of blocklaying, their productivity can be doubled, construction time can be shortened by 1/3 and costs reduced slightly as compared with brick construction.

When appropriate measures are taken, block construction can be seismic resistant. Five-storey block buildings may be built in zones where resistance against an earthquake intensity of 7 is required in the design.

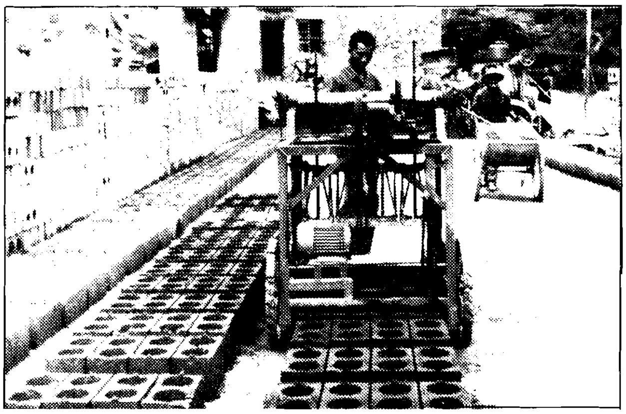
China is a country where earthquakes frequently occur. Naturally we are concerned with the question whether block construction can be earthquake resistant or not. After many years of practice, lot of experience has been accumulated as how to strengthen the structural integrity of block construction. For example, the installment of reinforced concrete collar beams that tie together the interior and exterior walls, and the overlapping of blocks at the junctions of longitudinal and transverse walls have both been proved to be effective. In the case of hollow blocks, steel bars can be placed in the cores and then concrete cast in-situ. Full size model tests prove that five-storey block construction can meet the earthquake resistant requirements for zones with an intensity of 7.

In order to promote block construction as well as to guarantee its quality, a specification for the structural design and construction of block buildings is now being compiled.

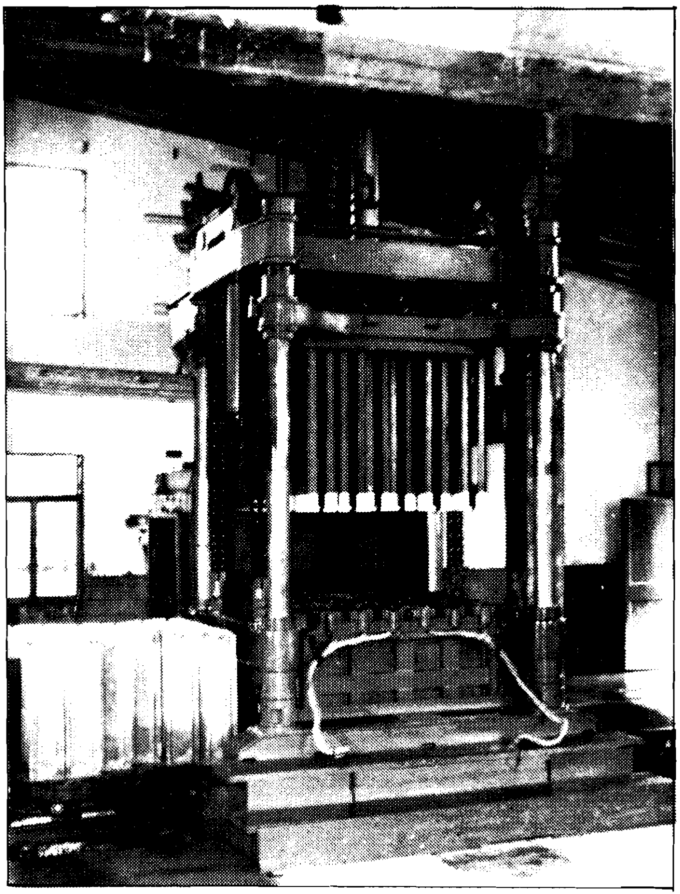
Five-storey hollow block residential buildings in Hangzhou.



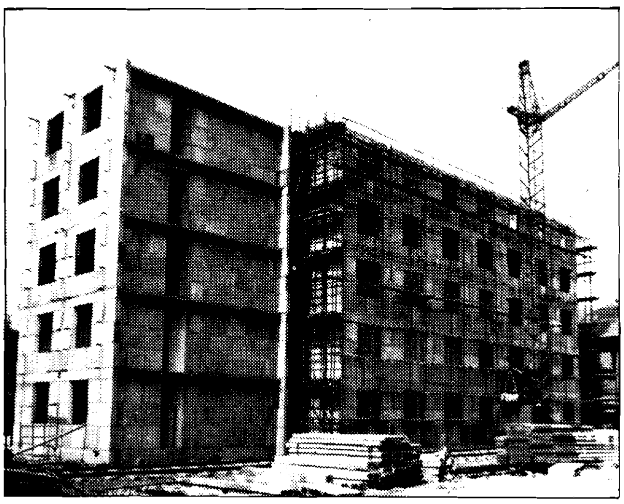
Circuit production line of hollow concrete blocks



Self-travelling small size block machine made in Guangxi. Simple, easily operated and low cost.



Medium size block making machine made in Hangzhou. Makes 7 blocks of 5 different sizes each time.



Full size model tests. Concrete hollow block residential building with two rooms on each floor. Measures taken for earthquake resistance: installment of collar beams, placement of steel bars in the cores at the junctions of longitudinal and transverse walls and concrete cast in-situ. Tests prove that the model can meet earthquake resistant requirements for zones with intensity 7.

SUBJECT SUJET 3B

Energy conservation: Installations
Heat exchangers, heat pumps, solar panels etc.

Installations pour économie d'énergie échangeurs de chaleur, pompes de chaleur, panneaux solaires etc.

An integral solar water heater for low income housing

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Summary

This paper describes the development of a simple low cost integral pipe-type solar water heater for developing areas where back-up energy is not available or is too expensive for low income families.

The use of standard pipes to contain the water affords ease of manufacture and also allows the use of a high pressure water supply.

The process of design and development is described, including attempts to reduce overnight heat loss. The latest model has relatively high thermal collection efficiency and heats sufficient water to supply the modest daily needs of a low income family.

Sommaire

Cet article décrit le développement d'unn chauffe-eau solaire simple de type tuyau intégral à bas prix pour des régions en voie développement ou l'énergie de réserve n'est pas accessible ou trop chère pour des familles avec un faible salaire. L'utilisation, pour contenir l"eau, de tuyaux de forme standard permet une fabrication facile en même temps que l'usage d'une provision d'eau à haute pression. Le procédé du plan et du développement est décrit, y compris les tentatives pour réduire la perte de chaleur durant la nuit. Le modèle le plus récent a une assez haute efficacité de collection thermale et chauffe l'eau suffisamment pour pourvoir aux plus modestes besoins journaliers d'une famille avec un salaire faible.

Introduction

South Africa is a country with both developed and developing economies and communities. The last three decades have seen a considerable rise of living standards, especially of the lower income groups, as well as increasing urbanization and an associated demand for housing.

There are currently more than 500 000 houses for the developing section of the community in the urban areas (1). Of these just over 400 000 have no electricity and a further 80 000 have limited facilities. Steps are already in progress to provide electricity for these communities. This will severely tax the country's capital resources and any procedure for alleviating the position should be investigated.

It is felt that the large scale utilization of solar energy for heating of water for domestic purposes can result in considerable savings, as water heating is by far the major consumer (45 to 50 per cent) of energy in the house. Consequently the National Building Research Institute (NBRI) has considered it desirable to do the necessary research into and development of a low cost integral solar water heater in which the functions of the solar collector and storage tank are combined into one unit (2). The first unit was of the flat tank type with a capacity of approximately 45 litres. Although it functioned well, with a high thermal efficiency, its two shortcomings were a relatively small water capacity and limited pressure rating.

Solar Energy for Low Cost Solar Water Heating

South Africa receives relatively large amounts of solar energy. The average insolation received on a surface inclined at an angle of latitude +10 to the horizontal, for selected locations, is shown in Table 1.

Table 1 Mean solar radiation received on a north facing surface inclined at an angle of latitude plus 10^{o} to the horizontal (3).

Location	Annual Insolation ($GJm^{-2}a^{-1}$)	Mean Daily Insolation during middle of winter ($MJm^{-2}day^{-1}$)	Comment
Bloem-fontein	8,4	21,1	Central part of country.
Cape Town	7,1	14,2	Winter rainfall area.
Durban	6,3	16,8	Sub-tropical coastal area.
Pretoria	7,7	21.6	Highly populated Pretoria/Witwatersrand area.

A large proportion of low income houses is in the interior area of South Africa where clear skies predominate in winter. Solar energy therefore offer eminently suitable opportunities for water heating, especially in low income townships where electricity has not yet been provided. Here the integrated solar water heater has the following advantages:

1 It is relatively cheap;
2 It has high thermal efficiency;
3 It is simple to manufacture, easy to install, with low operating and maintenance cost. The relatively small size and low roof slope of low income houses do not favour the conventional two component thermosiphon solar water

heater for which the tank would have to be installed on an exposed, costly and unsightly open stand;

4 It provides hot water at a time when families of low income houses mostly require it;

5 It could promote the establishment of home industries and small rural manufacturing concerns.

Although this type of unit has the disadvantage that the hot water stored in the unit cools down at night, as can be seen from Figure 3, low income families tend to use most of their hot water in the late afternoon and early evening for ablutions and preparing the main meal.

It has not yet been possible to fully assess hot water requirements of low income families. It has been noted, though, that for the same size of family the lower income groups generally use less hot water than the higher income groups, although 100 to 200 per cent variations occur in the same income group. It is nevertheless estimated that on average 140 litres of hot water at 40°C are required daily by a low income family of four persons.

Design of Pipe-type Integral Unit

Design of the pipe-type unit commenced during 1977 under the leadership of Mr W N Cawood. All the factors stated above were taken into consideration as well as the availability, cost and ease of fabrication of various materials. The pipe configuration was chosen because of the availability of standard piping manufactured from a variety of materials, as well as the high pressure rating of the cylindrical section. An initial cost analysis of various materials is given in Table 2.

Table 2 Cost of piping for integral pipe-type solar water heater (excluding connections - October 1977).

Material	Pipe diameter (mm)	Water capacity of unit (l)	Estimated cost (Rand)*
Steel water piping	100 150	85 90	54,3 76,9
High density polyethylene (60°C, 600 kPa)	100 150	83 92	60,7 56,5
Polypropylene (80°C, 600 kPa)	100 150	83 92	87,0 75,60
PVC - not suitable for temperature and pressure.			
Polybutilene - not available at this time			

*at the time of this analysis (1977) 1 Rand = 1 US Dollar

Although plastics have the advantage of superior corrosion resistance, they have the disadvantage of higher costs, extremely high coefficient of expansion, doubtful resistance to ultraviolet degradation and high stagnation temperatures, and do not lend themselves to cheap and simple fabrication by unskilled workers.

It was thus decided to manufacture the unit from steel, hot dip galvanized after manufacture, for the hard water areas in the interior of the country, and either copper or stainless steel for the soft water areas on the coast. Development work has been concentrated on the steel unit. It was also decided to develop two different units, as indicated in Table 3. After manufacture of the first prototype from standard water piping section, a change was made to tubes fabricated from sheet steel.

Table 3 Integral units developed, 1978.

Pipe diameter	Water capacity per metre length of pipe (l)	Water volume per unit projected area (lm^{-2})	Purpose	Materials
100	7,8	78	Quick morning heat up. Lower water volume. Higher temperature. Do-it-yourself applications. Low cost, limited life.	Galvanized steel rain water down pipes. Soldered construction.
150	17,7	117	Normal hot water requirements. Most cost effective.	Fabricated from 1,6mm sheet steel. Welded. Hot dip galvanized after manufacture.

The final design of the larger 150mm unit is shown in Figure 1. A number of changes had to be made to the design as problems were experienced in galvanizing the unit. It was found that certain design details created pockets where the air could collect during galvanizing, leading to unsuccessful zinc coating in these areas. The joint between the 150mm pipe and the manifold especially presented problems. The unit has the appearance of a glazed sheet metal box, as shown in Figure 2.

The development of solar water heaters is progressing along similar lines in other countries (5). A pipe-type unit has, for instance, been developed in India (6).

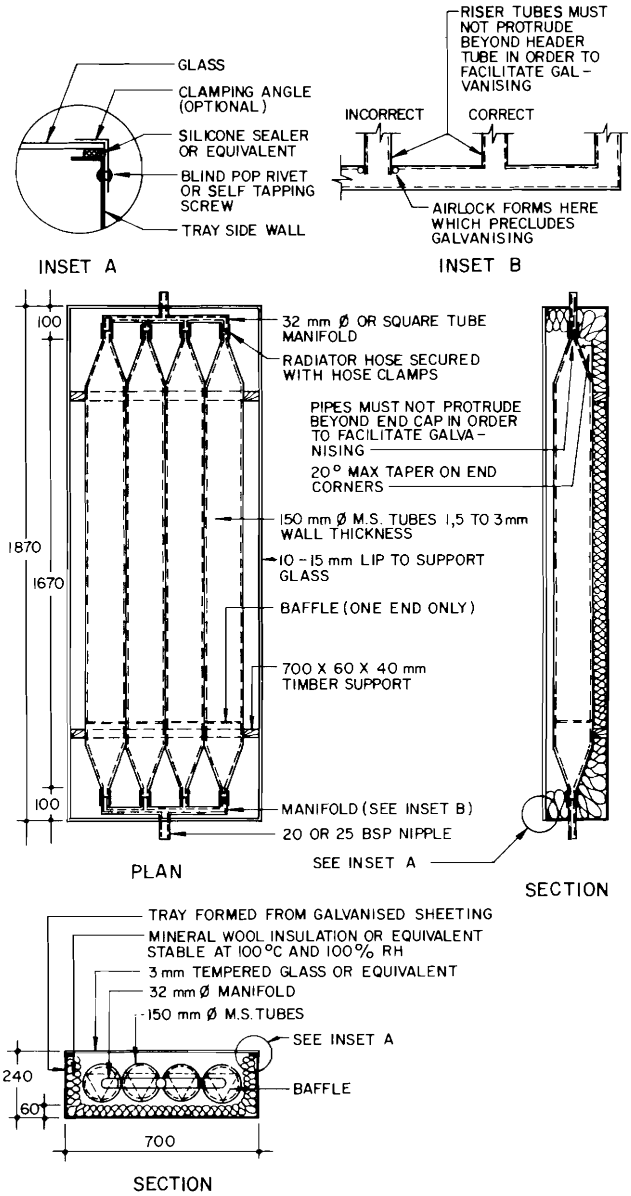

Figure 1. 150mm pipe integral solar water heater

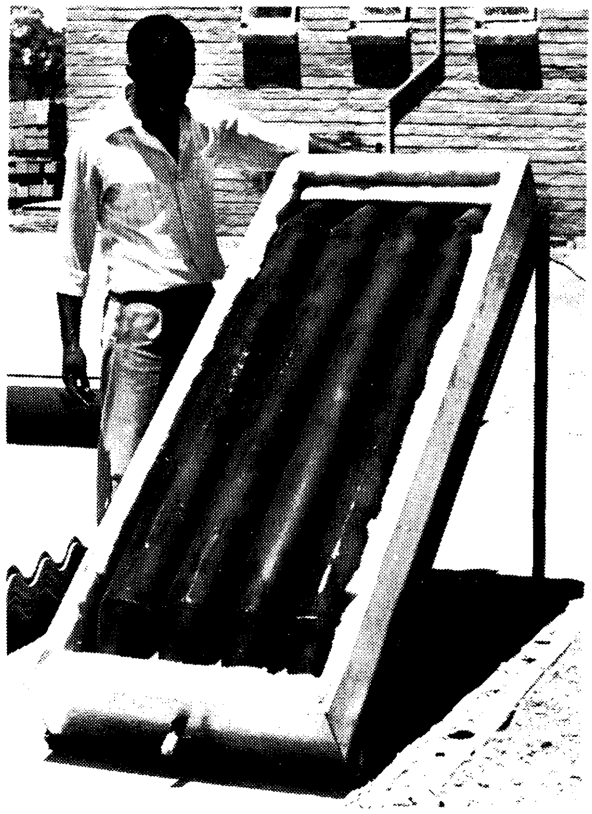

Figure 2. Photograph of integral solar water heater

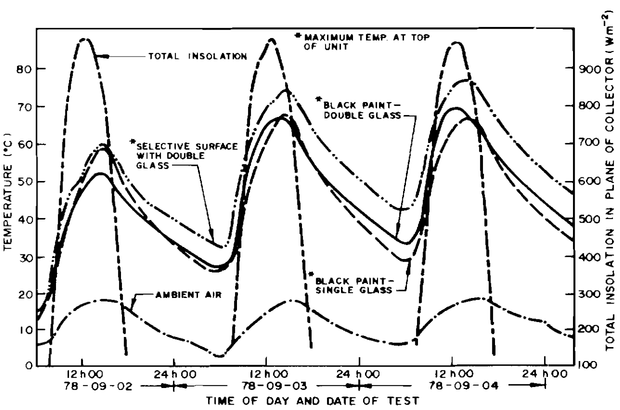

FIGURE 3
Temperature characteristics of different pipe type integral solar water heater

Solar Thermal Performance of the Unit

A number of 150mm units with different glazing and absorber surface finish combinations were tested. The nickel black selective surface was a stick-on film conducive to easy manufacture. Figure 3 shows maximum water temperatures in each of these units as a function of time of day for a three-day fairly cold spell, for the South African climate, with minimum night temperatures of about 4^{o}C, and maximum temperatures of approximately 18^{o}C. No water was withdrawn during these particular tests. For evaluation, units were installed facing due north at an angle to the horizontal of latitude +10^{o} - i.e. 36^{o} (4). The solar thermal efficiencies, based on the daily heating cycle (column 8) and a daily heating and cooling cycle (column 9) for the different collector combinations, are given in Table 4.

Table 4 Solar thermal performance of 150mm pipe solar water heater. Different variations of glazing and absorber surface finish

Cover: Material	Cover: Number of covers	Absorber coating	Mean water temp 08h30 (°C)	Mean water temp 16h00 (°C)	Mean water temp 06h00⊕ (°C)	Mean Insolation ($MJm^{-2}day^{-1}$)	Mean solar efficiency* Day only (%)	Mean solar efficiency* Day+Night ⊕ (%)
3mm glass	1	Matt black paint	21,1	52,7	29,6	19,5	72,2	19,2
Glass reinforced plastic (GRP)	1	Matt black paint	18,3	49,5	ND	21,8	69,9	ND
Transparent acrylic sheet	1	Matt black paint	19,1	43,8	ND	21,0	64,6	ND
Extruded polycarbonate	1	Matt black paint	18,8	47,2	ND	20,8	61,8	ND
Low emissivity glass	1	Matt black paint	18,8	42,3	ND	20,8	51,9	ND
3mm glass	2	Matt black paint	19,1	49,4	29,8	21,0	65,8	22,5
3mm glass	1	Selected nickel	20,0	48,6	30,9	19,9	66,3	24,2
3mm glass	2	Selected nickel	17,7	46,9	31,9	20,0	60,7	29,8

The mean daily wind velocity varied between 2,7 and 6,5 kmh^{-1}. Capacity of unit 105 l. Aperture area $1m^2$.
Insolation levels varied between 8,3 and 22,7 MJm^{-2}.
⊕ Calculated and interpolated using data from full day heating and heat loss test.

$$* \text{ Efficiency} = \frac{\text{Total energy absorbed by the water and collector during the period}}{\text{Available insolation in the plane of the collector}}$$

ND = Not determined

Table 5 Solar thermal performance of pipe type integral units

Pipe diameter (mm)	Season	Supply water temp. (°C)	Number of litres of hot water at a temperature higher than: 40°C (l)	50°C (l)	60°C (l)	Water temp. at 14h00 Mean (°C)	Max. (°C)	Average wind speed (kmh^{-1})	Total solar radiation ($MJm^{-2}day^{-1}$)	Mean daily efficiency (%)
100	Summer	25	57	55	45	68	71	7	23,2	55
150	Summer	25	105	80	30	59	63	7	23,2	68
100	Winter	18	55	46	10	56	61	0,8	18,1	60
150	Winter	18	78	37	0	48	56	0,8	19,3	72

From Table 4 it can be seen that the daytime thermal performance of the single glazed collector is the best, but it is the poorest when the night heat loss is also considered. Because of the additional cost, maintenance and manufacturing complications of double glazing and selective surfaces, it was decided to proceed with a single glazed matt black painted pipe integral unit. The solar thermal performance of the latest design of both the 150mm and 100mm pipe diameter units is shown in Figure 4 and Table 5. The volume of water above 40°C at 16h00, as indicated in Table 5, is especially significant, as this is the minimum temperature at which hot water is generally required for domestic purposes. Although Figure 4 illustrates virtually a worst case winter condition, it can be seen that 40°C water is available in the 100mm unit up to 21h00 and in the 150mm unit up to 17h00. Morning heat-up for the 100mm unit is rapid as water at 40°C is available from 11h00 onwards.

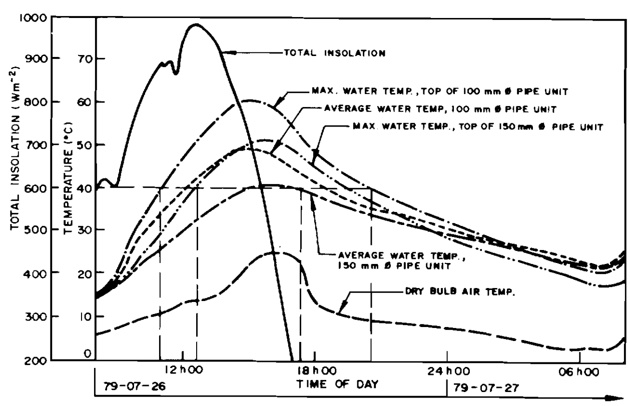

FIGURE 4

Temperature characteristics of different pipe types integral solar water heaters

Installation

For best all year performance the unit should be installed where it will receive direct sunlight from 09h00 to 15h00, at an angle to the horizontal of latitude +10°. The unit should face within 45° of true north in the southern hemisphere.

The following connecting procedures are possible:

1 As a 'push-through' system;
2 Supplied from a break pressure tank, with the tank approximately 1m higher than the highest hot water drain off point (shower head);
3 Directly from mains if the mains pressure cannot rise above 300 kPa;
4 Directly from mains through a pressure control valve for higher pressures. An expansion/pressure release valve must be installed in the cold water line.

In all cases, high points where air can collect and form airlocks, must be avoided. The 100mm unit has been pressure tested and starts deforming and leaking at 500 kPa, whilst the 150mm unit showed no distress at this pressure.

Operational experience

Tenders for the supply of 50 of the 150mm units, manufactured from steel and subsequently galvanized, were called for during 1979 and a contract was awarded at a price of R145* per unit. These units were installed on low income houses in different parts of the country to evaluate their performance, durability, acceptability and user reaction.

Despite the fact that these were used under temperatures of well below zero, no problems have to date been experienced with freezing. Ordinary 3mm glass has proved to be unsuitable in areas with a high incidence of hail with stones over 20mm. In these locations, 3 or 4mm tempered glass, or at least 5mm ordinary glass is recommended.

A commercial organisation is at present tooling up for the manufacture of this unit in a super-ferritic grade of stainless steel. Due to volume manufacture it is not expected that the cost of the unit will be much higher than the cost of the existing galvanized steel unit.

Great interest has been shown in using the integral unit as a preheater to a conventional water heating installation, because of its simplicity and low cost, although it was not developed for this purpose. When this type of application is being considered, maximum utilization of the unit is obtained only if the heated water is admitted to the normal storage tank between the hours of 12h00 to 20h00. To get the full benefit, the user will have to arrange consumption of hot water in such a manner as to ensure the transfer of the solar heated water to the conventional storage tank before 20h00.

Cost

The present total estimated energy costs of heating water in this manner are given in Table 6, from which it will be seen that the corresponding unit energy cost of the 150mm pipe unit is about 40 per cent less than that of the 100mm unit. This is due to the lower all year efficiency of the latter - 60 as against 70 per cent, and the relatively small difference in capital cost.

The cost of electricity for domestic consumers at present varies from about 2,8 cents* per kWh in Pretoria to 3,56 per kWh in Cape Town, which means that solar heated water can be provided at a much lower unit cost than electrically heated water if the unit lasts for 10 years or longer. It is considered that a 10-year life will be attainable in most parts of the country.

For a strict comparison of costs, the capital and installation costs of the electric geysers should have been added to the cost of the electricity, but this was not considered necessary for this paper.

Table 6 Equivalent energy cost of heating water by means of pipe type integral solar water heater

Location	Mean annual insolation on plane of collector ($GJm^{-2}a^{-1}$)	Water heating energy utilized (kWh)		Equivalent total cost of energy (c/kWh)			
				5-year life		10-year life	
		100mm	150mm	100mm unit	150mm unit	100mm unit	150mm unit
Cape Town	7,1	634	1 104	4,7	3,3	2,4	1,6
Durban	6,4	571	995	5,3	3,6	2,6	1,8
Pretoria	7,7	687	1 197	4,4	3,0	2,2	1,5

Based on an annual utilization of 80%

* 1 Rand = 1,2 US Dollars.

* 1 Rand = 1,20 US Dollars; 1 Rand = 100 cents

Conclusion

The low cost pipe unit developed by the NBRI is suitable for developing regions where electricity is not available. Even where this is provided, it can result in considerable savings of electricity.

Further development work on materials, performance, cost reductions by means of mass production, in-use monitoring and promotion of these units is, however, necessary.

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Advanced dehumidifiers for moisture control

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Summary

The importance of energy lost through ventilation grows as the fabric insulation levels improve in houses. In temperate climates, such as Britain's, this ventilation factor is closely related to the moisture generation and temperature within the house. The energy implications are complex and the ventilation rate is difficult to control in practice.

An alternative method of achieving moisture control is by means of a small heat pump. This has the potential to condense the moisture in the air and hence transduce its latent heat into useful sensible heat. This means that cool, damp air can be turned into warmer, drier air. Commercially available equipment is reviewed and design improvements examined. New designs incorporating a counterflow air/air heat exchanger enable units to have twice the present efficacy. This development offers a new approach to moisture and ventilation control.

Résumé

Déshydratants avancés pour contrôler l'humidité

L'importance de pertes énergiques à cause de ventilation croît ainsi que le niveau d'isolation matérielle des maisons s'améliore. Dans les climats tempérés tels que de la Grande Bretagne, ce facteur de ventilation se lie étroitement à l'engendrement d'humidité et la température à l'intérieur de la maison. Les implications énergiques sont complexes et la taux de ventilation est difficile de contrôler en pratique.

Un autre méthode de contrôler l'humidité est par moyen d'une petite pompe de chaleur. Celle-ci peut condenser l'humidité de l'air et puis de transformer la chaleur latente en chaleur utile et sensible. Ce veut dire que l'air frais et humide peut se transformer en air plus chaud et plus sec. On revoit les installations qu'on peut obtenir à présent, et examine les améliorations de dessein. Desseins nouveaux qui comprendent un contre-courant air à air échangeur de chaleur permettent les installations d'avoir deux fois l'efficacité actuelle. Cette innovation présente une approche nouvelle à l'humidité et la contrôle de ventilation.

Introduction

Space heating energy is lost through two routes. These are by conduction through the fabric and by infiltration of cold air displacing the warm inside air. Heating loss design procedures calculate with precision the heat conducted through the building fabric. The ventilation rate is arbitrarily assumed to be around 1 air change an hour and thereafter neglected. In present designs only 25-30% of the design heat loss is attributed to ventilation and therefore large errors can be tolerated without affecting the success of the heating installation. However, this situation is changing. Increasing use of thermal insulation is lowering the fabric heat loss and making the ventilation loss a much larger proportion of the total. In well insulated houses the arbitrary ventilation allowance can account for over half of the design day heat loss (1) (figure 1).

This ventilation term now becomes important for two reasons. The first is that the actual infiltration rate in a house will have a large effect upon the energy consumption. Field measurements (2) suggest that infiltration under standard weather conditions can vary from 0.2 air changes an hour to 1.6. The second reason is that the user's own ventilation habits will also have a dramatic influence on energy consumption (3). While the occupants can identify inadequate

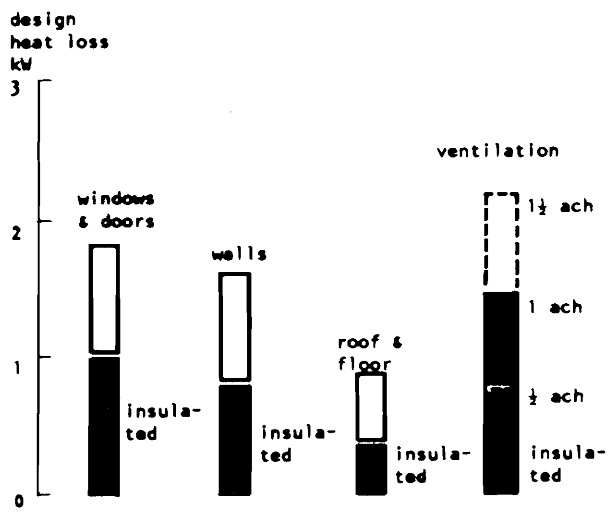

Figure 1. Relative magnitude of heat losses 0°C outside: 20°C indoor 90m² semi-detached house.

ventilation through odours or dampness, they have no way of identifying excess ventilation.

Ventilation needs

Fresh air is needed in a house to dilute both the odours and moisture generated within the house to an acceptable level. Odours are normally body odours and cooking smells and are defined prescriptively by experience. Moisture criteria are normally defined in terms of relative humidity. Below 40% R.H. the risk of static electric shocks and the increasing frequency of dry throats is reported. Above 70% R.H. organic materials tend to become damp and mould can develop on them. The quantity of air needed to control this moisture is, for any given temperature, a simple function of the outdoor vapour pressure and the internal moisture generation rate inside the house. In mild, temperate climates such as Britain's, the outdoor humidity runs just under saturation for the whole of the winter (4). It is approximately 90% R.H. as illustrated in figure 2. The

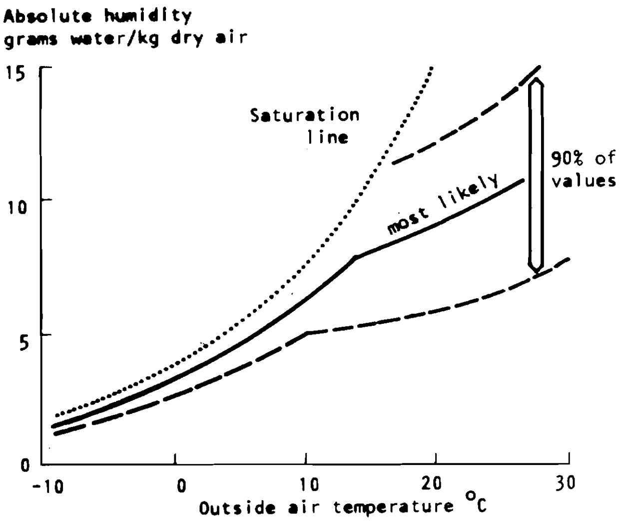

Figure 2. Variation of humidity with outdoor temperature in Britain.

moisture generation rate in Britain is estimated to be 7 kg/day on average for a five-person household but doubling on washdays where the clothes cannot be dried out of doors (5). In a normal day the biggest single moisture source is cooking. Between 1½-3 kg are linked to mealtimes. Almost 2 kg is the relatively gentle perspiration from the house occupants themselves. Small, intermittent loads, such as baths and dish washing make up the rest. Since this internal moisture generation is relatively constant throughout the year then the ventilation required to dilute it will be inversely linked to the outdoor vapour pressure. To maintain a relative humidity of 60% at an average house temperature of 17°C will require a fresh air supply which varies with the outdoor temperature. This is illustrated in figure 3.

Reducing the ventilation needs

The alternative method of controlling the moisture in a house is to dehumidify the air. Water will condense

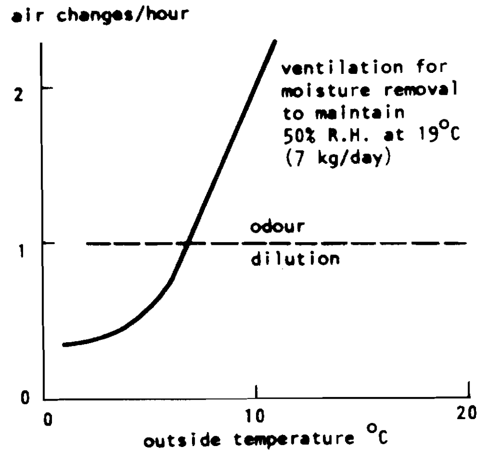

Figure 3. Ventilation needs for moisture and odour control.

out of air cooled below its dewpoint. Vapour compression heat pump refrigerant cycles can be used to achieve this as shown in figure 4. The air is cooled by the evaporator coil, the moisture condenses out and the latent heat of evaporation is transferred into the refrigerant in the evaporator. The same air then continues and passes over the condenser coil. Here the heat from the evaporator, together with that from the compressor, is returned to the air. Cool, damp air can therefore be converted into warmer, drier air. The latent heat

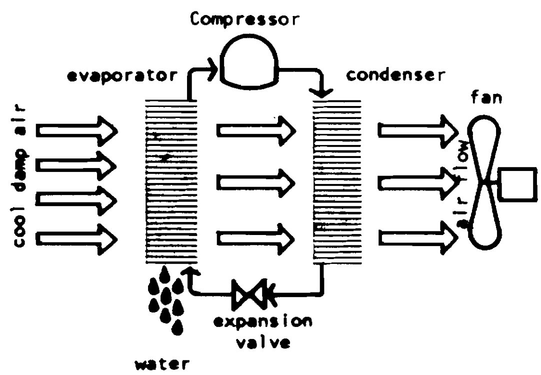

Figure 4. Simple vapour compression dehumidifier

of the moisture is used to provide sensible heat to the air. This means that a small heat pump dehumidifier will provide more heat than the electrical energy it uses (6). Its effective coefficient of performance will be around 1.2. Small portable units working on this principle are used in large quantities in Italy, Japan and the USA. Typical performance would be 3-4 kg of moisture extracted per day for a 300W machine.

Design analysis suggested that significant improvements in water extraction effectiveness could be achieved if the heat pump was combined with a heat exchanger (7). This is illustrated in figure 5. A large

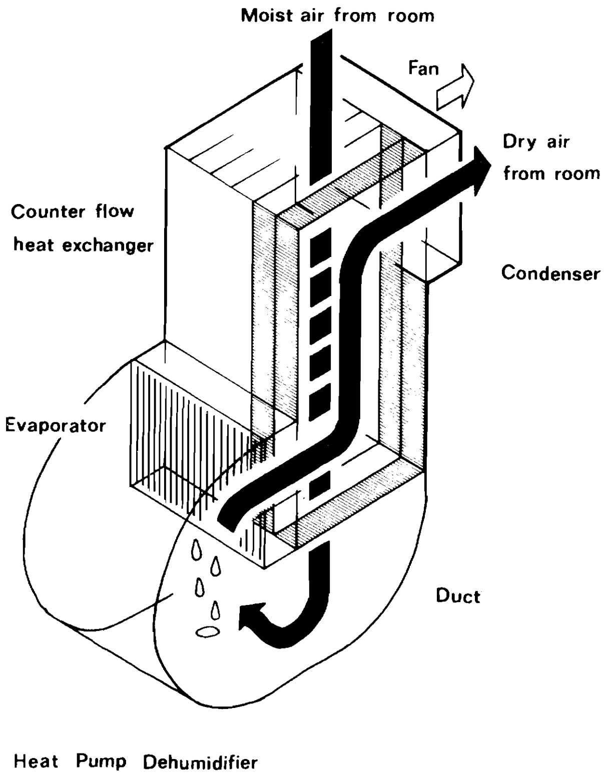

Figure 5. Diagrammatic illustration of the advanced dehumidifier.

part of the heat exchange is achieved by an air to air counterflow heat exchanger. In this arrangement, the bulk of the heat transfer is done by the static heat exchanger, enabling the extraction capacity of the heat pump cycle to be improved. Computer model predictions estimated that such a geared dehumidifier could have approximately three times the moisture extraction capacity and twice the effectiveness of conventional equipment. A prototype model has been constructed which successfully validated these predictions during environmental chamber tests. A comparison of the relative performance of the advanced unit is given in figure 6.

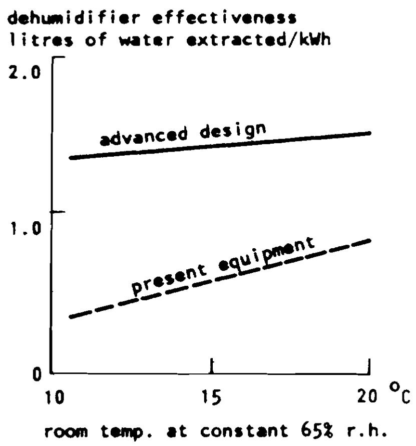

Figure 6. Performance effectiveness of the advanced dehumidifier.

Conclusion

Ventilation control becomes progressively more important as fabric insulation improves. The ventilation needs in temperate climates are partly for odour control and partly for moisture control. The actual values for moisture control vary with outdoor moisture and hence temperature. Crude ventilation control such as opening windows can only be wasteful. The alternative is a small, vapour compression, heat pump dehumidifier. Such machines are already in widespread use in Italy, Japan and the USA. The performance of such units can be significantly improved by the addition of a counterflow, air to air heat exchanger. Such a design has three advantages. The first is that it is less dependent upon the room temperature conditions and will work well in cool rooms such as in Britain. The second is that the moisture extraction capacity for a given compressor can be trebled, and finally the effectiveness of water extraction in terms of litres/kWh can be doubled. This means that the coefficient of performance of such a heat pump can be increased from 1.2 to around 2.

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Low Energy Building Design

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Summary

Low energy building design is important if ambient energy sources and free heat from people and processes are to be effectively used and thus reduce the demand for fossil fuels. Thermal insulation alone is not the answer. A combination of passive and active environmental control methods are necessary if energy collection and distribution are to be efficiently arranged in space and time and provide a comfortable environment for people. A low energy house is proposed which uses a heat pump to distribute solar and free energy via a thermal storage wall to the space; a heat pump may not be necessary in other climates for other built forms.

Sommaire

Il est important d'établir les plans de bâtiments qui requièrent peu d'énergie, si l'on doit utiliser à bon escient les sources d'énergie ambiante et la chaleur produite par les gens et leurs activités, et ainsi réduire la consommation de combustibles fossiles. L'isolation thermique en elle-même n'est pas suffisante. Il faut combiner des méthodes de contrôle du milieu, qui soient à la fois passives et actives, si l'on veut distribuer efficacement le captage et la répartition d'énergie par rapport à l'espace et au temps, et offrir aux gens un environnement confortable. On propose une maison à énergie réduite quit utilise une thermopompe pour distribuer dans l'atmosphère l'énergie solaire et produite par l'activité humaine, au moyen d'un mur d'emmagasinage thermique; il se peut qu'une thermopompe ne soit pas nécessaire sous d'autres climats ou pour différents types de constructions.

Buildings as Energy Systems

The world has a finite supply of fuels, as more become used the economic laws of supply and demand raise prices and limit availability. Ideally zero energy buildings are required, leaving the fuels available for industrial, chemical and transportation purposes and for a fairer distribution of them around all the countries of the world. It is sometimes argued that highly insulated buildings carry high energy costs in the manufacture of suitable materials, Herman (1975) (1) but this has to be balanced against the life cycle costs for operating the building and the fact that fuel costs are rising at a faster rate than insulation costs - but insulation alone is not the only important aspect of energy conservation. Natural ventilation energy losses are high, these may be reduced by employing tighter forms of building construction although this demand comes at a time when the standard of workmanship is not generally high.

The average annual net energy consumption of a UK house is 22500 kWh (81 GJ) per year (see BRE Current Paper 56/75). These figures can vary widely depending on the climate, the way in which people use the house and the heating system. Work by Ellis and Gaskell (1978) (2) has shown that there is a considerable spread of energy usage in houses having the same fabric heat loss. In well-insulated houses the 10% highest energy users may consume 2.5 times more energy than the lowest energy users, but in poorly insulated houses this variation may be nearly three times higher.

Buildings soak up heat from or emit it to the surroundings and the efficiency for this process can be likened to that of a heat pump. They may be designed to be isolated from the external climate and reflect incident energy back to the surroundings or to collect ambient energy and use it. At the time of collection the energy may not be required and controllable time delays have to be placed in the system.

Available Sources of Energy

Piped Energy

Coal, electricity, gas, oil and wood must be compared on a basis of useful heat output per unit cost. That is to say effective fuel costs depend not only on source but also on conversion efficiency. Electricity may be cheaper to use than natural gas if a heat pump with a COP of 3 is achieved. The choice of heating system, however, depends on capital and running costs besides other factors such as thermal response, flexibility in layout and control, reliability and maintenance.

Solar Heat

This comprises gains to the building via direct radiation through the glazing. Also it encompasses the heat gains from solar energy transmission through the building fabric, together with gains from active and passive solar collectors if used.

At a latitude of 53.3^{o}N the daily mean solar irradiation on a south facing sloping roof varies from 0.5 kWh/m^2 (December) to 4.5 kWh/m^2 (June), Siviour (1978)(3). In low energy buildings this is worth collecting. Air solar collectors allow both the heat collecting and building construction to be easily integrated. There are no freezing problems as there are with water; air collectors have a fast response but need more space for the circulation ductwork system.

Free Heat

The free heat is contributed by the occupants, lighting, cooking, domestic hot water, electrical appliances and processes within the space. In a highly insulated building these sources are significant and can partly offset the heat losses. Energy from people (about

3-5 kWh per day for a normal family), lighting, cooking, appliances (about 10-15 kWh/day) and hot water (5 kWh/ day in use losses and waste heat recovery) contribute nearly 5000 kWh per year of free heat. A detailed survey of data concerning free heat sources has been made, Siviour (1978) (3).

Waste Hot Water

An average household consumes domestic hot water at a rate of 120 litres per day at 55°C. In energy terms this amounts to about 2500 kWh (9 GJ) per year at the tap; some families will use three times as much hot water as this. It is reasonable to assume that at least half of this heat is lost down the drain; 1250 kWh per year is worth recovering when the net space heating requirements of the house are 4000 kWh per year and perhaps even on hot water heat requirements alone. Work at the Building Research Establishment has used a heat collecting tank containing the evaporation coil of a heat pump, the condenser and the compressor of which are mounted in the conventional hot water cylinder. Initial trials at BRE give heat pump coefficients of performance ranging from 3 to 4.2 for temperature differences between cylinder and collector or 36 to 12°C respectively Warren (1979) (4).

Heat Pumps

These make effective use of heat in the air or the water in the vicinity; their use to supply heat to buildings could save about 7% of the UK primary energy consumption (BRE Digest 191, 1976). When the heating requirements of a building are very low, heat pumps become most effective because the yearly variation in COP will be less; preheated air will decrease this even further.

Low Energy Buildings

The effective use of alternative energy sources depends on the energy consumption of a building being significantly reduced. The performance of three houses are shown on Table (I) and further analysed in Figure (1).

It can be seen from Figure (1) that as the degree of insulation increases:

a) the slope of the heating load bands decrease, showing that well insulated buildings are less influenced by climatic temperatures;

b) the heating season contracts because the heating load bands cross the thermal balance line further to the right (i.e. deeper into the winter);

c) the range of the heating load bands, for any given number of degree days, decreases. This indicates that the thermal behaviour of this type of building becomes more predictable as its energy consumption is reduced.

Table (I) Net Space Heating Demands (33 week heating season)

Construction and air changers/hour	Building Element	'U' Value ($W/m^2\,^oC$)	Net Space Heating (kWh/year)
Standard House	Window	5.7	16500
(2.0 a.c.h)	Wall	1.0	
	Roof	0.6	
	Floor	0.6	
Insulated House	Window	5.7	12000
(1.5 a.c.h)	Wall	0.5	
	Roof	0.6	
	Floor	0.6	
Well Insulated	Window	2.8	4100
House	Wall	0.3	
(0.75 a.c.h)	Roof	0.3	
	Floor	0.3	

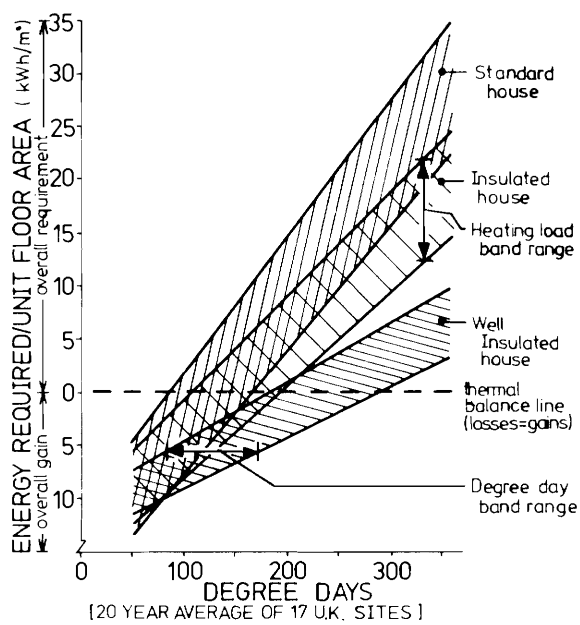


Figure 1
Heating Load Bands for 3 house constructions (detailed in Table I)

Energy Balance Equation

Ideally the energy balance for a building should be:

Fabric loss + ventilation loss $\leq$ ambient energy + free heat (1)

This equation shows that for a given temperature criterion the choice of materials, the air tightness of the building, the regional climate and the use of the building all interplay to dictate the amount of extra energy that has to be provided ultimately by fossil fuels.

During the night there are little free heat gains and no solar gains. This emphasises the importance of designing the structure to combat the effect of cold nights, or collection of cold dark days, by introducing time lags into the building fabric and including internal surfaces of sufficient thermal capacity to give a "flywheel effect". To utilise the output of solar collectors during these periods one requires an easily accessible storage system combined with output regulation control.

The equation is also important because it shows that when there is an energy balance the choice of fuel can be made in a more flexible manner because the differences between fuels become less important when the building is less dependent on them.

For effective low energy buildings, the distribution and storage of energy is an important as its collection. Using passive systems, the building envelope has an important role to play in controlling these funtions.

The energy balance equation can be expressed as:

$$\Delta\theta \left[(\Sigma(AxU) \times 10^{-3}) + (Vx0.33xn) \right] \leqslant \frac{F + S}{24} \quad (2)$$

where:

- $\Delta\theta$ = design mean temperature difference (^{o}C),
- A = area of external building fabric (m^2)
- U = 'U'value of external building fabric (W/m^2 ^{o}C)
- V = internal volume of the building less 10% dead space (m^3),
- 0.33 = kWh required to raise 1 m^3 of air through 1^{o}C (kWh/m^3 ^{o}C)
- n = number of air changes per hour (hours $^{-1}$)
- F = average free heat per day from miscellaneous gains during heating season (kWh/day)
- S = average abmient energy gains per day from direct solar radiation into space, glazing and the building fabric, together with input from active and passive solar collection systems (kWh/day)

Passive Environmental Control

Over the ages man has used his ingenuity to make his habitat safe, warm and weather protected. Troglodytic architecture sculptured out of the hillside landscapes of Morocco; the igloo of the Eskimoes; African courtyard houses; the Malaysian tree dwellings and even the English thatched cottage all have features which aim to orientate, to shape buildings and to contruct them from materials so that the inhabitants are comfortable during the hot or cold rigours of the regional climate. These features are the essential ingredients of passive environmental control where the building rather than the equipment primarily controls the internal environment. Whereas active systems have the disadvantages of heavy duty plant and complex networks to distribute hot and cold fluids; produce noise and require both maintenance and plant space.

The Trombe wall allows winter sun to warm the airsteams circulating around the room whilst in summer the airstreams carry room heat away and the wall acts as a solar barrier. Heavy floors or walls permit energy to be stored and may even have channels for night air to pass through them and cool the building down, whilst the mass not only attenuates but retards the maximum summer heat so that it does not occur when the people are working.

Buildings can collect, store and distribute ambient energy using simple princples such as gravity forces to circulate air, mass to delay and alternate heat flow, built form to protect from the sun but to encourage breezes to pass through the interior.

The building time constant T, for a given material thickness is defined as:

$$T = \frac{\text{material properties (product of mass and specific heat)}}{\text{heat flow/degree temperature difference}} \quad (3)$$

For passive control, buildings should have a value of T which not only exceeds the occupancy period for the building, T_O, but is also longer than the likely minimum time period for the lowest and highest temperature changes (T_W, min) so that $T_O < T > T_W$, min. This inequality expresses the important balance between selecting building materials whilst taking into account building use and the regional weather pattern. Some current and future trends in passive environmental control are now described which reduce the energy requirements and also the heating and the cooling plant by allowing the building structure to act as a dynamic environmental control.

Hollow Block Ventilated Floor

Outside air is passed down a hollow block floor so that the external daily temperature curve is attenuated by the mass of the floor to give a comfortable supply temperature; background heat may need to be supplied in winter. In summer night air can be used to give cooling. No ducts or suspended ceilings are necessary for heating and cooling services. Noise and air movement characteristics are good. Economic studies have indicated that a 2-3% reduction in total building cost is possible and the refrigeration load will be reduced by about 70% Isfält(1979) (5). Figure (2) shows the principle of the hollow block ventilated floor system.

Recent studies by Södergren (1979) (6) on an office block (Sollentuna Local Authority near Stockholm) have shown that the temperature in a space is strongly affected by the floor temperature. By using airways in concrete floors and the airspace in double glazing for distributing warm air or cool air heat gains can be used effectively, heat losses can be reduced, and the concrete floor can also be used to delay the transfer of heat to or from the room.

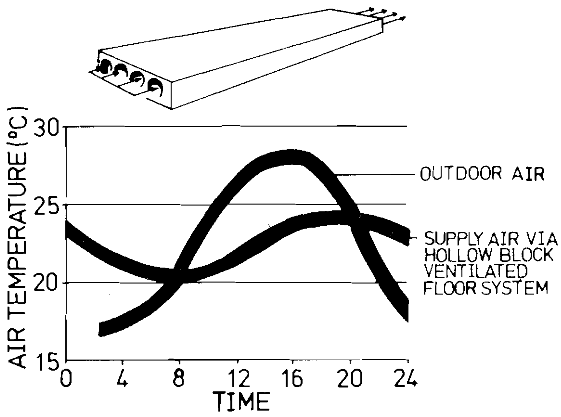


Figure 2
The Principle of the Hollow Block Ventilated Floor System

The basic principle is designing the building so that the winter heat losses throughout the occupied and unoccupied periods are balanced by the heat gains; in summer night air circulates through the floor slabs to cool the building down and so balance the daily heat gains collected and stored in the slab.

If the floor slab is assumed to be affected only by air passing through the airways (whereas in reality disturbances at the floor-ceiling surfaces are superimposed) it is possible to determine the temperature variation of the outgoing air assuming a sinusoidal input temperature function.

The damping factor (Z) and the time lag (ø) of the output temperature function have been found by Isfält (1979) (5) to depend on the two dimensionless numbers: -

$$\frac{hA}{Gc_p} \quad \text{and} \quad \frac{Gc_p}{\omega mc} \qquad (4)$$

where h = the film coefficient ($W/m^2\,^oC$)
A = are of the hole surfaces (m^2)
G = air mass flow per time unit (kg/s)
c_p = specific heat capacity of air (kJ/kg^oC)
m = mass of the slab (kg)
c = specific heat capacity of the slab material (kJ/kg^oC)
ω = angular velocity of temperature variation (radians/s).

Figure (3) shows curves for constant damping factor (Z) and time lag (ø) (for 24 hour variations 360^o = 24 hrs) as functions of these dimensionless numbers.

In order to obtain an effective system the parameter combinations have to be chosen with care. For an angle lag less than 60^o (corresponding to a time lag of 4 hrs for a 24 hour variation) the lines of constant damping factors fall rapidly and so to be effective the combination of parameters in a system should fall to the right of the curve ø = 60^o. Isfält regards a damping factor Z = 3 as a lower limit for an effective system. Combinations below the curve Z = 10 correspond to extremely heavy structures with low airflow rates (e.g. a Cathedral) and are not of interest here. A zone of effective parameter combinations can be seen on Figure (3) outlined by a heavy line.

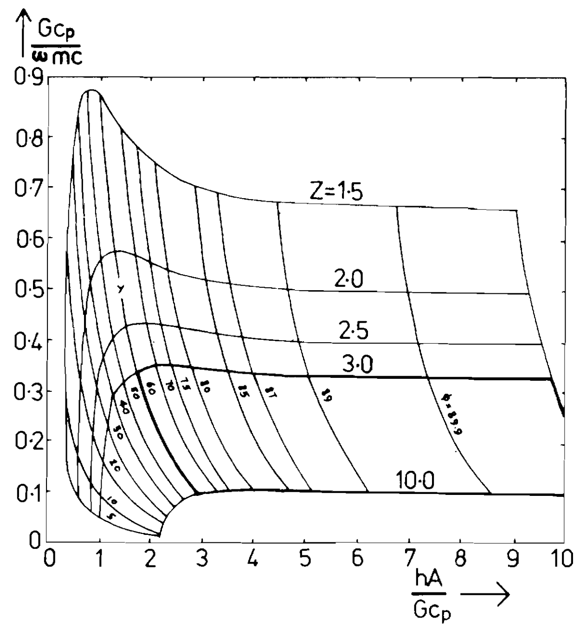


Figure 3. Damping Factor Z and Angular Lag ø in dimensionless representation for Hollow Block Floors (Isfält 1979) (5).

Airvent Window

Heating and cooling loads are reduced by letting an airstream (10-20 l/s per m width) pass between two glass panes. The 'U' value will be in order of 1-2 $W/m^2\,^oC$ depending on the airflow rate. Warm extract air is removed via the window and discharged or recirculated remembering that ventilation rates up to about 4 air changes per hour have a very significant effect on reducing heat gains. In winter the glass surface temperatures are increased; in summer heat in the space is removed whilst air movement is provided. The total heat flux through the structure is reduced and significant decreases in environmental services plant will result. Figure (4) illustrates the window and shows the expected thermal performance Södergren (1973) (7).

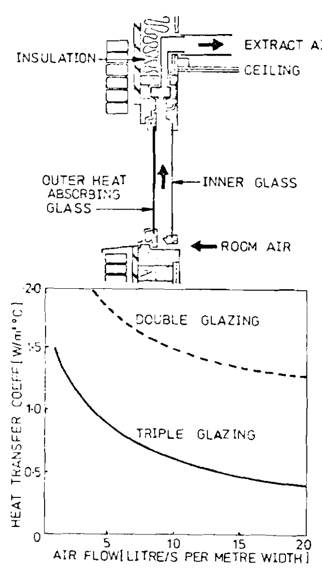


Figure 4. Airvent Window. Heat Transfer as a function of extract air flow, from full scale model tests. (Södergren 1973) (7).

Thermic Controls

Structures can be designed to behave like thermic diode valves. By sandwiching a thick storage layer between two layers of high thermal resistance, and using water to separate the layers, heat can be conducted from one outer layer to the other outer one or alternatively can be stored in the sandwich. This heat flow can be controlled by a thermic oil pressure valve linking the water layers each side of the storage layer (Buckley (1978) (8) and Fig. (5)). Room heat or external heat gains are utilised and by incorporating some air ducts, independant control of the radiant and convective components can be achieved. Domestic hot water distribution can be incorporated into the system.

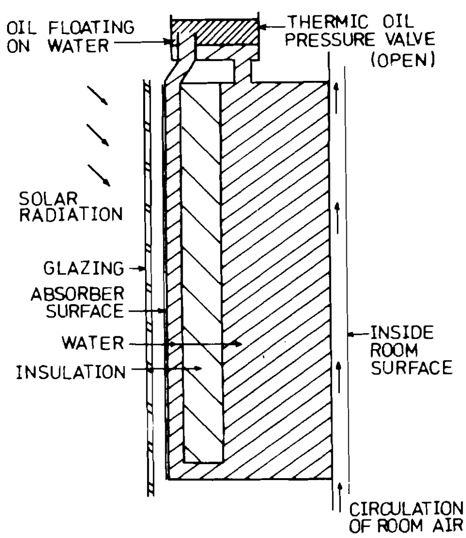
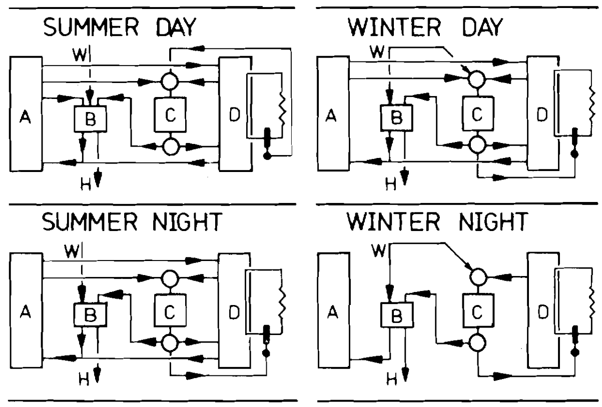


Figure 5. Thermic Oil Pressure Valve in Thermic Storage Wall (Buckley 1978) (8)

These systems offer the possibility of directly transmitting, or delaying, the heat flow to and from a space through opaque or transparent building structures besides using natural radiant (solar) or convective (air) heat sourses, and decreasing considerably the traditional plant, piping and ducting networks.

In the experimental low energy house design, shown in Figure (6), passive environmental control is achieved by roof and wall solar collectors plus an internal mass wall (or floor) for distributing and storing heat.



KEY:

A	Ambient energy collection
B	dhw/heat pump pre-heat cylinder
C	Heat pump(s)
D	Mass storage wall/floor
H	Feed to dhw cylinder
W	Energy input from waste hot water
O	Heat pump input/output selector
→	Direction of energy flow
⌇	Warm air space heating/cooling
▮	Heating/cooling coil in room supply air

Figure 6. Environmental Control System for an Experimental Low Energy House.

Microprocessor technology is to be applied to control the system, which until recently would have proved prohibitively expensive.

Ranking Energy Conservation Strategies

Heap (1979) (9) describes a simple ranking procedure using an energy return factor, R, defined as: -

$$R = \frac{E}{M + \frac{C}{L}} \qquad (5)$$

where R = energy return factor (kWh/£)

E = annual energy saving (kWh)

M = annual maintenance cost (£)

C = purchase cost (£)

L = lifetime (years)

The reciprocal of R may be compared directly with present or expected fuel costs. If R^{-1} exceeds the fuel cost considered then the energy conservation measure will not be cost effective.

Low Energy House Design

Objectives

Conservation of energy by reducing amount of energy required and using ambient energy and free heat sources wherever possible.

Emphasise passive environmental control so that the external climate is modulated through the structure, form and building envelope.

Satisfactory environmental conditions - low total cost by reducing equipment and distribution costs, decreasing fuel consumption and plant maintenance.

Solution

- Emphasise passive environmental control; minimise the use of active systems; use the energy balance equation to evaluate the balance of materials needed for climate and building type.
- Utilise as much of the building for collecting, distributing and storing energy as is practically possible.
- Select building materials and constructions with insulation and thermal response as important factors; distribute high mass storage walls, floors and internal walls appropriately.
- Link active system design with passive control system; consider heat pumps and combined heat power schemes where possible; evaluate response of convective and radiant methods of heating spaces.
- Orientate buildings between SE and SW; loss in solar efficiency is within 8% of south facing building Lakmaker (1979) (10).
- Optimise angles for solar collectors inclined to the horizontal Lakmaker (1979) (10).
- Use landscaping to provide wind relief around buildings; wind tunnel tests will be required.
- Space buildings to avoid overshadowing Ó Catháin (1979) (11).
- Housing is more energy efficient in terraced rather than detached or semi-detached forms Nelson (1979) (12).
- Facade design can help to give solar and wind protection.
- Maximise glazing on SE to SW faces
- Use maximum overall thermal transmittance of U = 0.3 W/m^2 ^{o}C for roofs, walls and floors; provide insulating shutters for windows where applicable.
- Reduce infiltration to a minimum by draughtstripping of all opening lights and external doors, but provide small on-off fans to give ventilation where necessary for vitiation and condensation control.

These measures determined the form of the experimental house described below, which could be constructed using present building methods and technology:

Experimental Low Energy House

Two storey semi-detached 5 P dwelling with internal floor dimensions of 6 m x 7 m:

Construction

- External wall, 'U' value = 0.3 W/m^2 ^{o}C

Construction to give a wall with a time lag of over 8 hours and an internal leaf of high thermal capacity. Some parts may incorporate air solar collectors.

- Windows, 'U' value = 2.8 W/m^2 ^{o}C

Standard double glazing with insulation filled frames incorporating a thermal break, frames having adjustable ventilation slots.

- Floor, 'U' value = 0.3 W/m^2 ^{o}C
- Roof, 'U' value = 0.3 W/m^2 ^{o}C

Incorporating air solar collectors.

- Weatherstripped external doors and openings.
- Internal storage walls 300-400 mm dense concrete with prefabricated air circulation channels; insulated externally with 50 mm insulating material plus surface finish.

General Concept

The integrated energy system for the dwelling consists of a passive-active environmental control system illustrated in Figure (6). An array of roof mounted air solar collector panels are incorporated in a closed system which circulates air via a small fan through the internal storage wall. In winter, warm air will be circulated using free heat and "back-up" heat supplies, together with a waste-water heat recovery system. In summer, cool night air will be circulated to cool the store and hence balance the daytime heat gains.

A second small fan supplies fresh air to a diverting box. This directs the air through insulated or uninsulated airways in the internal storage wall, depending on the extent of the heating or cooling effect desired. The air is then supplied to the spaces at high or low level via a small "back-up" heating coil for use in extreme conditions.

The introduction of 0.04 m^3/sec (0.75 ach) fresh air is adequate for vitiation and condensation control, but local extract is required in moisture producing areas, e.g. the kitchen. The pressurisation of this well-sealed building will lessen the extent of natural infiltration and the required "leakage" from each space can be fine-tuned by adjustable air slots in the window frames.

Energy Balance for the Heating Season

Using a mean temperature difference of 10°C and a heating season of 26 weeks, as suggested by Figure (1) the energy balance is as follows: -

Fabric Loss	- 4491 kWh
Ventilation loss	- 2043 kWh
Domestic Hot Water	- 2500 kWh
Free heat + solar gains (25 kWh/day x 70% ultilisation factor)	+ 3185 kWh
Solar heat from solar collectors and heat store	+ 2200 kWh
Balance:	- 3469 kWh

Solar heat is calculated for 40 m^2 of roof mounted solar collectors, orientated SE/SW with 40% efficiency and 70% utilisation factor. Average solar radiation per month taken as 120 MJ/m^2. (1MJ = 0.278 kWh). Solar heat = solar radiation x area of collectors x collector efficiency x utilisation factor, (kWh) = (kWh/m^2) x (m^2).

The balance of "back-up" energy required is 3649 kWh/ year. This can easily be provided by one air source heat pump using off-peak electricity. One water-air heat pump may be used for heat recovery from waste hot water. When the heating demands have been satisfied then the excess heat collected can be used for preheating domestic hot water.

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The Energy Implications of Ventilation in Houses.

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Summary

The ventilation rate and heating energy requirements of an 85 metre^2 brick and tile semi-detached house having one upstairs window open by various calibrated amounts were measured during one heating season. The average whole house ventilation rate of 0.3 air changes per hour increased to 3 air changes per hour when the bedroom window was at its maximum opening. The corresponding measured increase in heating energy was 64%.

If, as frequently occurs, air leaves the house predominantly from the upstairs rooms, then the ventilation heat loss will be dependent on the temperature in these rooms rather than on the mean air temperature in the rest of the house. This was confirmed by measurements.

Resume

On a mesuré le taux de ventilation et la quantité d'énergie exigée pour chauffer une maison jumelle de briques de 85 mètres carrés, avec une fenêtre à l'étage supérieure ouverte à plusieurs ouvertures calibrées, au cours d'une saison de chauffage. Le taux moyer de 0.3 échanges d'air par heure pour ventiler toute la maison a augmenté à 3 échanges d'air par heure quand la fenêtre de la chambre à coucher est ouverte au maximum. L'augmentation résultante mésurée d'énergie pour chauffer a été de l'ordre de 64%.

Si, comme fréquemment, la grande partie de l'air quitte la maison des chambres en haut, la perte de chaleur à cause de ventilation dépendra de la température de ces chambres au lieu de la température moyen de l'air dans l'autre partie de la maison. Les mesures l'a confirmé.

Introduction

Openable windows represent the most common way of controlling ventilation.

As heat loss through the house structure is progressively reduced by improved thermal insulation, heat loss by ventilation becomes more significant and may be the dominant mode of heat loss in a "low energy" house.

Therefore, only be reducing the ventilation and closely matching actual ventilation rate to needs can the energy used for house heating be minimised.

The ventilation rate has been measured for a selection of typical open window arrangements to determine how effective windows are in satisfying ventilation needs.

The resulting energy cost of the extra ventilation has been measured.

Description of house

The measurements were carried out in a house which satisfies current U. K. Building Regulations (1975) but would not be considered "well insulated". The house is one of a pair of semi-detached houses, separated by an instrumentation space. The floor plan is shown in Figure 1. Total floor area is 85 metre^2; house volume is 200 metre^3.

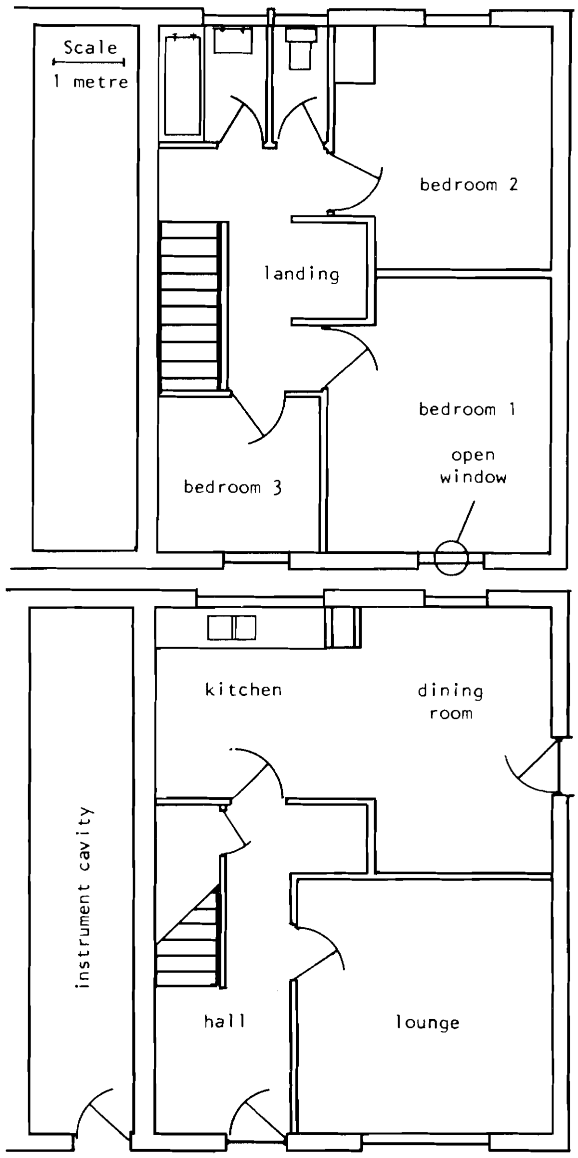

Figure 1: Floor plan of test house.

The window type is shown in Figure 2, with the window of Bedroom 1 opened to three positions referred to as 01, 02 and 03 as indicated. The effective open areas were measured by a flow/pressure technique using a fan installed in the doorway of the room. Calibration was achieved by opening the window and covering by an adjustable slot of known size.

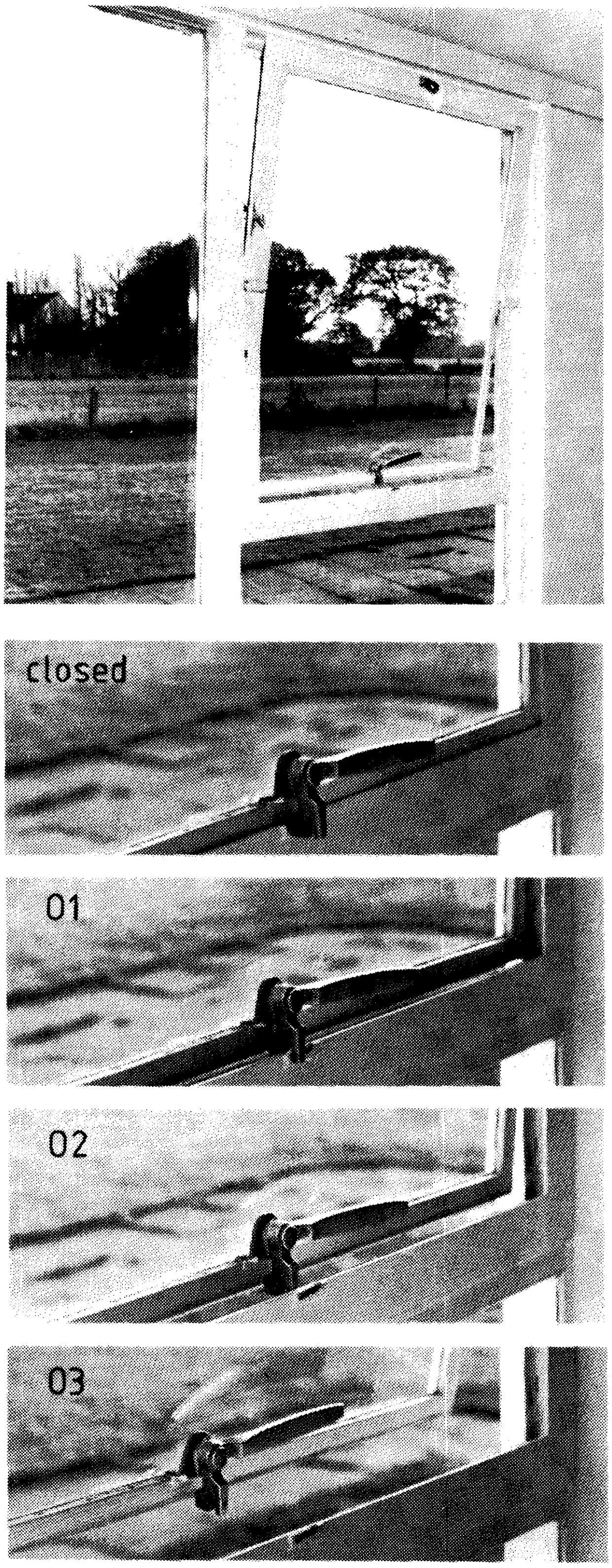

Figure 2: Window of house with open positions.

The equivalent areas found thus for the three open positions are 0.013, 0.026 and 0.11 metre^2 respectively.

The total house leakage measured by the same technique but with the fan installed in place of the front door is 0.12 metre^2 (16 ach at 50 Pa). Smoke tests showed the window weatherstripping to be sealing well, but the windows leak mainly between the wooden outer frame and the adjacent brick wall, with further leaks occurring around skirtings and service.

Experimental procedure

The average whole house ventilation rate was measured continuously by the equilibrium concentration method, using nitrous oxide tracer gas. The tracer gas concentration (10 to 100 ppm) throughout the house was measured at six sampling points in the centres of the main rooms. The nitrous oxide concentration was measured using a Miran infra-red gas analyser at a sampling rate 20 litres/minute. The output of the analyser was continuously recorded on a chart.

The tracer gas flow was measured by a Rotameter which was calibrated for nitrous oxide by timing the travel of soap film along a calibrated tube attached to the outlet. The gas analyser was calibrated by connecting the outlet to the inlet forming a closed circuit of known volume into which nitrous oxide was injected with a microsyringe.

Ventilation results

When all windows were closed the whole house ventilation rate seldom exceeded 0. 5 air changes per hour, Figure 3.

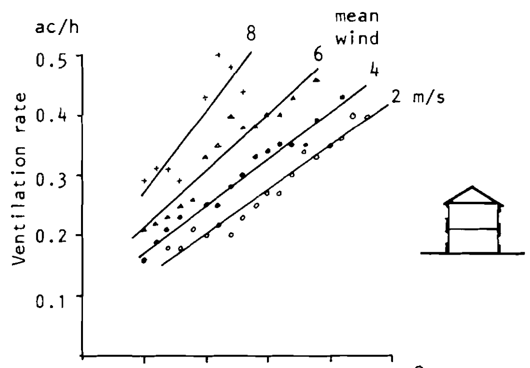

Figure 3: Ventilation rate with windows closed.

The house would therefore be classed as fairly 'tight' by British standards. The weather conditions encountered were inside to outside temperature difference ΔT from 5°C to 23°C and mean wind speeds up to 8 m/s. In this house all the windows are on the front and back of the house (although there is a side door) and although winds on the front and back gave slightly higher ventilation rates than winds onto the ends of the house the difference was generally less than 30%.

When the ventilation rate with open windows is considered, the immediate problem is the wide range of possible options of which windows to open and by how much. The position of internal doors will also be significant but to reduce the number of variables, these doors were left open throughout.

Surveys have shown that upstairs bedroom windows are commonly left open for long periods. The present investigation was therefore restricted to open windows in upstairs rooms.

The ventilation rate considered relevant was an average fresh air rate for the whole house, since this is directly related to heating costs. Individual room rates depend on whether the room is ventilated directly from outside or with air from other rooms in the house.

The large front bedroom window was opened and the average whole house ventilation rate measured continuously. The three open window conditions shown in Figure 2 were used:

(01) catch on first notch

(02) back of catch resting on window frame

(03) window open to main stop.

By leaving this one window open all the time both leeward and windward orientations of the opening were achieved as the wind direction varied from day to day.

With the window open (01) the increase in whole house leakage is only 10% and consequently the ventilation rate was not significantly greater than with all windows closed, except at high wind speeds, Figure 4.

With the window wide open (03), the increase in leakage area is comparable to the whole house leakage area and the resulting ventilation rate was very variable, up to 7.5 air changes per hour throughout the house but sometimes as low as 0.5 air changes per hour depending on the wind speed and direction, Figure 5. During these tests the wind blew either on the end of the adjoining house or almost directly onto the front facade. In the former situation the ventilation rate was 0.5 to 1 ach with very little weather dependence. In the latter the ventilation increased linearly from 1 ach at 2.5 m/s wind to 7 ach at 8 m/s wind. Temperature difference appeared relatively unimportant in the range $\Delta T = 7$ to $13^{o}C$. This position 03 represents the most likely open window position in practice.

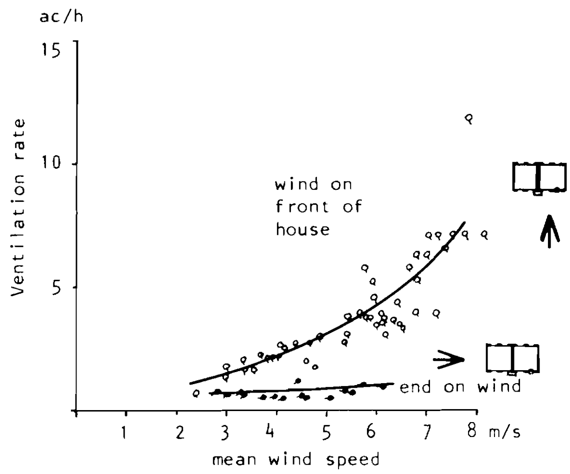

Figure 5: Ventilation with one window open to main stop (03)

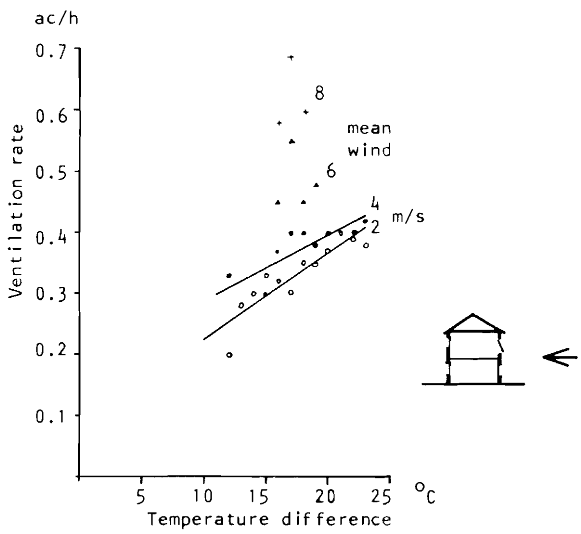

Figure 4: Ventilation rate with one window slightly open (01)

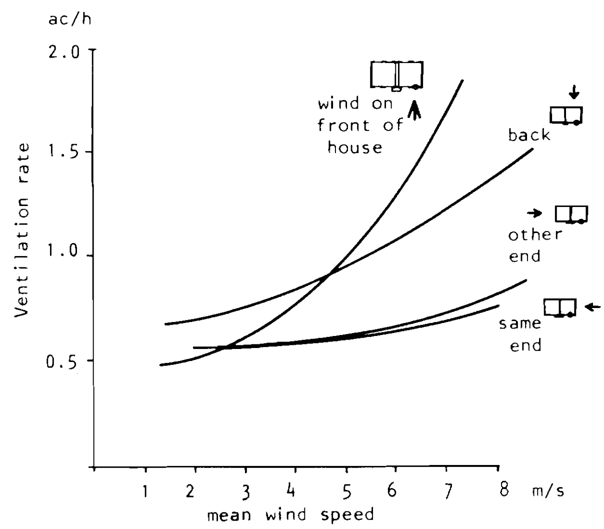

Figure 6: Ventilation with one window open (02)

Note:
In conditions of Figures 5 and 6, temperature effects were much less significant than wind effects.

At the intermediate open window position (02) the ventilation was increased by a useful amount without being excessive. The ventilation rate throughout the house varied between 0.5 and 2 air changes per hour depending on the weather as shown in Figure 6. Wind direction now influenced the ventilation rate. End-on winds of 2 to 10 metre/second gave ventilation rates of 0.5 to 1 ach, almost independent of wind strength. When the wind direction was onto the back of the house (i.e. on the opposite side to the open bedroom window) the ventilation rate increased approximately linearly with wind speed from 0.7 ach at 2 metre/second wind to 1.5 ach at 10 m/s wind. Wind on the front of the house (i.e. directly into the open window so that wind and stack effects are opposed at the opening) produced marginally lower ventilation rates at very low wind speeds but the ventilation increased rapidly with wind speed to more than 2 ach throughout the house when the average wind speed reached 8 m/s.

Measured energy usage

The house was heated electrically to a uniform temperature of 20°C for 24 hours per day. Thermostatically controlled panel heaters were used in the main rooms, hall and landing supplemented by an extra fan heater in the large front bedroom when the window was open.

Energy consumption of each heater was monitored by kWh meters which were read daily. Temperatures in the kitchen/diner, lounge, hall, landing and both large bedrooms were continuously recorded on thermohygrographs. The results are given in Table 1.

Table 1 Daily average energy measurements

Window condition	Ventilation rate h^{-1}	Temperature difference °C	Electrical heating kWh	Solar heating kWh	Ventilation loss kWh
Closed	0.219	9.94	45.34	2.29	3.70
"	0.314	15.31	75.55	2.16	8.17
"	0.323	14.48	67.84	7.36	7.95
"	0.319	11.49	39.79	14.63	6.23
Open 01	0.334	17.71	83.93	1.57	10.06
"	0.362	18.18	92.71	1.95	11.19
Open 02	0.728	19.03	108.53	3.08	23.55
"	0.736	15.84	81.05	6.59	19.82
"	0.637	17.50	90.38	6.80	18.95
"	0.769	15.63	82.85	7.98	20.43
Open 03	2.95	10.89/ 7.87*	86.55	1.26	39.47**

Note: ** Ventilation heat loss was calculated with reference to bedroom temperature* rather than whole house temperature.

The house energy balance can be written as: (Electrical + Solar) Gain = (Ventilation + Fabric) Loss where convenient units are kWh/day averaged over 10 day periods to ensure that thermal storage effects are insignificant.

The electrical energy input was measured directly. The solar energy input was estimated using the following calibration procedure from the roof-mounted solarimeter reading of kWh per m^2 on the horizontal plane.

Since the temperature difference between inside and outside is varying continuously and also since heat loss from the house is proportional to this temperature difference, it is convenient to work in kWh per degree day thus:

$$\frac{\text{Elec - Vent}}{\Delta T} = \frac{\text{Fabric}}{\Delta T} - \frac{\text{Solar}}{\Delta T}$$

where Elec, Vent, Fabric and Solar are expressed in kWh/day. Thus if $\frac{\text{Elec - Vent}}{\Delta T}$ is plotted against the integrated solarimeter reading of kWh per m^2 horizontal surface per day divided by ΔT, the intercept at Solar = 0 will give the fabric heat loss coefficient in kWh/(degree day) and the slope will give the effective solar energy input to the house as a function of the daily integrated solarimeter reading. However, first a relationahip between the measured ventilation rate and the associated energy loss is required.

Let the air in the house be at a uniform temperature T, and the outside temperature be T_o. If V = house volume = 200 m^3, A = ventilation rate (ac/h), ρ = density of air = 1.25 kgm^{-3} at 10°C and Cp = specific heat of air = 990 J $kg^{-1}K^{-1}$ then the ventilation heat loss is

$$1.65 \times A \times (T_1 - T_o) \text{ kWh/day}$$

or

$$1.65 \times A \text{ kWh/(degree day).}$$

If for the purpose of estimating the solar heating effect it is assumed that this estimate of the ventilation heat loss may be in error by as much as 30% then by selecting periods when the estimated ventilation heat loss is less than 20% of the total heat loss the maximum error due to wrongly estimating the ventilation heat loss is only 6%. With this proviso, $\frac{\text{Elec - Vent}}{\Delta T}$ plotted versus $\frac{\text{Solarimeter reading}}{\Delta T}$ gives (correlation coefficient 0.97)

$$\frac{\text{Elec-Vent}}{\Delta T} = 4.46 - \frac{4.08 \text{ Solarimeter}}{\Delta T}$$

Thus the fabric heat loss coefficient is 4.46 kWh/(K day) and the conversion factor from solarimeter daily integrated kWh/m^2 horizontal to useful kWh into the house is 4.08.

This solar heating factor is now used to replot the data in the form

$$\frac{\text{Elec + Solar}}{\Delta T} = \frac{\text{Vent}}{\Delta T} + \frac{\text{Fabric}}{\Delta T}$$

Now data points are omitted in which the estimated solar heating effect is more than 20% of the total energy into the house. A fitted straight line (correlation coefficient 0.90) gives

$$\frac{\text{Elec + Solar}}{\Delta T} = 4.45 + 1.70 \times \text{air change rate h}^{-1}$$

showing the fabric heat loss coefficient confirmed as 4.45 kWh/(K day) and the ventilation heat loss coefficient of 1.70, very close to value 1.65 assumed above.

From these results Table 2 shows the ventilation heat loss as a percentage of the total energy input to the house and the increase in heating energy required to maintain the house temperature when the bedroom window is opened by various amounts.

Table 2 Ventilation heat loss

Window condition	Mean Ventilation rate	Measured (Ventilation heat loss / Total heat loss)	Measured increase in heating energy as a result of one open window	Extra kWh per design day (ΔT = 18°K)
Closed	0.30	10% (18%)		
01	0.35	12% (21%)	3% (3%)	1.7
02	0.73	21% (36%)	14% (27%)	13
03	3.0	45% (62%)	64%* (115%)	80

However this house is relatively poorly insulated. If the fabric heat loss was one half of its present value then energy increase due to ventilation, although still the same absolute value, would be a much greater percentage of the total energy consumption.

Energy costs of ventilation

The heat loss associated with ventilation was estimated in the previous section assuming all the air in the house was at a uniform temperature. However, all the rooms in a house are seldom at the same temperature and opening a window may cause local cooling unless the heating system is responsive and of sufficient capacity.

Consider a house at a non-uniform temperature in which the ventilating air passes in turn through regions of air temperature $T_1\ T_2 \ldots\ldots T_n$. Let the air flow through each in turn be Q kg/sec.

Consider the mth region. The power required to maintain its temperature at T_m is

$$Q\ C_p\ (T_m - T_{m-1}) + \text{Fabric heat loss}_m$$

Note

* Less than expected because bedroom cooler than rest of house. Figures in brackets refer to "well insulated" house.

For the whole house the power required to maintain existing temperature is

$$\sum_{m=o}^{n} Q\ (T_m - T_{m-1})\ C_p + \text{Fabric loss}_m$$

$$= Q\ (T_n - T_o)\ C_p + \text{whole house fabric loss i.e.}$$

the ventilation heat loss depends only on the outside air temperature and the temperature of the air which is leaving the house. Intermediate temperatures do not matter.

To a first approximation air leaves the house upstairs leeward which means that heat loss due to ventilation should be related to bedroom rather than whole house temperatures. This was confirmed experimentally as indicated in Table 1. In strong wind conditions, however, air will also leave the house downstairs leeward.

Conclusions

One open first floor window was found to increase the ventilation throughout a house by a large and variable amount. Most British windows do not have provision for obtaining the small openings necessary to give the ventilation rates actually needed, with the result that 5 air changes per hour are commonly achieved with only one open window. Even a small opening of one window produced 1 to 2 air changes per hour throughout the house.

Energy measurements showed that in a typical British house one open window can result in about half the heating cost being caused by ventilation.

Since ventilation heat loss is related to the temperature of the air leaving the house, ventilation heat loss is related to bedroom rather than whole house temperatures.

Design, Construction and Instrumentation of a house incorporating high standards of insulation and a solar/solid fuel powered air and water heating systems

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Heriot-Watt University,
Edinburgh, Scotland

The opportunity to carry out this study fell to the author with the acquisition of a building plot 27 kilometres west of Edinburgh. The house is being built at his own expense. The Department of Building, Heriot-Watt University, are providing instrumentation and research facilities.

The roof will support approximately 40 square metres of solar air heating panel. A further 40 square metres of solar panel will heat water. A 'rock-pile' heat store of 11 cubic metres and a pre-heat water store of 300 litres can be accommodated.

The panels and stores are designed to utilise such components and materials as can be bought 'off the shelf' and/or made up using commonly available building trade skills and equipment.

A microprocessor will control collection of data from 250 sensors, record data on magnetic tape, run the systems and with meteorological data maximise use of heat store or panel as appropriate. All recorded data will be analysed weekly on the University's main computer. The house will be complete autumn 1980.

La possibilité de realiser cette ètude a été donnée à son auteur par l'acquisition d'un terrain à batir situé à 27 kilometres d'Edinburgh. La maison est construite à ses frais. La section Construction del'Université Heriot-Watt lui fournit toutes facilités au point de vue appareils et recherches.

Le toit supporter environ 40 m^2 de panneaux solaire chauffant l'air. 8m^2 supplémentaires de panneaux solaires serviront a chauffer l'eau. 11m^3 de pierres réfractaires servant d'accumulateur de chaleur et une réserve d'eau pré- chauffée de 300 litres jeuvent être adaptés.

Les panneaux et réservoirs ont été prévus de fagon à utiliser des pièces et matériaux jouvant être achetés sans difficultés dans le commerce, et/ou fabriqués à l'aide de matériaux et techniques d'usage courant dans le domaine du bâtiment.

Un microprocesseur controlera un ensemble de données provenant de 250 sensurs, les enregistrera sur bande magnétique, mettra en marche le systeme de chauffage, et, avec les données météorologiques portera au maximum l'utilisation de la réserve de chaleur ou des panneaux selon le cas. Toutes les données enregistrées seront analysées chaque semaine sur l'ordinateur principal de l'université. La maison sera terminée à l'autome 1980.

Generally

The house layout has been designed to give a southerly aspect for most rooms and to present the widest area of roof to support solar/air heating collectors. Figures 1 and 2. Access is from the street on the north side with the garage and car parking space. The ground slopes up to the south side of the site to a railway embankment. The south side of the railway has a considerable drop and is zoned for housing after gravel extraction. With current planning restrictions there will be a 2 storey limit on development, thus ensuring no blockage of sunlight to my collectors.

The ground slope and embankment are such that 15 days prior to the winter solstice the sun does not reach the ground floor windows, but returns 15 days later.

Despite its northerly latitude (56^{O}N), Edinburgh and district enjoys a fair proportion of solar radiation. Typical figures are given in Table 1.

	Central Scotland	Southern England
March	1.90	2.20
June	4.60	5.30
Sept.	2.60	3.10
Dec.	0.30	0.50

Table 1. Average daily total of solar radiation on a horizontal surface in kWh/m^2.

The annual total radiation received on a horizontal surface in Central Scotland is 800 kWh/m^2 against 1000 kWh/m^2 in Southern England.

The degree/days for East and West Scotland and the Southern part of the UK vary considerably.

	Central Scotland		Southern
	East	West	England
Jan.	383	373	342
Feb.	344	336	307
March	328	319	297
April	254	238	216
May	190	163	141
June	102	84	69
July	70	61	41
Aug.	72	64	42
Sept.	106	104	77
Oct.	185	179	145
Nov.	309	303	258
Dec.	371	359	331

Table 2. Average Monthly Degree Day Values over period 1958-1977. (60^{O}F. Base (15.42^{O}C.)) by permission of the Editor, Energy Management, Dept. of Energy, Thames House South, London.

The figures above clearly show that Central Scotland has a longer 'heating season' and this enhances the viability of any capital intensive heating system such as the use of solar energy.

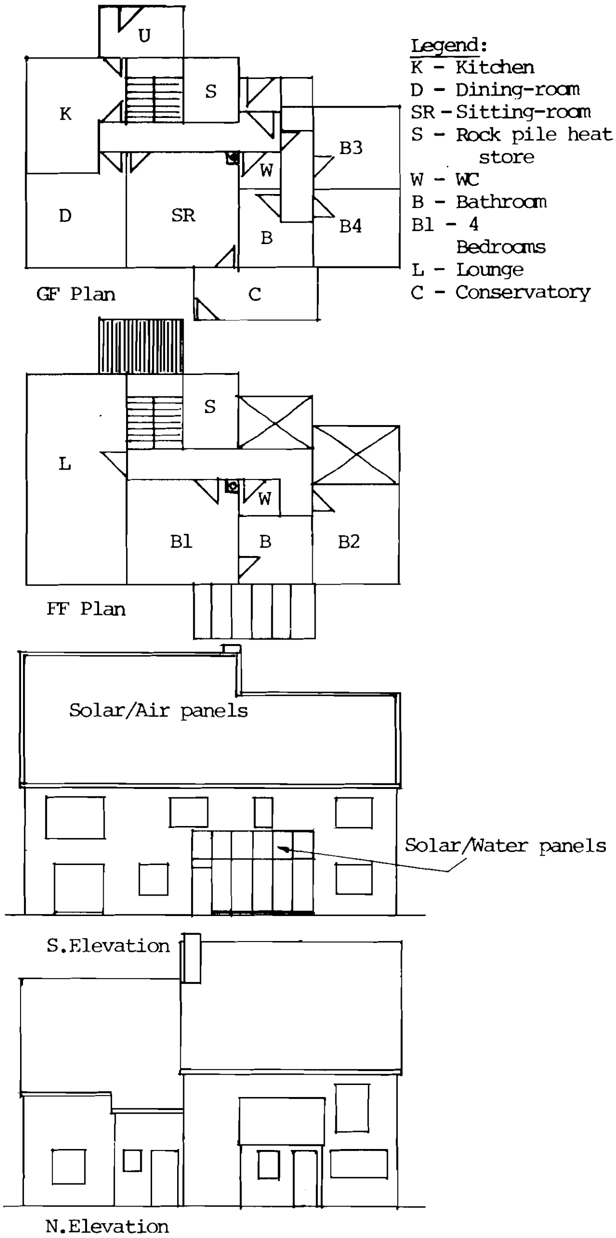


Fig. 1 General arrangement plans & elevations

Providing one can intercept a reasonable amount of sunshine with an efficient system, one's hopes of viability are enhanced the further north one travels in UK - not south as has been previously supposed. This has been demonstrated by Mr. A.W.K.Macgregor ✱.

The Heating System

The solid fuel portion of the heating system will be a closed stove suitable for wood burning and having a high output boiler. The boiler will indirectly heat a domestic hot water cylinder by gravity.

The house, generally, will be heated by ducted hot air and in the absence of solar powered heat the back boiler will feed a heat exchanger in the main air supply duct. This will be controlled by using a pump to feed water to the exchanger and by having motorized three-way valves on the junctions to the flow and return pipes to the hot water cylinder.

Solar air heating panels form the south face of the roof at an angle of 65° giving the optimum collection angle from equinox to equinox over the winter solstice. This steep angle also means that summer radiation will be reflected from the panel covers to a greater degree and combined with a free venting system should prevent overheating of the panel components, particularly the seals on the panel covers. These panels will be manufactured using galvanised mild steel sheet as a heat transfer medium, the sheet being painted with heat resisting matt black paint.

Turbulence in the air flow will be induced by fastening galvanised expanded metal lath to the sheet.

✱ A.W.K. Macgregor, Napier College Edinburgh. 'The potential for solar assisted space heating at high latitudes in the British Isles.'

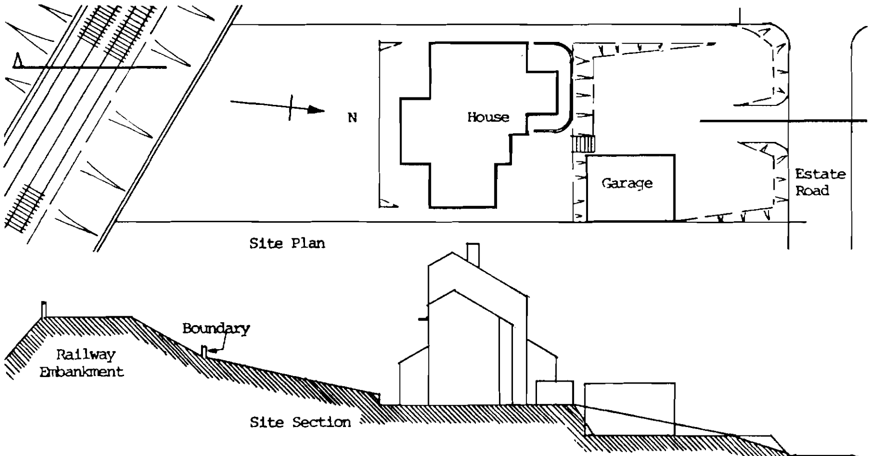


Fig. 2 Site Plan & Section

Two air flow configurations are being considered, both involving a double pass of air, first between the plate and the cover glass, and then between the plate and the back of the panel. System (a) in Fig. 3 shows the air being ducted into the top of the front air space, down the panel, under the plate edge and up the rear space, where, fully heated, it is drawn off to heat either store or house. System (b) in Fig. 3 shows the air introduced into the bottom of the front air space, up the panel and through perforations into the rear air space where, fully heated, it is drawn off from the top to heat either store or house. Prototypes of both systems are being tested in the Spring of 1980. Glazing will be 'Filon' translucent GRP sheet coated with Tedlar, set in aluminium glazing sections with a silicon based compound. The casing back will be of plywood and will incorporate 100 mm glass fibre insulation to back and edges.

Total area of air panel is 42.70 square metres.

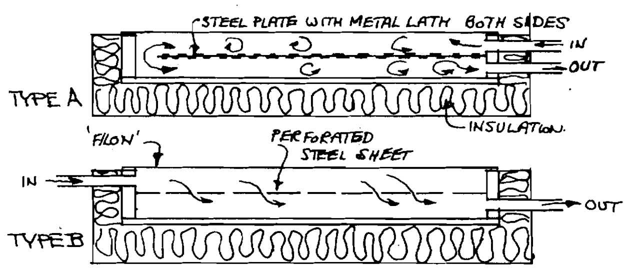


Fig. 3 Configurations of Solar Panels for air heating

The solar water heating panels will be mounted on the conservatory roof and will be manufactured from a serpentine of copper tube on copper strip, all painted with heat resisting matt black paint. The casing will be of plywood with 100 mm glass fibre insulation to back and sides. Glazing will be the same as the air heating panels. Total area of water panel is 12.50 square metres.

The low position of the panels will allow the installation of a thermosyphoning, and therefore self-regulating system. The angle of the panels - approximately 35^{o} - will allow peak efficiency during the late spring to autumn. Winter water heating by the closed stove will be supplemented by an immersion heater.

Both panel types will be manufactured in the author's own workshop. Because only material costs will be available, economic assessments will be difficult. However, once the design has been finalised and all installation work complete, a full specification will be sent out for quotations from suitable manufacturers. The principal criterion in the design of the panels has been the need to use ordinary materials and components available to the building trade and to use only the normal building trade skills.

The heated air from the solar hot air panels may be used to heat the house direct or may be passed over a storage medium where the heat is extracted and retained for future use. Two media are under consideration. 75 mm single size river-washed ballast, selected to ensure that the stones are roughly spherical. This last requirement cuts down on heat migration from top to bottom of the store by conduction. Problems arise with containment when one has a pile of loose stones approximately 2.00 x 1.00 x 6.50 metres high (4.25 cubic metres of stone). One can build a rigid container and use it as part of the storage medium. This allows the use of a soft insulation material on the outside of the container. This still requires cladding - another form of 'container' must be built. Container and cladding combined require internal insulation and this must be a rigid board, such as dense polystyrene or urethane. Predictions of air flow and heat transfer characteristics are difficult.

The second medium under consideration is a block of built masonry with ducts running from top to bottom. Either brick or precast concrete blocks could be used. Containment is no longer a problem and insulation can be soft or rigid and only cladding need be applied. Heat migration from top to bottom of the store must be stopped. This can be done by layering at intervals with a rigid insulating material. A great thickness should not be necessary.

The volume of storage in the built masonry store will be approximately 10.50 cubic metres and should give a capacity of 5.90 kW for each $1^{o}C$. rise in temperature of air output. The store of ballast will only have a capacity of 3.00 kW for each $1^{o}C$. rise in temperature of air output. It should be borne in mind that only 85% of heat stored can be extracted ✳. Assuming that reasonable temperatures can be attained in the storage medium then 3 to 4 days carry-over could be achieved.

Figure 4 shows the interdependence of these components when storing heat or heating the house.

House Construction

The construction of the house is not wholly traditional. The following elements are specially designed or modified to save energy.

The ground floor is timber-joisted and sheeted with tongued and grooved chipboard but incorporates a 100 mm thick layer of mineral wool batt supported on a wire mesh. The underfloor space is ventilated but this is controlled by keeping vent sizes in outer walls to the legal minimum and vents in partitions only where they will prevent dead air pockets.

✳ Close, D.J. Rock Pile Thermal Storage for Comfort Air Conditioning, Mechanical & Chemical Engineering Transactions, May 1965, The Institution of Engineers, Australia.

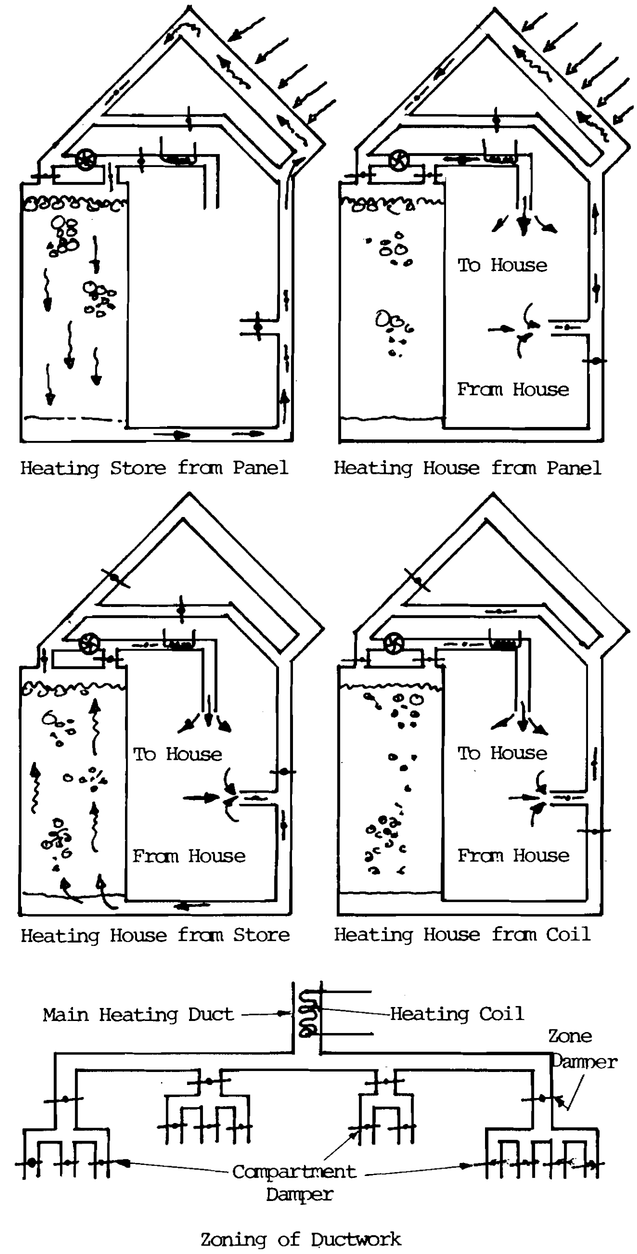


Fig. 4 Heating System Modes

Outside walls are built with 215 mm thick aerated concrete blockwork. The inside will be dry-lined and the outside will be clad with an external grade metal lath with a cement rendered finish. Between the blockwork and the lath one of two types of insulation will be installed. Initial designs incorporated a 75 mm thick layer of fibreglass mat - 'Dritherm' - with a breather paper and an absorbent paper between it and the lath. The principal advantage is that the wall is porous and can 'breathe' naturally. A recent argument has arisen in the UK regarding the possibility that fibreglass and mineral wool insulation can cause corrosion in gang nailing plates in roofs. This arouses doubts in my own mind regarding the security of the fastenings for the lath and render which must pass through the insulation to the blockwork. 'Soft' insulation also has the possibility of water logging should the rendering break down although 'Dritherm' has its fibres aligned and resin bonded.

Subsequent considerations have evolved the idea of filling the space between lath and wall with a 50 mm layer of rigid foam board on 25 mm thick rigid foam vertical strips, the lath being fixed through the foam layer and strips to the blockwork. The cavity so formed would be vented at the top, immediately under the eaves. This should obviate the objection that those foams are non-porous and could be a condensation trap. However, it is felt that the thickness of aerated concrete wall will tend to absorb vapour under high humidity conditions and give this off slowly as the humidity of the atmosphere decreases. The breather and absorbent papers would not be required.

Various foams are under consideration; high density polystyrene; urethane foams; isocyanurate foams. The last two named are manufactured with aluminium foil bonded on to one or two faces. Polystyrene is, however, some 40% cheaper.

Roof insulation will be 100 mm thick glass or mineral wool. (Gang nail trusses are <u>not</u> being used).

Condensation is the biggest risk in such a well insulated building and much work is being done elsewhere in this sphere. Breathable structures do help; incorporation of vapour barriers are a must but must be in the correct position; timbers will be treated to resist fungal attack.

Total heat loss from the building is calculated as 0.26 kW for each 1^{o}C. difference between internal and external air temperatures. (0^{o}C. outside, 18^{o}C. inside - 4.75 kW total).

Instrumentation

The following lists indicate proposed sensors in and around the building.

Weather data Total solar radiation by silicon cell radiometer. Wind direction above building. Wind speed above building and across face of collectors. Air temperatures using temperature sensitive micro-circuits (silicon chips). Relative humidity measurement utilising wet and dry bulb 'chips' is being investigated. Rainfall using a tilting bucket rainfall recorder.

House data - Internal environment Room temperatures using 'chips'. General relative humidity in return air duct using wet and dry bulb 'chips'.

House data - Energy consumed Electricity using modified meters on power, light, cooking and heating circuits. Gas using a modified flow meter.

House data - Systems status The following temperatures using 'chips':

Heat store (several sensors at different layers). Collector fluid inlet and outlet, exchange plate and cover glass. Delivered air in main and sub-ducts. Return air. Cold mains water inlet. Foul water outlet. Water/air heat exchanger. Domestic hot water cylinder top and bottom. Solar pre-heat water tank top and bottom. Hot and cold water delivery temperature.

The following quantities will also be measured using appropriate meters:

Cold mains water inlet. Cold supply to domestic hot water tank. Cold supply to other applicances (A thermostatically controlled mixing valve will be placed on the main hot water supply outlet linked back to the cold water storage tank. This will cut down the temperature of hot water left in pipework to appliances and so save on energy). Air flow to and from store, collector and house.

A further temperature sensor will be used to determine whether or not the solid fuel stove is lit.

The readings from these sensors, some 250 in all, will be supplemented by data on diffuse and direct solar radiation, air temperatures and wind speed and direction from a nearby research project operated by my colleagues ✳ and from the meteorological station at Turnhouse. Fuel costs, and quantity of solid fuel will also be added as will capital expenditure and current interest rates.

Data gathering and System control

Sensor readings will be standardised and multiplexed with suitable circuitry to be received at, in many instances, 5 minute intervals by a Commodore PET microprocessor. Supplementary data will be input via the PET's keyboard. The microprocessor configuration is 16K of progamable memory plus cassette drive, dual 5¼" floppy disk unit and a dot matrix printer. Data gathered will be transferred daily to a separate 9 - channel tape recorder and the reels of tape taken weekly to the main University computer for processing.

A program is being currently developed which will instruct the PET to gather data from all the sensors in correct sequence and at the correct time intervals. Some of the data gathered will be recorded for later analysis only; the remainder, whilst being recorded will also be required by the program to operate the heating system. The relationship of the steps to achieve this is complex but could be summarised as:

1. Comparison of air collector/store/external and room temperatures to switch heating on and off and to optimise on heat available in collectors and store.
2. Time setting of heating zones, e.g. full heating not required overnight; bedrooms require full heating mornings and evenings; living accommodation full heating all day at weekends. This will be physically achieved by the use of dampers in the distribution ducts.
3. Reference to temperature parameters for compartments, e.g. living areas 20°C, bedrooms 16°C, etc. No thermostats will be provided. The microprocessor will work entirely from room temperature sensors feedback and parameters set manually on the keyboard.
4. Acceptance of supplementary data through the keyboard. This could include meteorological forecast data to extend the optimisation of heat available.
5. System breakdown warning and diagnostic routine through VDU.
6. Ability to assess previous 24 hours data allowing inspection prior to weekly processing on the main frame computer.
7. Audio/visual request to light stove if heat not available elsewhere.
8. Having the system temperature and time switching (1 and 2 above) as a progam allows adaption of the control system through the keyboard. This will be useful for determining the optimum requirements for different weather conditions as well as differing living patterns adopted by the users.

Analysis of data

At this stage, one looks back at the mass of data which will become available and wonders - "precisely what do we do with it all?" The analyses possible are legion but we principally wish to know the following:

1. The efficiency of the solar collectors - heat collected against heat available.
2. Were room temperatures maintained at desired limits and at what cost in terms of power used to run the solar part of the system and at what cost in terms of auxiliary heat from the stove?
3. Was hot water available either from solar collectors or solid fuel stove and at what cost for the immersion heater?
4. Ratio of heat stored to heat collected and used without storage. Ratio of heat input to and output from store.
5. Examination of heat flow through fabric will allow assessment of value of insulation techniques used and validity of 'U' value calculations.
6. Assessment of alternative fuel usage and therefore some degree of economic analysis should be possible.

Acknowledgements: I must first express my appreciation of the help and encouragement given by Professor V.B. Torrance, Head of Department of Building, and my colleagues in that Department and in the Department of Electrical and Electronic Engineering. I must also acknowedge the debt I owe to all those who have published data, experience and theory on the subjects of solar power, insulation, condensation, etc. I feel that a short list of references now would insult the many others whose work has helped me but who have been excluded. Should you feel aggrieved by the omission of references to your own or your favourite work, then be comforted by the knowledge that if I have not read it, it is only because of my ignorance of its value.

✳ V.B. Torrance & R.A. Mutch. Better Insulated House Project/Scottish Development Department, Bo'ness

PERFORMANCE EVALUATION OF SOLAR-INTEGRATED BUILDINGS

WALTER ESPOSTI CNR ICITE

1. INTRODUCTION

In 1977, the Italian National Council for Scientific Research started, within the framework of Progetto Finalizzato Energetica, a performance evaluation programme in the field of solar integrated buildings. We briefly summarize the main objectives of such programme:

- evaluation of the possibilities to cover a share of the thermal supply required by users for heating and domestic hot water by the use of solar energy;
- evaluation of the interactions between external climate and projected internal climate, medited by particular building /plant systems;
- preparation of a known data support, concerning both the climate and the building /plate systems, for the purpose of testing simulation programmes;
- identification of suitable elements as a basis for working out new testing methods for components and systems, to be introduced in the standardization context.

Although all objectives are equally important, the last one is worthy of particular attention in this stage of the solar energy development.

It is clear, in fact, that the preparation of adequate technical-methodological instruments is necessary for the formulation of techinical standards, in order to safeguard users and improve the production quality. This issue becomes even more important if legal instruments are prepared to promote and develop technologies for the exploitation of solar energy. Eight experiments have been undertaken all over the national territory. Out of these, the following can be considered to be at a fairly advanced stage:

- the solar-integrated I.A.C.P. building of Pordenone, at Fiume Veneto(Pordenone) which has now been working for one and a half years;
- the solar-integrated building at the ENEL thermo-electric power plant of Rossano Calabro, which has now been working for three months;
- the four one-family houses built on behalf of Associazione Nazionale Alpini at Sequals (Udine), which have now been working for about six months;
- the nursery school at Crosara di Marostica, which has now been working for three months.

While other experimentations are being completed, we present, for the four mentioned, "technical sheets" modelled after the one prepared for the E.E.C. Such sheets have been devised so as to include all the parameters necessary to correctly identify an experimentation from the viewpoints of both planning and data collection.

Although the sheets are not fully completed (they are now being perfected), they already point out a few interesting elements, not only as information, but also for the study on the value of certain parameters or the dimensioning of some plant or building elements.

2. THE EXPERIMENTATION OF FIUME VENETO

2.1. Experimentation description

This building was designed in 1975 according to the cost-containment criteria typical of social housing. The architecture and construction of the building is therefore conventional, and the nergy saving does not exceed the level established by I.A.C.P. at the time of construction.

The main purpose was to evaluate the potential possibilities of solar-integrated systems in covering a share of the thermal supply, nad the users' response to them.

The absorption system(aluminium roll-bond absorbers) is not embodied in the building and it represents the simplest type of solar-integration system .

The philosophy of this solar-heat exploitation project is to use solar energy as far as possible, when it is available, circulating directly the coolant fluid for use, and accumulating only the excess fed back to the collectors. For this reason the storage for heating has been underdimensioned in relation to the absorbing surface (3 m^3).

We also tried to clearly distinguish the solar energetic contribution to that of the auxiliary system, providing for a double heating battery in the venticonvectors.

The data acquisition system is by microprocessor - controlled data-logger. The expected performance covers 21% of the building thermal supply,

2.2 Climate description

Latitude: 46° 05' longitude 13°

Total solar radiation 1159 Kwh/m^2 year

Diffuse radiation: 41%

Degree days : 2386

Annual sunshine hours: 2012

2.3 BUILDINGS DESCRIPTION

The design and construction are very traditional. The external walls consist of a double layer of hollow bricks separated by a cavity.

The solar and auxiliary systems are placed in a room under the roof.

The main charachteristics are:

Building Type: 12 apartment building		
Floor area: 1,011.3 m2		
Design temperature external: - 5 C°		
Ventilation Rate:	0.5 a.c.h.	
Heated Volume:	27.30	m^3
T Internal:	20	C°
Vol. Heat Loss:	1.82	$W/m^3.K$
Glazing:	14%	
'U' values:Walls	1.7	$W/m^2.K$
thermal mass:	500	kg/m^3
Area:	160	m^2
Floor:	1.2	$W/m^2.K$
'U' value:	6	$W/m^2.K$
Roof/loft:	1.5	$W/m^2.K$
Annual energy Dem.:	335.000	kWh

2.4 System Description

There is the direct use of the solar heat in the distribution system . The thermal storage is at the return of the ambient fan coil and collects the excess energy.

The main characteristics are:

Absorber type: flat Al-Roll bond, black paint

Collector area: 125 m^2

Orientation: 180°

Storage volume: 3 m^3

Auxiliary System : gas fired boiler

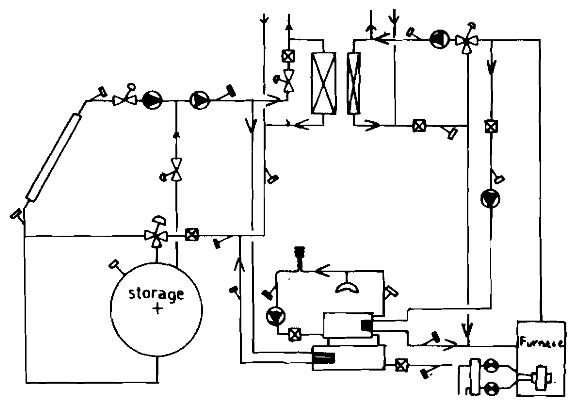
Tilt: 60°

Coolant: water & monoeth. glycol

Glazing: single

Heat Emitters: fan coil& radiators

The diagram of the system is the following:



3. THE EXPERIMENTATION OF ROSSANO CALABRO

3.1 Experimentation description

The experimentation consists of two twin buildings, one of which is solar integrated, located in the vicinity of the ENEL thermo-electric power plant of Rossano Calabro.

The building tipology adopted is very simple and traditional; the opaque parts of the external walls do not have particular heat-insulation characteristics whereas components with good transmittance characteristics have been adopted for the glazing.

The absorption system (extruded and corrugated aluminium collectors and aluminium roll-bond collectors) consists of two sets one of which has a certain degree of integration in the external envelope.

The solar -heat exploitation plant has a primary circuit and an exchanger by accumulation (7.5 m^3).

The auxiliary system is an electric night storage heater: one of the objectives of the experimentation is, in fact, to evaluate the possibilities of combining the solar source with the electric heating, in view of a hypothetic difference in the electric rate between day and night.

The data acquisition system is data-logger type.

The expected performance covers the thermal supply by 53% of the annual 63.400 kwh.

3.2 Climate description

Latitude: 39.04

Longitude: 17.04

Total solar radiation: 1382 kwh/m^2 year

Diffuse radiation percentage: 32%

Degrees Day: 1297

Annual sunshine hours: 2200

3.3 Building description

The design and construction are traditional. The external walls consist of double hollow brick work (8 cm. 5 cm. cavity 12 cm). The roof is insulated with 15 cm light weight concrete.

The main characteristics are:

Building Type: 6 Apartments

Floor area: 780 m^2

Design temperature External: +2 C°

Ventilation mass: 05 a.c.h.

Heated Volume 3300 m^3

Internal: 20 C°

Vol. Heat Loss: 1.51 W/m^3 K

Glazing: 10%

'U' values:Walls: 1.3 $W/m^2.K$

Thermal mass: 500 kg/m^3

Area: 74 m^2

Floor: 1.8 $W/m^2.k$

'U' value : 3.3 W/m^2. K

Roof/loft: 1.0 $W/m^2.k$

Annual energy Demand: 63,400 kWh

3.4 System description

Absorber Type: 50% Al Roll Bond. 50% Extrud Aluminium

Collector Area: 120 m^2

Orientation: 195°

Storage Volume: 7.5 m^3

Tilt: 90° 25°

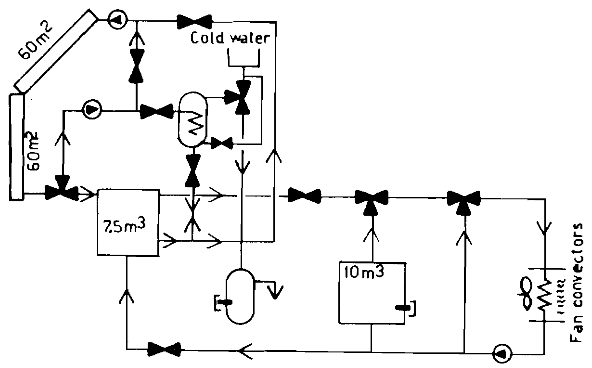
Coolant: Water/Glycol

Glazing: Single

Heat Emitters: Fan Coil

Auxiliary System: Electric Night Storage Heaters

The diagram of the system is the following



4. THE EXPERIMENTATION OF CROSARA DI MAROSTICA

4.1 Experimentatation description

The experimentation cónsists in the solar integration of a nursery school, designed to harmonize with the environment and to favour passive absorption thanks to its glazing in the southern side, which also holds the solar collectors.

The insulation performance is not particularly advanced, as it is typical of a later period around 1974-1975. The heating plant consists of two thermoventilation units provided with a solar-energy pre-heating battery and a post -heating battery fed by a gas oil generator. The supply of hot water is guaranteed by two superimposed boilers; the lower one, with a capacity of 1000 litres, is thermically fed by a solar circuit; the upper one has a gas oil integrated system in winter and an electric resistance system in summer.

The data acquisition system is a data -logger controlled by a microprocessor.

Solar energy covers 19% of the annual thermal needs passive excluded.

4.2 Climate description

Latitude 45.35 Longitude 11.35

Total solar radiation 1155 kwh/m^2 year

Diffuse radiation percentage 45%

Day degrees 2175

Annual sunshine hours 2126

4.3 Building description

The main characteristics are:

building type: reinforced concrete

Heated area: 558 m^2

Design temperature: external: -6°C

Glazing: 48% Area 270 m^2

'U' value: walls 0.81 W/m^2.k

Thermal mass 600 kg/m^3

Surface/volume ratio 0.29

Heated volume 1,900 m^3

Internal 20°C

'U' value 5W/m^2.K

Floor: 1.51W Roof 1.4W/m^2.K

Annual energy demand 100,800 kWh

4.4 System description

Absorber type: BLACK ALUMINIUM ROLL-BOND

Collector area: 106 m^2

Orientation : South

Storage volume: 1 m^3

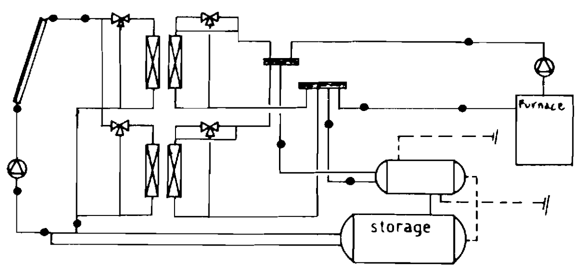
Auxiliary system: Gas Oil

Coolant: water/glycol

Tilt: 13° Glazing: single

Heat emitters: warm air

The diagram of the system is as follows



5. THE EXPERIMENTATION OF SEQUALS

5.1 Experimentation description

The experimentation consists in four solar-integrated one-family houses in Sequals(35 km. from udine). The main purposes of the project is to assess the possibility to apply solar energy to the one-familiy building tipology.

The prefabrication system has been used by means of tridimensional components.

The building heat insulation characteristics are in accordance with the requirements of the energy consumption containment N.373.

One of the purpose of the experimentation is to evaluate the external walls performance.

The absorption system consists of two sets of different tilt having a certain degree of building integration in order to exploit component techniques already known (aluminium roll-bond aborber).

The philosophy of the system is to exploit solar energy when it is available, keeping low storage values (1 m^3). In one of the four houses, a heat pump system has been installed between solar heat exploitation and use, in order to raise the thermal level of the coolant when it is not sufficiently high for a direct distribution.

The data acquisition system can be considered a second generation one as it is provided with selective data collection and a very high processing capacity. The thermal demand is expected to be covered by 42%.

5.2 Climate description

The climatic characteristics of this locality are the same as those of Fiume Veneto, already mentioned.

5.3 System description

The main characteristics of the system are:
The house is prefabricated by means of tridimensional components, generally parallelepiped boxes. These components are completely finished at the factory before being assembled on site. The wall insulation is obtained by means of a polyurethane layer placed between two structural concrete layers.
The structural performance of the house meet Italian law concerning earthquake prevention.

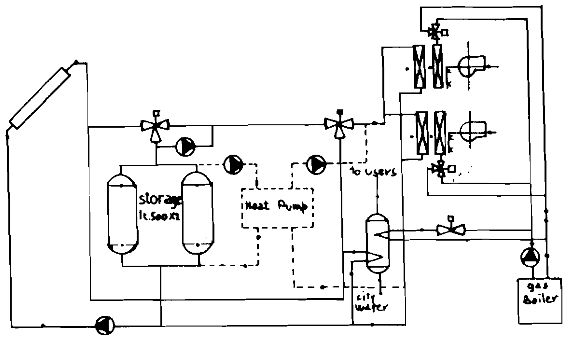
Building Type: Prefabricated house
Floor area: 95 m^2
Design Temperature: external -5 C°
Ventilation rate: 0.5 a.c.h.
Heated volume: 332 m^3
internal: 20 C°
Vol. Heat Loss: 1.035 $W/m^3 \cdot K$
Glazing: 9%
'U' values: Walls 0.71 $W/m^2.K$
Thermal mass: 380 kg/m^3
Area: 15.7 m^2
Floor: 0.58 $W/m^2.K$
U value: 3.3 $W/m^2.K$
Roof/loft: 0.71 $W/m^2.K$
Annual energy demand: 16513 kWh

5.4 System description

The main characteristics of the system are:

Absorber type: Aluminium Roll Bond
Collector area: 33 m^2 (apertura)
Orientation: 180 Tilt: 90° 45°
Storage volume: .5+.5 m^3
Auxiliary System: Gas boiler
Coolant: Water/glycol
Glazing : single
Heat emitters: Warm air
Heat pump: in 2 houses

The diagram of the system is as follows



6. FIRST RESULTS

At the current stage of data collection, we cannot yet evaluate the energy balances of the building/plant systems (about 8 discontinous months' data from Fiume Veneto and a few weeks' from Sequals are being processed); three orders of considerations have been however, identified.

The need of a better technical knowledege of the system running

The need of technical knowledge is better explained by referring to the work of the group reporting to the EEC, co- ordinated by Stephen George and Partners of London, carried out on the basis of the information relative to about 30 European experimentations

In the course of Fiume Veneto experimentation, several os the mentioned problems have been detected, concerning mainly the poor functioning of solenoid valves and of the regulation system, which caused a discontinuous functioning of the plant.
A further problem was represented by the high loss caused by the flowmeter, which did not allow to comply with the design requirements. Despite the many fluid stagnations within the collectors, caused by the above-mentioned deficiencies, no particular effects due to overtemperature have been observed.
As to the first quantity projections, it has been noted that the system efficiency appear to be remarkably low, around 12-15% (for the plant in Fiume Veneto); a more accurate design of the plant seems to be necessary in order to improve the heat distribution efficiency, trying to exploit the useful heat losses of the system as far as possible.

CONSIDERATIONS RELATIVE TO THE DATA ACQUISITION SYSTEM

In the course of the research we had to face two orders of problems: the first concerns the large amount of data to be managed, the second concerns the continuous and correct data recording on magnetic medium. These problems induced the researchers to set up a more versatile and efficient data acquisition system, whose technical description is here reported.
The system management and storage capacity are such as to release from a data collection with fixed-time sampling, and to organize data collection on the basis of" calls " from the various subsystems operating at a given moment, thus avoiding too frequent a sampling to systems which are not working (as, for example, the absorption system at night). This, combined with the good computation capacity, allows to reduce the number of data to be processed and consequently the time necessary to come to final results. Two systems of this type have been installed in the buildings of Sequals and Crosara di Marostica.

CONSIDERATIONS RELATIVE TO METHODS

The adoption of a data acquisition system of the above -described type can clearly allow to overcome, after checking, one of themost difficult problems relative to the significance of the data collected that is, the time of sampling.
It has to be remembered that in NBS(2) documents the suggested time of sampling was in the region of 5', and the simplified procedure that was first established for Italian buildings was 15'. (3)
From the point of wiew of measure, our main concern is the need to assess the working loss due to heat loss in the pipeline and to accumulation in the room to be heated. The phenomenon has resulted to be rather significant, and possible solutions for its precise assessment are being pointed out.
The thermographic analysis procedure, established when dealing with simplified procedure, was tested on the external walls of Sequals buildings. The results obtained surely allowed to properly evidence the thermal irregularities of the building external walls even if the global usefulness of this test is still being tested, in order to assess the building behaviour correlated to its solar integration.
It seems absolutely necessary to measure air temperature in various rooms which are significant in order to check the maintenance of comfort conditions.
In the next few months, we expect the preparation of a second series of the testing procedure for solar-integrated buildings, which will have a complete and long-run data-collection validity.

The final purpose is to establish a method, that is, procedures and instruments for control and testing operations of solar-integrated buildings after installation.

Summary

In this paper we describe an experimentation programme on solar-integrated buildings carried out by the Italian CNR within the framework of the "Progetto Finalizzato Energetico".
The main characteristics of experimentation are given together with the information on: climate, building, installation for four tested buildings which represent various types of building: multistorey apartment buildings, residential one-family houses, schools.
We eventually describe the first results obtained.

Résumé

Dans ce travail on décrit un programme d'expérimentation sur des bâtiments solaires entrepris par le Conseil National des Recherches au sein du "Progetto Finalizzato Energetica". On donne les caractéristiques saillantes de l'expérimentation aussi bien que des informations sur: le climat, le bâtiment l'installation pour quatre bâtiments mesurés qui représentent plusieurs types de bâtiment: maisons à plusieurs étages pour appartements, habitations résidentielles pour una famille, écoles. On decrit enfin les premiers résultats obtenus.

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Comparison of the performance of air/air heat pumps in small commercial premises

Mr E G A Goodall, MSc, MCIBS, CEng, MIEE, The Electricity Council, London, United Kingdom

Summary

An examination of the energy consumption of air/air heat pumps in various commercial premises shows considerable disparity between the actual and estimated energy consumption used by the heat pump and that of the direct electric heater batteries.

Recommendations as to sizing and operation of both heat pump and direct electric heating are given to ensure a reduction in peak electrical load and consumption of direct electric heat.

Sommaire

L'examen de la consommation d'énergie des pompes à chaleur air - air utilisées dans divers locaux commerciaux montre une disparité importante entre les valeurs des consommations d'énergie réelles et estimées pour la pompe à chaleur, d'un côté, et celles des installations de chauffage direct par résistance, de l'autre côté.

On précise des recommandations relatives à la taille et au fonctionnement de la pompe à chaleur et des installations de chauffage direct par résistance pour permettre d'obtenir une réduction de la charge de pointe ainsi que la consommation d'énergie électrique pour le chauffage direct.

Introduction

In the 're-discovery' of the heat pump considerable emphasis has been devoted to estimating the theoretical energy savings achievable in given situations, and subsequently to base all economic comparisons on the cost of this energy. Actual monitored results show that considerably more energy is used by the supplementary electric heaters than theory would predict and hence the theoretical energy savings are likely to be somewhat optimistic or at the worst misleading.

In the case of heat pumps of the air/air type, which often include electric supplementary heaters, little regard has been given to the implications of their operation either in energy or cost terms, particularly if the heat pump is subject to a demand related tariff. The effects of under-sizing a heat pump and not controlling the electric supplementary heaters sufficiently have emerged during the monitoring work by the Electricity Council on air/air heat pumps in differing commercial premises.

With the growing application of heat pumps of this type in commercial premises the full cost and energy saving potential of the heat pump will not be achieved if there is insufficient care taken in sizing, operating and controlling both the heat pump and the associated electric heater battery.

One notional method of demonstrating the amount of supplementary heating required is based on the S curve which is a frequency plot of the number of days a given external temperature occurs. Fig 1. For continuous heating with steady state analysis the area under the curve therefore represents the energy requirement for a given set of weather conditions and inside temperature. When the heat output from the heat pump is equal to the heat loss of the building, the temperature at which this occurs is designated the balance point and is generally 2°C to 4°C. It is assumed that the energy required for heating below this balance point will be made up by supplementary heat. Even if the heat pump is switched off (alternative operation) this amount of supplementary energy is still theoretically shown to be small.

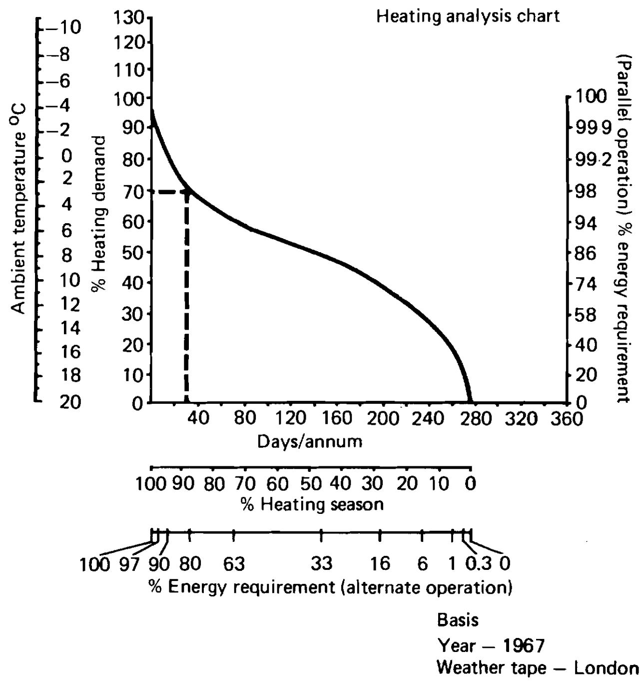

Figure 1. Distribution of energy requirement vs outside temperature.

Figure 1 shows that with a balance point of +3.5°C the supplementary heat in 'alternative operation' is 20%. [1] However, this simple analysis does not take into account intermittent operation of the heat pump, any errors in controlling the input of fresh air or control of the system. It was therefore no surprise that in the installation monitored, high energy consumptions by the supplementary heaters were recorded which increased the overall maximum demand charges and running costs generally.

Normal practice

With air/air heat pumps it has up to now been normal practice to select a unit to meet the cooling requirement of the building and to supplement the heating output of the heat pump, if necessary, by electric heater batteries. This direct electric heating is then normally divided into stages and is often controlled by outdoor limit thermostats. Thus the heaters can only come into operation when the outdoor temperature falls below the preset level of these overriding thermostats. However, the use of a simple 'two-stage heating' indoor thermostat, where operation of stage two calls for the additional supplementary heat, means that if the room temperature has fallen sufficiently, ie to stage two, the supplementary heaters can be brought into operation on a cold day even if the capacity of the heat pump is sufficient to meet the building heat demand. This will also occur if the preheating period in early morning is too short or if fresh air is introduced into the building during this time thereby increasing the effective heat demand. A similar situation could arise if the heat pump were undersized.

In energy and cost terms, therefore, the direct acting heater battery can 'steal' the duty of the heat pump, and if as is generally the case the heat pump is operated on demand related tariff, additional charges can result if preheating is carried on into the morning and coincides with the loads from lighting, water heating etc.

This fact tends to be omitted by many manufacturers presenting their running cost 'savings' for heat pumps and together with an underestimation of energy consumption of the supplementary heaters a misleading 'optimistic' cost savings potential is presented.

From a capital cost point of view heat pumps should not be sized to meet the full heating requirements at design day conditions, consequently some level of supplementary heat must be incorporated. The problem, therefore, is to minimise the use of this supplementary heating, either by varying the preheat period with an optimum start control or by including a multi-step controller on the staging of the electric heaters to 'off' load them as the outside temperature rises, thus reducing the effective maximum demand. A controller which incorporated both these features would undoubtably simplify the control of such heat pumps.

Method of energy analysis

In order to take into account the more practical aspects of heat pump operation in actual buildings a simple analysis has been devised which takes into account hours of occupation, preheat, ventilation and lighting for day/week, hours/day. Table 1. [2] Using basic heat loss data of the building, Table 2, and by considering the ratio of the output of the heat pump to the building heat requirement during preheating $^{Q}/_{Q_h}$ and during occupation when heat gains have to be taken into account $^{Q}/_{Q_H-Q_G}$, two factors identified as Rp and Rd are read off. These empirical factors are a measure of the amount of energy supplied by the heat pump and have been derived using weather data for the UK. See Table 3. For example, if $\frac{Q}{Q_H-Q_G}$ = 0.6 ie the output of the heat pump is 60% of the total design heat loss at $-1^{\circ}C$, then Rd = 0.64 which implies that the heat pump will provide 64% of the energy requirement. Alternatively, if $\frac{Q}{Q_H-Q_G}$ = 1 then obviously the heat pump will meet the full heating requirements with only the minimal use of supplementary heating, ie Rd = 0.94.

Table 1 Equivalent Hours of Operation Based on 20 Year Average Weather Data

Days Per Week	Hours of Occupation Per Day	Fabric Heat Loss Q_h kW Hours Per Annum		Ventilation Heat Loss Q_v kW Hours Per Annum	Lighting Heat Gain Hours Per Annum
		Preheat	Occupied Period		
5	7	960	620	750	1050
	8	900	750	850	1200
	9	850	860	950	1340
	10	800	960	1050	1500
	11	760	1050	1150	1640
	12	720	1130	1250	1800
6	7	1140	740	880	1260
	8	1070	870	1000	1440
	9	1010	990	1130	1620
	10	950	1100	1260	1800
	11	900	1200	1380	1980
	12	860	1280	1500	2150

In this method it has been decided that in order to minimise the use of the supplementary heaters the output of the heat pump including supplementary heaters during preheat should be approximately 1.5 times the fabric heat loss. Consequently when $Q/Q_h = 1.5$, Rp = 0.94.

Q_h = Fabric heat loss plus external distribution loss at -1^oC	- kW
Q_v = Ventilation heat loss at -1^oC	- kW
Q_H = Total design heat loss at -1^oC	- kW
Q_G = Internal steady state heat gain	- kW
Q = Heat pump output at -1^oC	- kW
A = Area of premises	- m^2

Table 2 Basic data required

Having determined Rp and Rd for a given installation the next stage of the calculation is to determine the heat pump and supplementary heat output for preheat and daytime operation. Table 4.

Whilst the method includes the effect of heat gains up to 20 W/m^2, gains above this level are calculated separately and 50% of this figure then deducted from the heat pump output.

The final calculation is to apply the average COP for the heat pump to obtain the heat pump energy input, and this together with the calculated supplementary energy will give the total energy input.

The accuracy of this method can be determined when compared with actual measured results. Table 5.

Whilst the calculated figures for the total energy requirement show a reasonably good degree of correlation to the measured figures, the split between heat pump and supplementary heating varies, and direct acting energy consumption varies as a proportion of total heating energy from 11% to as high as 66%. [3]

By referring to Table 6 some indication is given of the deviation of the actual heat pump installation from what may at present be considered as the ideal, ie an output of 1.5 x fabric heat loss with a maximum preheat of 6 hours, together with no fresh air during preheat and good control of the supplementary heaters. The large variation of supplementary heating energy 11 - 66% is a clear indication of the importance of correct sizing, extended preheat, control over fresh air intake during preheat and above all control over the staging of the supplementary heaters.

Table 3 Operation Factors for Heat Pump

Calculate Preheat Ratio Q/Q_h =									
Determine Rp =									
Preheat Q/Q_h	1.5	1.4	1.3	1.2	1.1	1.0	0.9	0.8	0.7
Factor Rp	0.94	0.83	0.77	0.73	0.69	0.66	0.64	0.62	0.6
Calculate Daytime Ratio $\frac{Q}{Q_H - Q_G}$ =									
Determine Rd									
Daytime $\frac{Q}{Q_H - Q_G}$	1.0	0.95	0.9	0.85	0.8	0.75	0.7	0.65	0.6
Factor Rd	0.94	0.85	0.8	0.76	0.73	0.7	0.68	0.66	0.64

Note: When $Q/Q_h > 1.5$ use Rp = 1; $\frac{Q}{Q_H - Q_G} > 1$ use Rd = 1

Table 4 Theoretical Heat Output (Using Equivalent Hours Table 1)

Heat Pump Output			Supplementary Heat Output		
Preheat			Preheat		
Q_h x Equivalent Hours x Rp	=	kWh	Q_h x Equivalent Hours x (1-Rp)	=	kWh
Day Operation			Day Operation		
Q_h x Equivalent Hours x Rd	=	kWh	Q_h x Equivalent Hours x (1-Rd	=	kWh
Q_v x Equivalent Hours x Rd	=	kWh	Q_v x Equivalent Hours x (1-Rd)	=	kWh
Total Heat Pump Energy	=	kWh	Total Supplementary Energy	=	kWh

Table 5 Comparison of actual and calculated energy consumptions

	Actual Energy Consumption kWh		Calculated kWh		Percentage Electric Heater Battery to Total Heating Energy: Actual	Percentage Electric Heater Battery to Total Heating Energy: Theoretical (from S curve)
School	Heat Pump	9,920	Heat Pump	10,475		balance point +6°C
	Heater Battery	19,751	Heater Battery	16,166		
	Fan	4,860	Fan	5,880	66%	10%
		34,531		32,521		
Shop	Heat Pump	8,904	Heat Pump	12,850		balance point +2°C
	Heater Battery	15,738* (total for H&V system)	Heater Battery	5,763		
	Fan	2,470	Fan	2,700	26%	1%
		27,112		21,313		
	* (Electric Heater Battery - Heat Pump 3263)					
Bank	Heat Pump	6,127	Heat Pump	4,180		balance point <-1°C
	Heater Battery	806	Heater Battery	2,217		
	Fan	3,017	Fan	1,320	11%	<1%
		9,950		7,717		
Office	Heat Pump	38,831	Heat Pump	30,591		balance point +1°C
	Heater Battery	37,808	Heater Battery	16,244		
	Fan	10,764	Fan	7,444	49%	<1%
		87,403		54,275		

Table 6 Assessment of heat pump capability to meet preheating and normal operation requirements

	Q/Q_h	Rp	Preheat Capability by Heat Pump	$\frac{Q}{Q_H-Q_G}$	Rd	Normal Operation Capability by Heat Pump	Comments
School	0.91	0.64	Insufficient	0.56	0.50	Insufficient	Heat pump undersized. Poor preheat control on direct acting heaters
Shop	1.23	0.75	Slightly low	1.3	0.94	Sufficient	Less heat from heat pump directed to stock room than anticipated. Higher consumption by localised heaters
Bank	1.57	0.94	Sufficient	3.2	0.94	Sufficient	Heat pump operated longer in cold weather to offset increased heat loss to unoccupied floor above - heat pump energy increased
Office	1.05	0.68	Low	1.14	0.94	Sufficient	Ventilation during preheat. Higher internal temperatures. Increased energy consumption

100% heat pump capacity $Q/Q_h = 1.5$

100% heat pump capacity $\frac{Q}{Q_H-Q_G} = 1.0$

Maximum demand costs

Shop

Output control of the heat pump was by a two-stage room air thermostat with the second stage controlling the electric heater battery subject to an external limiting thermostat set at 0°C. A time delay prevented the heater battery from operating for one hour from the beginning of the main timed period.

Nevertheless the peak demand of the heat pump was co-incidental with all other demands in the shop between 8 and 9am. Since preheating by the heat pumps continued until midday an unnecessary demand of approximately 15 kW arose. With a demand charge of £3.18/kVA a total additional charge of £47 was incurred for that month. Figure 2.

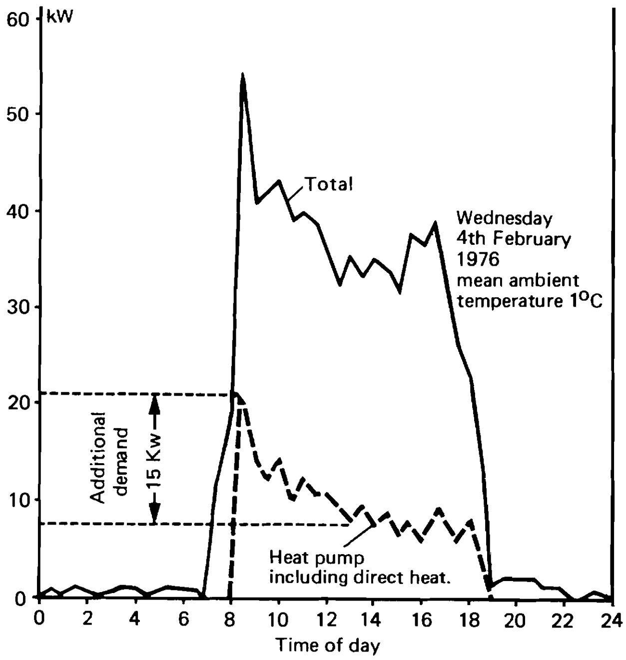

Figure 2. Electrical demand profile - shop

When considered on an annual basis the cost of energy for the heat pump was equal to the maximum demand charges which were incurred, ie £0.54/m^2.

Office

The output control was again a two-stage room thermostat with stage two controlling the electric heater battery, which in turn was subject to an outside limiting thermostat. Time switch control was used to give a fixed preheat period. As the electrical demand profile shows, Figure 3, the heat pumps were still preheating as other loads in the building were switched on at 8am, thereby creating a peak demand at 8.30am. The additional load created by the heat pump did not stabilise until midday and as such produced a further unnecessary 40 kW of load. With a maximum demand cost of £2.78/kVA a charge of £82 was thereby incurred for that month. The effect over the year was that the maximum demand charges of £1.50/m^2 were approximately half of the actual kWh costs of £2.70/m^2.

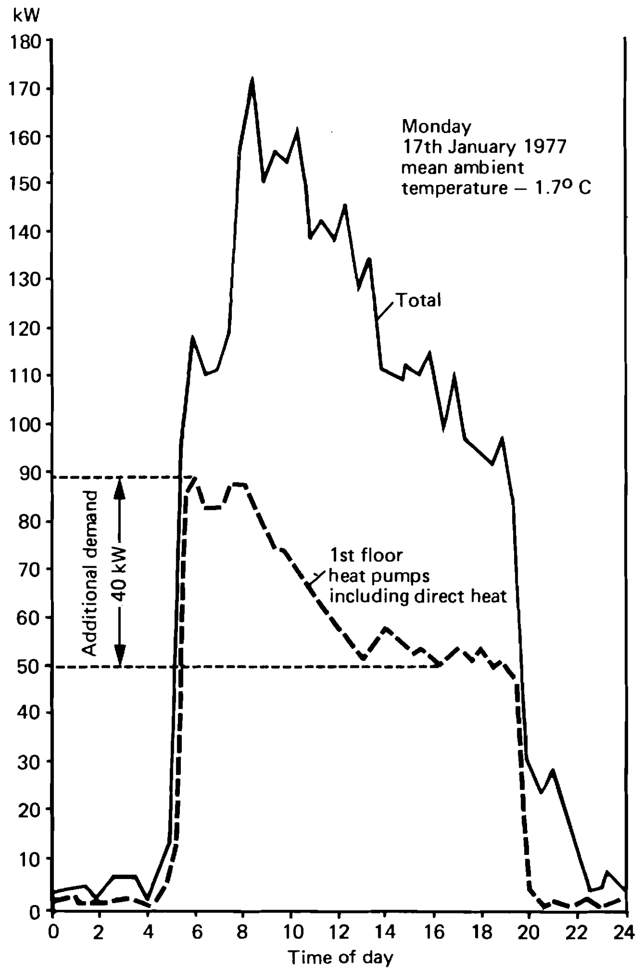

Figure 3. Electrical demand profile - office

Bank

Room temperature is under control of a two-stage heating room thermostat, whilst a duct thermostat in the return air ensures that during heating the dampers are set to give one air change per hour. A time switch is used to give a pre-set start but was actually reset during the trials to meet varying weather conditions, whilst overnight use of a set-back thermostat was also incorporated. The electric heaters were held off during preheat.

The demand profile in Figure 4 is shown for a Monday and even though a set-back temperature of 15°C had been maintained over the weekend preheating was too short. This, together with the low outdoor temperature created a high demand by the electric heaters during the occupied period.

The net effect over the year resulted in a total energy cost of £3.33/m^2 with maximum demand charges again being half of the unit cost.

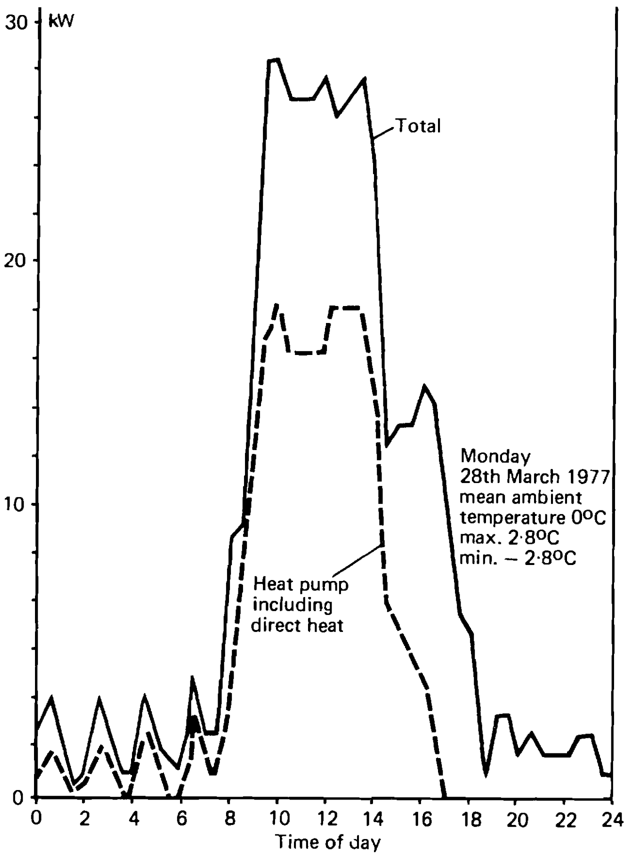

Figure 4. Electrical demand profile - bank

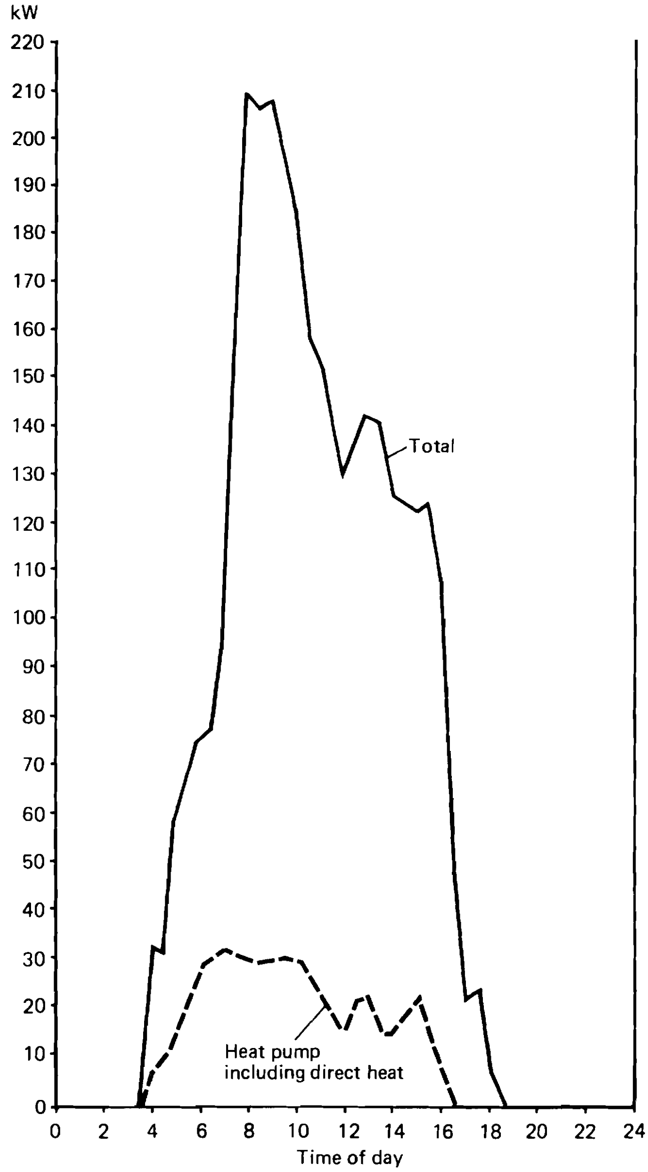

Figure 5. Electrical demand profile - school

School

Whilst an optimised start control is used to give varying preheat start times the proportional room temperature controller brought on all stages of the heater batteries until the room temperature was satisfied, therby reducing the effectiveness of the heat pump. Figure 5.

The overall energy cost was £2.30/m^2 but results are not available on the actual cost of the demand charges associated with the heat pump.

Conclusions

These four heat pump installations show the effect of incorrect preheat control and the subsequent need for a variable time/temperature start. This in turn has a direct effect on the consumption of the direct electric heater batteries and costs. Additional to this is the unnecessary cost of the demand charges which subsequently arise when preheating extends into the occupied period.

In calculating the energy consumption of a building heated intermittently by a heat pump, the inter-relation of the preheat period, the size of heat pump and control of the direct electric heating must in particular be taken into account. It has been demonstrated that oversimplification using steady state conditions can lead to serious underestimates of both energy costs and energy consumption.

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[1] von Cube, H L and Steimle, F
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A low energy house for a warm dry climate

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Summary

A research project to investigate potential energy conservation and improved thermal performance in dwellings is described. Water and space heating are identified as major areas of importance in terms of energy usage. This paper deals mainly with the design, construction and thermal performance of the building envelope. The installation and operation of a solar heating system using air as the heat transfer medium is also discussed. The results achieved to date in the low energy house indicate that where electric radiant room heaters are used, an energy saving of 70 per cent for intermittent space heating can be expected. The low energy house is shown to have an acceptable winter environment, even without room heating.

Sommaire

On décrit un projet de recherche qui examine un potentiel de conservation d'énergie et d'amélioration de performance thermale dans des demeures. Le chauffage de l'eau et de l'espace sont identifiés comme des zones importantes en tant qu'usage d'énergie. Cet article traite principalement du plan, de la construction et de la performance thermale de l'envelope du bâtiment. L'installation et le fonctionnement d'un systeme de chauffage solaire utilisant l'air comme moyen de chaleur transférée est aussi discuté. Les résultats obtenus jusqu'à cette date montrent que là ou dans une maison à énergie basse des radiateurs électriques à rayonnement sont utilisés, une économie d'énergie de 70 pour cent est prévue pour le chauffage intermittent de l'espace. La maison à énergie basse se montre comme ayant, même sans chauffage de pièce, une ambiance hivernale acceptable.

Introduction

As is the case with many countries, South Africa is now experiencing a relentless increase in the cost of all forms of energy. Consequently all sectors of the economy are engaged in energy saving programmes which are in various stages of development, and this paper describes such a project.

The electrical energy used in households in the domestic sector represents approximately 20 per cent of total national electricity consumption (1). Although this proportion is expected to remain nominally constant to the year 2000, there will be a move within the domestic sector towards electricity and away from solid fuel. Hence over the next 25-year period, a five-fold growth in the consumption of domestic electricity is anticipated.

Low Energy Experimental Housing Project (LEEHP)

In 1977 the National Building Research Institute (NBRI) commenced work on the low energy experimental housing project (LEEHP) as part of its ongoing contribution to national energy conservation. Surveys have indicated that water heating typically accounts for 45 per cent of domestic energy and that space heating possibly consumes another 15 per cent(2). Work on solar water heaters was already well established at the commencement of the project, and LEEHP brought together many well known and individually proven aspects of building technology in one comprehensive project. However, several features are new to the local housing industry and at an early stage of the project particular attention was given to the regular release of information to the media and the public. The LEEHP objectives were defined as follows :

(i) "to demonstrate that a home constructed from traditional materials, by traditional methods, can operate at low levels of energy utilization without the indoor environment being adversely affected";

(ii) "to evaluate the long term cost benefits of different energy saving options".

This meant that a direct comparison between measurements taken from full scale houses was a fundamental requisite for the project, and it was therefore established on that basis. It was decided to build, instrument and monitor two houses in Pretoria. The control house is a typical traditional middle-income home, whereas the low energy house embodies low energy features and an air space and water heating solar system. Sponsorship from the insulation and glazing industry was obtained for the low energy house, and the control house was financed by the national housing authority.

The north elevation of these two houses is given in Figure 1 and a floor plan of the low energy house is given in Figure 2.

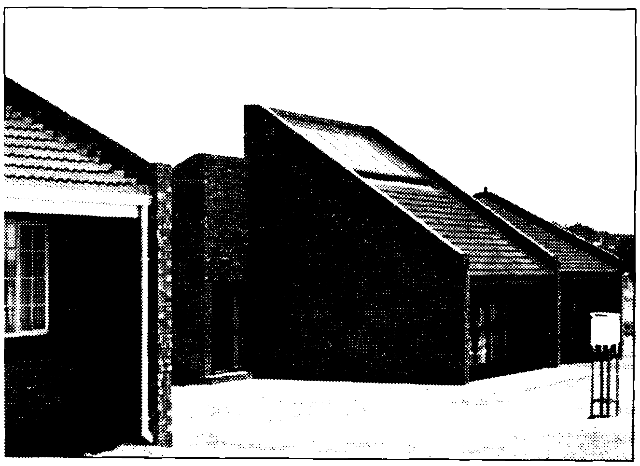

Figure 1. Low Energy House.

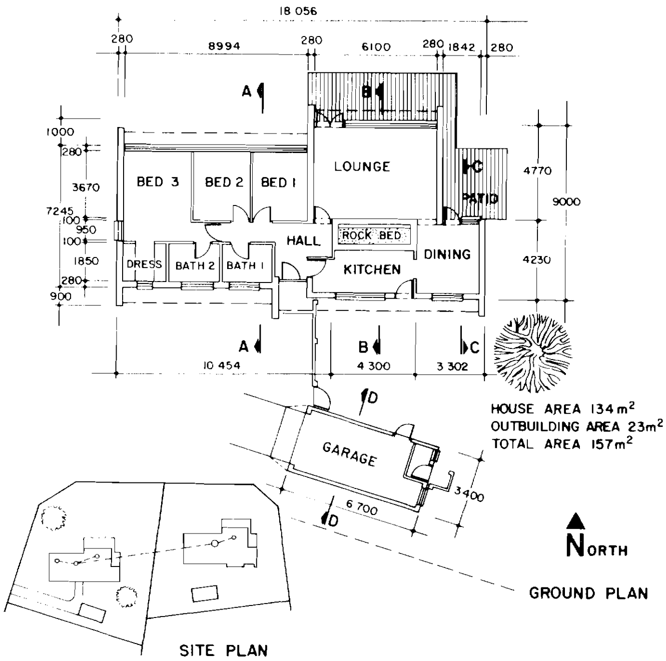

Figure 2. LEEHP floor plan

South African climate and its effect on house design

South Africa extends from latitude 22°S to 34°S and its inland climate can be broadly described as warm and dry. It receives a high level of solar radiation throughout the year, in all parts of the country, which varies from 5 700 MJ/m^2 on a horizontal surface at Durban, to 7 400 MJ/m^2 at Upington(4). Rainfall, humidity and summer and winter air temperatures vary considerably in different regions.

To cater for the relatively large daily fluctuations in our temperature and solar radiation, the majority of suburban houses are brick built, single storey, with sheet metal or concrete tile roofs. The plan-form is generally rectangular and the recommended orientation is north/south - i.e. with the long axis running east to west. This allows the north elevation to receive maximum solar radiation during the winter, while the roof overhang restricts solar gain during the summer. Glazed areas to the east, south and west are restricted according to the function of the rooms. The thermal design of the control house is better than that of the average existing house, or of the average new house which is currently being designed or built.

In broad terms, the climatic year can be divided into two parts. The winter period lasts between 90 and 120 days in most areas of the country, and some form of room heating is required in the evenings as the minimum outdoor temperature approaches freezing on a few nights per year. Spring and autumn are short and merge quickly with the hot summer period to form an 8-month period when ventilation and at least some cooling are the chief design criteria, because the average maximum temperature is in the order of 30°C. Figure 3 indicates a typical winter temperature profile, whereas Figure 4 indicates a typical summer profile as measured at the LEEHP site during 1979.

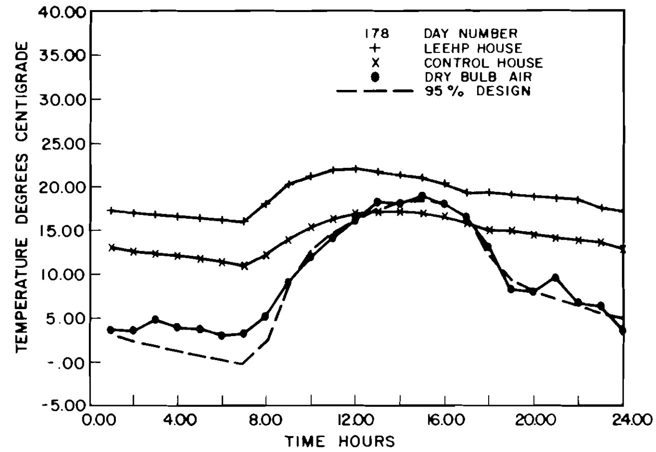

Figure 3. Thermal performance of low energy house. Typical winter day.

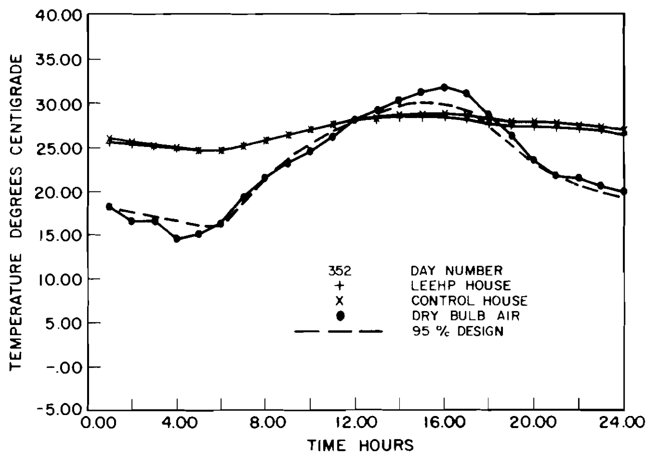

Figure 4. Thermal performance of low energy house. Typical summer day.

Winter heating was traditionally done by coal fire but this has gradually changed to electric heating, mainly radiant, as the latter is more convenient, and as a result of the introduction of no-smoke zones. The use of energy for summer cooling is very limited apart from the use of stirrer fans.

Design process

The design specification for LEEHP contained the following main points, and allowed for a two year monitoring period of the houses while they were unoccupied, followed by limited monitoring when the houses were occupied:

(i) two adjacent houses to be produced of identical size and appearance;

(ii) the floor area to be 135 m^2 and to include three bedrooms, two bathrooms, lounge, dining-room and kitchen;

(iii) both houses to have 280 mm cavity brick walls, with the 50 mm air space in the low energy house filled with glass fibre;

(iv) standard size, single glazed steel frame windows in the control house, with no special attention given to air infiltration. In the low energy house the maximum possible area of glazing to be provided on the north elevation with double glazing on all four elevations;

(v) a pitched roof sloping at 36° to the horizontal, clad with concrete tiles and supporting a prescribed area of solar collectors on the low energy house;

(vi) provision for either prescribed rock bed or water heat storage above ground floor level in the low energy house;

(vii) the low energy house to be heated by either warm air or warm water directly from the solar system;

(viii) both houses to have hot water storage cylinders of 180 litres capacity with 3 kW electric immersion elements. The domestic water in the low energy house to be pre-heated by the solar system;

(ix) the ceiling of both houses to be insulated with glass fibre; and

(x) consideration to be given to underfloor insulation in the low energy house.

The preparation of these specifications was influenced by the following factors:

(i) the overall approach was to be traditional rather than radical so that a majority of the public could easily identify their lifestyle with the project;

(ii) those energy conservation aspects which could be retrofitted into existing houses were to be given prominence;

(iii) the heating and lighting were to function in a constant and traditional manner whether or not the houses were empty or occupied; and

(iv) data logging was also to continue uninterrupted whether the houses were empty or occupied.

Thermal performance and analysis

Prior to the erection of the experimental houses, the NBRI had been investigating the possibilities of thermal performance analysis by computer. This resulted in the development of a modified version, namely ENERGY LOAD, of the NBSLD computer program developed by NBS in the USA (3), and LEEHP has really become the first building to be designed and monitored for the validation of this program in South Africa.

ENERGY LOAD comprises about 3 000 Fortran statements and is operated in batch mode. It has no direct graphical or financial analysis routines, and has been linked to other standard packages for the LEEHP analysis.

A comprehensive report on thermal performance of a building is produced from input data describing the building and its environment. This includes inside and outside surface temperatures, air temperatures in various zones, and the heating and cooling load, all on an hourly basis.

The procedure can be applied to a single design day, usually mid-winter or mid-summer. This was the method adopted for LEEHP. The alternative is to evaluate a full year of operation on an hourly basis so as to calculate heating and cooling energy requirements.

In the LEEHP analysis the variable factors were structured to minimize the computer time. The rate of air infiltration was initially set at 1,5 air changes per hour for both houses, although less air leakage was expected with the double glazing window frames on the low energy house. The required winter indoor drybulb air temperature was set at 20°C for the period 18h00 to 21h00 inclusive in both houses. Since the wall structure was fixed by the specification, it only remained to compare a range of window sizes with single and double glazing, combined with roof insulation and underfloor insulation. The result of this analysis was that the low energy house would require at least 6 kWh of heating during the period 18h00 to 21h00 to maintain 20°C during a mid-winter evening, and this could only be achieved if the infiltration rate was as low as 0,75 air changes per hour. To maintain the same condition in the control house, at least three times as much energy would be required if the roof space was not insulated. The results of the completed analysis are indicated in Table 1.

With regard to roof insulation, it was decided to initially have no insulation in the control house and 80 mm thick glass fibre in the low energy house.

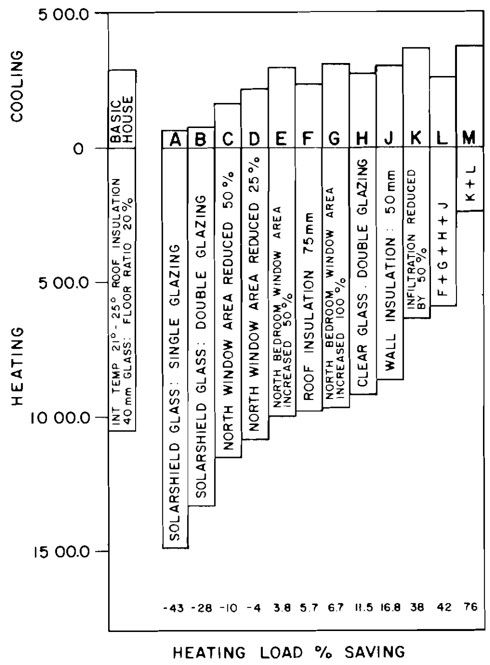

TABLE I

Estimated total yearly heating / cooling load. k WH.

Insulated ducting and ceiling diffusers; and

$6m^3$ of rockbed storage with its insulation and duct connections.

Since for domestic water heating in summer only about $4m^2$ of solar collector area is required, flexibility was introduced by means of a 1 000 litre water tank in the roof.

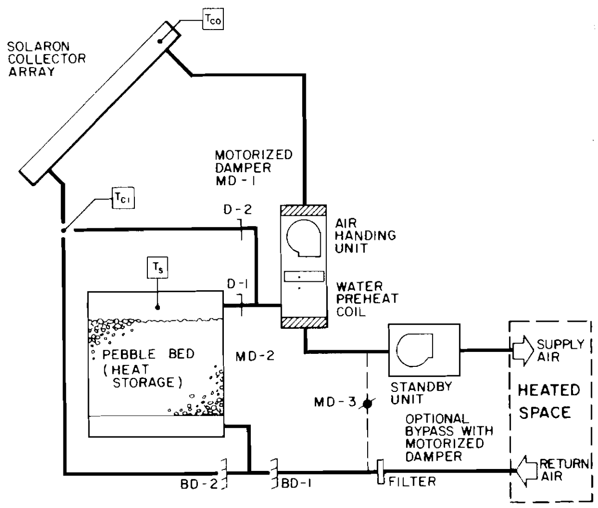

Figure 5. Solaron Schematic

Solar heating system

Having achieved a building envelope with a minimum rate of heat loss, consistent with practical and economic consideration, a solar system for space and water heating had still to be selected. Since no reliable information on the life of available water-based systems could be obtained, and because there was also doubt about the feasibility of maintaining a sufficiently high temperature for space heating purposes, the choice fell on an air-based system. Such systems also have no problems with corrosion or freezing, and a 20-year life can be anticipated for most components. Rockbed heat storage can maintain adequate supply temperatures, although it requires more space in the house - Figure 5. All the fans, controls and ducting can be located in the roof space, where working access is reasonable, but where vibration and noise can be a problem. Thus, although costing more initially than the equivalent water-based system, the SOLARON system as manufactured in the USA was selected. The system comprises the following components:

$12\ m^2$ of double-glazed selective surface collectors;

Main supply fan;

Motorized and manual air dampers;

Control unit;

Air/water heat exchanger;

Water pump;

Room thermostat;

Construction process

The control house was priced at R22 000, and the low energy house at R30 000, excluding ground costs. At the time of construction \$1 was equivalent to about 0,8 rand. The R8 000 cost difference was made up as follows :

Double glazing in timber frames:	R2 500
Floor, wall and roof insulation:	R 500
SOLARON system installed:	R5 000

The cavity wall insulation was manufactured in accordance with British Agrément Certificate No. 74/222.

Cavity wall insulation was also placed on all sides of the rockbed, except the top where access for filling and instrumentation was needed. The rockbed was filled using a nominal 37 mm crushed granite. No attempt was made to wash the rock exceptionally clean or to keep rigidly to the stated sieve size.

Data monitoring system

Transducers for the data logging system were installed at appropriate stages of construction. Platinum-resistance thermometers in matt black-painted globes were used in various parts of the house to measure globe temperature. They were also installed below floor level, in the rockbed, and at various points in the solar air ducting. Copper-constantan thermocouples were used in the cavity walls, on the plasterboard ceilings, and also in the solar water system. A solarimeter was mounted on the north facing roof in the same plane as the solar collectors. An underground cable carried data from the control house giving a total of 130 channels at one central data logger, scanning on an hourly schedule and recording onto magnetic tape. A heat source equal to the energy consumption of the logger was placed in the control house in the same physical location as the logger.

Data collection and analysis

The monitoring equipment was commissioned early in 1979 and a computer program to analyse the data was developed. It was decided that the first winter would be devoted to a study of the heat load requirements of both houses using electric radiant heaters, and to a comparison of the thermal performance of the two houses.

As far as the former was concerned, a daily routine was established in late April whereby room heaters in both houses were activated by a time switch. The capacity of the heaters can be set to either 750 or 1 500 W and this facility, linked to a progressive increase in the heating period, was employed as the weather became colder. Prior to each increase in the heating level, several days' data were accumulated to decide whether the stipulated 20°C internal temperature had been achieved in each house, to a satisfactory tolerance and in relation to the weather. The heaters were not controlled thermostatically.

When compared to previous years, the temperatures of the winter of 1979 were late in settling down and although the season was shorter than usual in its duration, it was more severe. However, by early June the heaters in both houses were in operation between 18h00 and 21h00 at the following capacities:

low energy house - 2,25 kW
control house - 7,50 kW.

The same quantity of electrical lighting was used in each house throughout the winter, also controlled by a time switch.

In order to evaluate the effectiveness of 40 mm of glassfibre roof insulation, this material was installed in the control house on 2 July. Room heating was terminated towards the end of June and 10 days' data in the unheated condition were obtained. Having insulated the control house ceiling, a further 10 days' monitoring without room heating was carried out. Room heating was restored to the previous capacity and the control house was found to be warmer by between 2° and 3°C. Towards the end of July, the heating capacity had been reduced to 6 kW in the control house in order to maintain an evening temperature of 20°C.

From the above figures the differences in heating capacity before and after insulation of the control house roof were 70 per cent and 62,5 per cent respectively. During the unheated period the average difference in night time temperature in the two houses between 18h00 and 05h00 the following day was :

before insulation - 4,5°C
after insualtion - 3,0°C

the low energy house being warmer in both cases. During this period, the temperature in the low energy house decreased from 19°C at 18h00 to 16°C at 05h00 the following day, while in the control house the corresponding figures were 15°C and 12°C. The low energy house was consistently about 12°C warmer than the outside air from early evening, while the control house was 9°C warmer after the roof had been insulated. This means that the low energy house does not really require any heating in the Pretoria climate.

Performance of the SOLARON system

During installation, several small changes were made to the system. Anti-vibration pads were included in the mounting of the fan to reduce ceiling noise. The individual solar panel assemblies were clamped together so that the air channel gaskets were well compressed. This point is particularly important since the panels are under negative pressure, and a small deflection of the roof structure could permit air leakage into the system. A visual display unit was constructed to indicate how the air dampers were set and which fans and pumps were running.

The system was run for long periods in March and again at the end of the winter. Although it was not run on the coldest days of the year, the results were encouraging although not up to design predictions. It was found that under fully automatic control the main fan started at about 10h00 in the morning and stopped at 14h30 in the afternoon. This is with the difference between the panel air temperature and the return air duct temperature sensors at the recommended factory setting of 25°C. During the 4,5 hour operating period, the supply of air temperature measured in the duct near the heat exchanger fell steadily from 60°C to about 45°C, while the return air temperature increased from 25°C to 30°C. By 15h00 most of the rockbed was at a temperature above 40°C while the water in the top half of the 1 000 litre water tank was also at about 40°C. In summer when the rockbed was not used, the return air was at 50°C.

Two fundamental problems were identified with respect to the unsatisfactory performance of the solar air heating system. At the air/water heat exchanger, reverse flow takes place as soon as the main fan switches off and considerable heat radiates back from the coil to the air in the duct.

The second problem concerns the gravity damper at the rockbed where the room air returns for re-heating. It was found that negative pressure extended through the panels and return air duct to the bottom of the rockbed and this was drawing in room air. Thus the demand of the fan was being satisfied by air from outside the system, and rockbed penetration was by pressure only.

These problems will, however, be rectified before the next winter when the system will be more fully evaluated.

Conclusion

Although the experiment has not been completed yet, the preliminary results show that considerable savings of energy are possible by paying careful attention to the proper thermal performance design of buildings. In this respect good correlation has been found between computer predicted and actual results.

A provisional cost benefit analysis indicated that the passive conservation measures added about 15 per cent to the cost of the house, but that the estimated energy saved would make the project viable.

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Balancing of water-heating systems

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Summary

Increased fuel costs and the threat of sudden rationings will strengthen the demands for actions to save fuel. Among the most important ones is the balancing of the heating system. Many heating systems are very badly balanced or not balanced at all. The reason often is that the pre-setting values and details concerning pressures and flow are omitted from the plans. Furthermore performance requirements are omitted or are not adequatly formulated.

A correct distribution of the water circulating in a central heating system between the different terminal units can be achieved in a number of different ways, depending of the size and nature of the system, the information provided by the designer and the outdoor circumstances.

In order to be able to check the performance of a system and to balance it, it is essential to be able to measure certain parameters easily. Certain physical equations, known to hold quite generally for central heating systems then can be applied.

Resumé

L'augmentation du prix du pétrole et les risques de rationnement éventuels, placent en priorité les mesures d'économie de l'énergie. Une de ces measures, parmi les plus importantes consiste à equilibrer les installations de chauffage. De nombreux systèmes de chauffage son déréglés ou n'ont jamais été équilibrés.

La raison de cet état de chose réside souvent dans le fait que les valeurs de préréglage et de débit ne figurent pas sur les plans d'installation.

Un équilibrage correct de l'eau circulant entre les différents radiateurs d'une installation de chauffage s'obtient différemment selon la saison, la conception et l'importance du système, et doit également tenir compte des données fournies par l'entrepreneur ou l'architecte.

Pour être à même de règler et contrôler le fonctionnement d'une installation, il faut pouvoir mesurer facilement certains paramètres tels que, température, différences de pression et débits. Connaissant ces valeurs, il est possible d'utiliser les relations physiques existant entre ces différents facteurs dans une installation de chauffage.

Introduction

Undesired temperature differences between the various rooms as a result of an uneven heat distribution exist in most buildings. The difference in the temperature between the warmest and coldest room may be quite high. An investigation including approximately 150 multi-family houses with heating systems not under full control showed that the differences averaged $4^{o}C$ and, in the worst cases, $8^{o}C$.

The coldest room will be the deciding factor when it comes to the fueleconomic operation. The heating systems in, say, dwellings, are normally dimensioned so that the room temperature can be maintained at $20^{o}C$. If the coldest room is to have a temperature of $20^{o}C$ then the other rooms will have a higher temperature because of an uneven heat distribution. Some people thinking it is too hot try themselves to lower the temperature by shutting off the heat. However, a very common way to lower the temperature, is to air out the surplus heat.

The main cause of uneven heat distribution is that the heating system is insufficiently balanced - or not at all. Other factors may also influence the room temperature such as the condition of the building construction, the functioning of the ventilation system, addition of heat of various kinds etc.

When calculating a two-pipe heating system it is assumed that the temperature of the supply water will drop an equal number of degrees in each heater. In order to meet this condition the flow of water must be proportionate to the size of the heat out put of the heater. The flow resistance of the heater valves must be adjusted partly according to the efficiency and the pressure difference available at each heater.

That means that if the heating system is not balanced in this way, the water circulating in the heating system will be wrongly distributed. With a pumping system the water circulation will be too strong in the terminal heaters close to the pump and too weak in those heaters situated farther away from the pump. The former heaters will then emit too much heat and the later too little heat. Because of this, the distribution of the room temperatures will be uneven.

There are several different methods for adjusting the heating system. The method chosen depends on the size of the heating system, the information provided by the designer, possibilities of carrying out check measurings, the time of the year when the work is carried out etc.

Previously the procedure was to feel with the hand on the bottom and top of the radiators and, guided by the estimated temperature difference, to determine the presetting. However, this method is fairly inaccurate since the hand is not a reliable measuring instrument. The method is acceptable when it comes to smaller installations, for example in bungalows, smaller family houses etc. In the case of larger installations it is necessary to proceed in a more rational and systematic manner and check the function by means of measuring instruments.

In the case of heating systems installed since the '50's one knows the resistance characteristics of the radiator valves fitted and of the control valves which are to be inserted for the branches. In addition, plans and drawings are available. Thus it is comparatively easy to calculate the pre-setting, if this has not been done by the designer. A good deal of the balancing process can therefore be carried out independent of the time of the year.

However, the calculations can not be carried out exactly and, in addition, one will have to allow certain unavoidable errors with regard to the resistent characteristics of the valves etc. For this reason the actual result should always be checked. This can be done by measuring the flow, pressure and temperature differentials.

As a rule the possibilities to penetrate the pipe systems for accurate measurements of flow, temperature or pressure are good except for old plants. Thus the relationships between the measurable parameters then are needed for determining of the required re-adjustment of the control valves during the balancing procedure.

Physical correlations

For a given circuit

$$\Delta p = \text{const}\ (G)^2 \qquad (1)$$

where Δp = the pressure loss/pressure difference and
G = the flow

One can also write

$$\frac{\Delta p}{\Delta p'} = \left(\frac{G}{G'}\right)^2 \qquad (2)$$

where the sign ' denotes the value at a changed setting.

For a number of parallel circuites, fig 1, numbered 1, 2...n, it is possible to show that

$$\frac{\Delta p}{\Delta p'} = \left(\frac{G_1}{G'_1}\right)^2 = \left(\frac{G_2}{G'_2}\right)^2 = \dots = \left(\frac{G_n}{G'_n}\right) \qquad (3)$$

and also that

$$\frac{\Sigma G}{\Sigma G'} = \frac{G_1}{G'_1} = \frac{G_2}{G'_2} = \dots = \frac{G_n}{G'_n} \qquad (4)$$

It also applies that

$$\frac{\Delta p}{\Delta p'} = \frac{\Delta p_1}{\Delta p'_1} = \frac{\Delta p_2}{\Delta p'_2} = \dots = \frac{\Delta p_n}{\Delta p'_n} \qquad (5)$$

At a given outside temperature the following approximation applies

$$\Delta t = \text{const}/G \qquad (6)$$

Where Δt = the temperature difference.

From (4) and (6) we get

$$\frac{\Delta t}{\Delta t'} = \frac{\Delta t_1}{\Delta t'_1} = \frac{\Delta t_2}{\Delta t'_2} = \dots \frac{\Delta t_n}{\Delta t'_n} \qquad (7)$$

Where Δt and $\Delta t'$ correspond to ΣG and $\Sigma G'$.

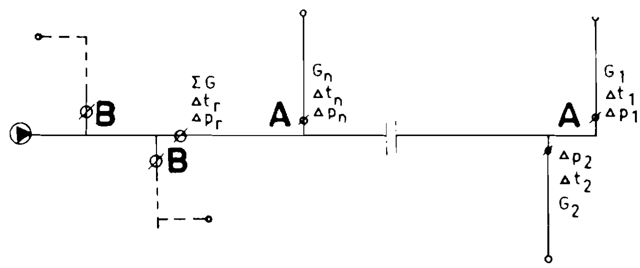


Fig. 1. Distribution net with check valves for branches (A) and larger groups (B).

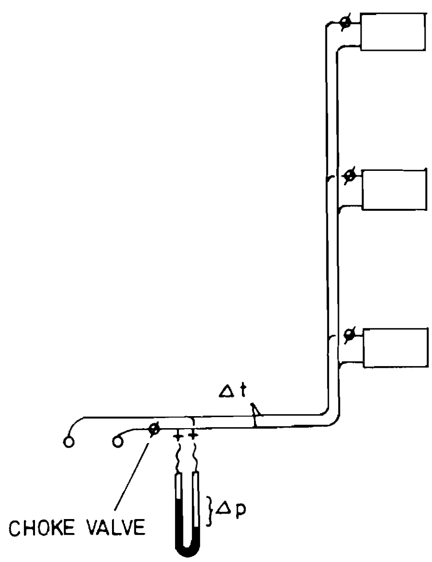


Fig. 2. Checking branch circuit and adjustment based on measured temperature and pressure difference.

When the setting of a control valve is changed the flow, pressure and temperature differentials according to (4), (5) and (6) are changed proportionally in the circuits "downstream" from the valve i.e. in the circuits from the checking point reckoned up to and including that furthest away from the pump. The so called proportional method for adjusting is based on this property of the heating system.

In certain cases it may be suitable to determine the presetting value with a combined pressure and temperature difference measurement, for example if a re-adjustment is required.

From equation (1) and (6) it follows that

$$\Delta p = \frac{const}{(\Delta t)^2} \qquad (8)$$

The correlation is shown graphically in fig 3. As a guide it is possible to apply the assumption done when carrying out the projecting, that the size of the temperature drop in a radiator system must be the same in all branches.

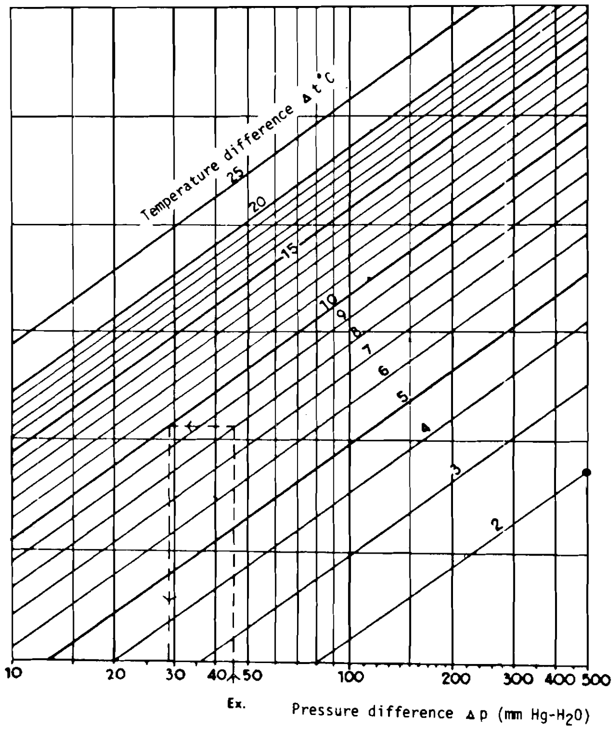


Fig. 3. Aligment chart for adjustment of branches taking the combined pressure and temperature difference measurements as a guide. In this example the pressure difference has been measured as 45 mm Hg and the temperature difference as 8°C. If a difference of 10°C is required, the control should be choked so that the pressure difference is 29 mm Hg.

In circuits where it is possible only to measure the temperature drop for instance in the heaters, one can work out a simple correlation between this and the coefficient of resistance of the radiator valve.

The following correlation applies to a circuit consisting of, say, radiator and coupling pipes (fig 4):

$$\Delta p = \zeta \gamma \frac{v^2}{2} + Rl \qquad (9)$$

where ζ = the resistance figure of the radiator valve and return coupling

γ = the density of the water

Δp = pressure difference

v = velocity of the water in the pipe

R = the coefficient of friction of the pipe

l = length of the pipe

Furthermore

$$G = const \cdot v \qquad (10)$$

and according to (6)

$$\Delta t = const/G$$

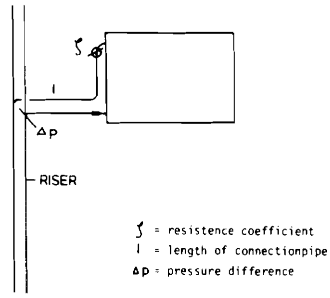


Fig. 4. Terminal unit with balancing valve connected to a branch.

From (6), (9) and (10) it is possible, after the following simplification, to obtain a simple manageable correlation. The term Rl in (9) can be omitted since the pressure losses in the connection pipes are normally small compared to the pressure losses in the valve. When carrying out adjustments of the pre-setting of the valves, as done during the final stages of the adjustment, the changes in the pressure conditions are relatively insignificant, so that Δp can be set as constant. When Δ is virtually constant, we get, after eliminating G and v

$$\zeta = const\ (\Delta t)^2 \qquad (11)$$

This correlation is shown graphically in fig 5.

This equation is applicable to branches too, if the pressure drop in the check valve is great in relation to that of the branch circuit.

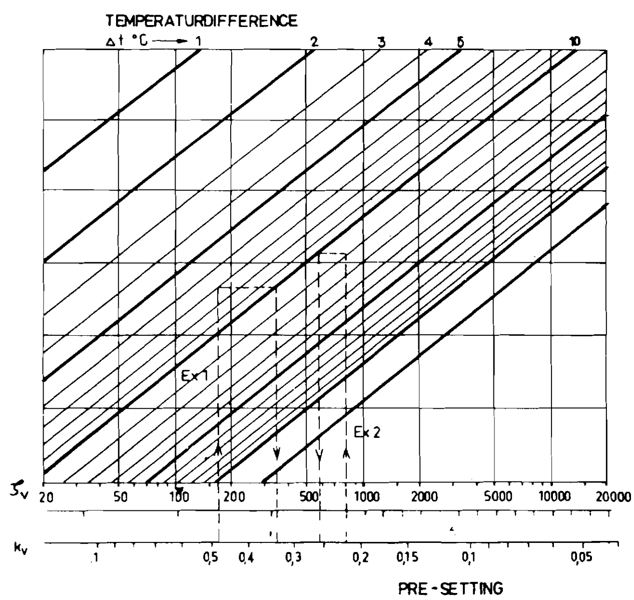


Fig. 5. Aligment chart for determining the pre-setting taking the temperature drop in the heaters as a guide.

Segeunce for balancing

1. Determining the pre-setting of the radiator valves

If the pre-setting is given on the drawings, then check the pre-setting scale referred to, the k_v-scale or any special scale applicable to certain valve makes.

If no calculations concerning the pressure losses in the circuitry are available, there is a short cut method to estimate the pre-setting value without re-calculation of the pressure losses, but of course this is less accurate. From the radiator description on the drawing, one can find the design value of the heat out put for each radiator. With that value, the k_v-value can now be found from table 1. This table will hold for systems with control valves in the branches.
This method has been used with good results in Sweden for more than twenty years.

2. Pre-setting of radiator valves

The setting of the radiator valves is carried out based on details obtained according to 1. After pre-setting each valve must be opened - the heat must be on. This is very important because of the consequent measurings. In a system just taken into use there is a risk for obstacles of the valves due to contaminations,
It is therefore advisable to wait with the pre-setting of the radiator valves until the contaminations in the tube system have been flushed out and the residues have been sedimented.

3. Determining and adjusting the pre-setting of the branch valves

3.1 Pre-setting of the branch control valves is given on the drawings.
Check the pre-setting scale referred to. If there are other types of valves then convert the pre-setting.

When all valves are pre-set, check the distribution of the water.

If no information is given on pressure or rates of flow it is possible to use the temperature drop in the branches as an indicator of the function. According to the design pre-requisites the temperature drop must be equal in all heaters and consequently also in all branches. As a guide line when carrying out checks and adjustments, the difference between the temperature of the main feed and return pipes, being the average value of the vhole heating plant, can be used.

By combining the measurings of pressure and temperature differences the adjusted pre-setting can be determined by means of the nomogram, fig 3. This gives a possibility to adjust the branches even when no pre-setting values or other information is given.

Another advantage by using the temperature drop as a guide line is that various sources of error are automatically eliminated, such as the uncertainties concerning the pipe calculation, safety factors when determining the pump data, changes in the layout of the pipeline, dimensions and number of heaters. Furthermore one must be aware of the fact that there is normally a great discrepance between the actual and design valves of the temperatur drop.

3.2 Pressure losses or rate of water flow in branches are given at the drawings.
In this case the balancing can be carried out according to the proportional method. Then it is advisable to have two pressure difference gauges, one should be situated on the branch farthest away from the pump to serve as a reference point. Guided by the other instrument the branche valves are then choked, starting with the one nearest the reference point so that the quotient between the measured value and the value given on the drawing agrees with that of the reference branch for

Table 1. Pre-setting values, kv-scale for two-pipe pump system.

Floor nr. 1)	Heat emission kcal/h at 20°C temperature drop / Flow l/h																Available pressure mm wg 2)
	200 10	300 15	400 20	500 25	600 30	700 35	800 40	900 45	1000 50	1200 60	1400 70	1600 80	1800 90	2000 100	2200 110	2400 120	
1	0,10	0,15	0,20	0,25	0,30	0,35	0,40	0,45	0,50	0,60	0,70	0,80	0,90	1,00	1,10	1,20	100
2	0,08	0,13	0,16	0,20	0,25	0,29	0,33	0,37	0,41	0,49	0,57	0,65	0,74	0,82	0,90	1,00	150
3	0,07	0,11	0,14	0,18	0,21	0,25	0,28	0,32	0,35	0,42	0,50	0,57	0,64	0,71	0,78	0,85	200
4	0,06	0,09	0,13	0,16	0,19	0,22	0,25	0,28	0,32	0,38	0,44	0,51	0,57	0,63	0,70	0,76	250
5	0,06	0,09	0,12	0,14	0,17	0,20	0,23	0,26	0,29	0,35	0,40	0,46	0,52	0,58	0,63	0,69	300
6	0,05	0,08	0,11	0,13	0,16	0,19	0,21	0,24	0,27	0,32	0,37	0,43	0,48	0,54	0,59	0,64	350
7	0,05	0,08	0,10	0,13	0,15	0,18	0,20	0,23	0,25	0,30	0,35	0,40	0,45	0,50	0,55	0,60	400
8	0.04	0,07	0,09	0,12	0,14	0,17	0,19	0,21	0,24	0,28	0,33	0,38	0,42	0,47	0,52	0,57	450
9	0,03	0,07	0,09	0,11	0,13	0,16	0,18	0,20	0,22	0,27	0,31	0,36	0,40	0,45	0,49	0,54	500
10	0,04	0,06	0,09	0,10	0,13	0,15	0,17	0,19	0,21	0,26	0,30	0,34	0,38	0,43	0,47	0,51	550
11	0,04	0,06	0,08	0,10	0,12	0,14	0,16	0,18	0,20	0,25	0,29	0,33	0,37	0,41	0,45	0,49	600
12	0,04	0,06	0,08	0,10	0,12	0,14	0,16	0,18	0,20	0,24	0,28	0,31	0,35	0,39	0,43	0,47	650
13	0,04	0,06	0,08	0,09	0,11	0,13	0,15	0,17	0,19	0,23	0,26	0,30	0,34	0,38	0,42	0,45	700
14	0,04	0,05	0,07	0,09	0,11	0,13	0,15	0,16	0,18	0,22	0,26	0,29	0,33	0,37	0,40	0,44	750
15	0,04	0,05	0,07	0,09	0,11	0,12	0,14	0,16	0,18	0,21	0,25	0,28	0,32	0,35	0,39	0,42	800

1) The floors are numbered from top downwards.

2) Estimated average values of pressure lossers in risers form the base for the table.

each branch. Please note that the qoutient will increase during the balancing procedure. When the last branch valve has been pre-set and if the calculations are correct, this should be equal to 1. Probably this will never occur, because of discrepancies between the actual values and those calculated by the designers. That doesn't matter, the main point is that the qoutes are equal.

Of course, the valves can also be set directly according to the values given on the drawing. If so, measure the pressure drop or alternatively the flow at the branch valves and then pre-set so, that the values on the drawings are obtained. When doing this start,with the branches nearest to the pump. The disadvantage of this method is that the pre-set value obtained the first is not correct because of the fact that pump head increases when the subsequent branches are choked. It is therefore necessary to go through it all again some times in order to obtain the correct value.

However, with regard to blockages in pipes and sources of errors when carrying out the pipe calculations, it is not at all certain that only adjustment of the branch control valves, so that the given pressure drops are obtained in the respective branch, will give the same temperature drop in the branches. Since the object of balancing above all is to obtain equally great temperature drops in all terminals, a measuring of the temperature should be decisive for the setting of the control valves. By combining pressure and temperature measurements the result will therefore be more accurate.

The water flow distribution can alternatively be chacked by measuring the flow by different devices such as flow turbine, Pitot-tubes incerted through self-sealing test plugs, calibrated valves, making the balancing procedure independent of the season.

4. Control and adjustment of radiator valves

Just like the branches the temperature drop in the radiators according to the design pre-requisites must be virtually equal to the system's average temperature drop. If the pre-setting of the radiator valves could be carried out quite correctly from the beginning, the temperature drop in the radiators should be the same after the branches have been adjusted. If the radiator valves are accurately made and if the calculations are sufficiently exact, it may be sufficient with a spot check to measure the temperature drop and check it. Further adjustment of the radiator valves to a greater extent may be necessary in certain cases, partly because some types of valves are not all accurately made and partly because of the error in the estimated values of the pre-setting. If the temperature drop across the radiator deviates from the average value of the entire system then the nomogram in figure 5 may assist to determine how much the pre-setting is to be changed.

In those cases where the resistance characteristics of the radiator valves are not known it will be necessary to estimate the necessary changing of the pre-setting and check again after a while.

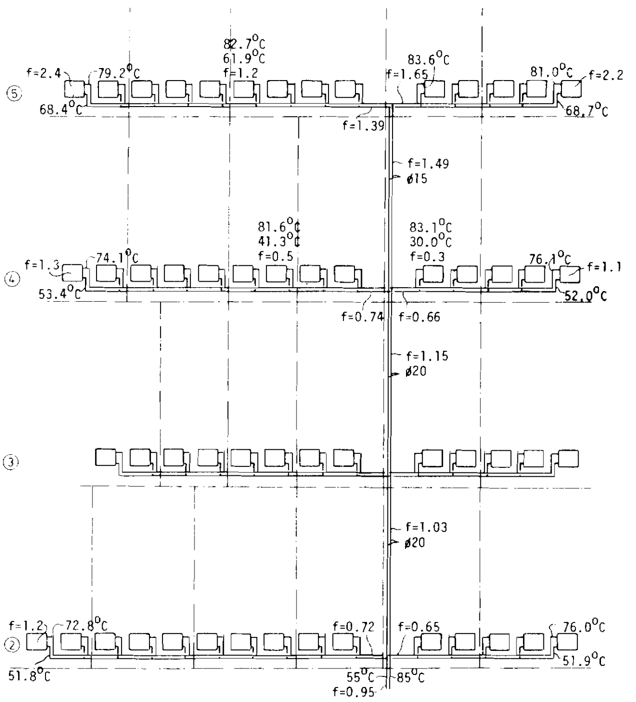
It is however completely meaningless to try to obtain exact equal temperature drop in every radiator. A few degrees deviation may be permitted.

A comment

The rule that the temperature drop should be equal in all heaters must be applied with some discernment, for example in systems where the emission of heat from pipes lying free has not been taken into consideration when dimensioning the radiators. In rooms with uninsulated pipes the consequently too large radiators should be compensated by choking the radiator valves so much that the temperature drop is higher than that which is average for the whole system. In rooms without uninsulated risers - normally on the top floor - the radiators must have a temperature drop which is smaller than the average. In well insulated buildings it is not uncommon that the heat emission from the pipes covers 20 to 30% of the heat losses from a room. To increase the heat emission by, say, 10% in excess of the design value makes it necessary to double the water flow. The pre-setting calculations can be quite complicated for such systems and can most suitably be carried out by means of computers (fig 6).

5. Re-adjustment of radiator valves in rooms, where the discrepancies between the actual and the calculated heat requirement causes deviations from the desired value of the room temperature to a degree which is not acceptable. The importance, from a heating economic point of view, is to eliminate too low room temperatures since these are decisive for the temperature within the entire building.

Too small a radiator can be compensated for to some extent by increasing the flow to the heater. In order to cut the energy comsumption, naturally the first measure is to eliminate the faults, whether it is due to the building construction, ventilation system being not balanced and so on. In unfavourable cases it may be necessary to change to a larger heater.



Floor	Heating effect W Designed	Required	From Pipes
5	4 800	5750	860
4	4800	4280	1050
3	4450	4280	1100
2	5140	4650	1150

Flow and return temperature, designed value 80/60°C

" " " " required " 85/55°C

$f = \frac{\text{required rate of flow}}{\text{designed rate of flow}}$

Fig. 6. Required rates of flow - according to computer calculations - related to design values to cope with undersized radiators on the top floor due to insufficiently insulated floor slab of the attic. The water temperature is decreased due to the heat emission from the uninsulated pipes.

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The function of heating systems with thermostatic radiator valves having no pre-set maximum flow.

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Summary

Thermostatic radiator valves are becoming more and more common in Sweden, but they have not always fulfilled expectations of reduced energy consumption and improved functioning of heating systems. One of the reasons for this is that in planning new systems or replacing manually regulated valves in existing systems those properties of thermostatic valves that are a consequence of their self-contained function have often been neglected. These properties make certain demands of any system in which thermostatic valves are to funtion. This is particularly true for dual-pipe systems, which must be balanced by pre-setting either the thermostatic valves or an auxiliary valve so as to ensure the correct flow distribution between the different heaters.

Resumé

Les vannes thermostatiques équipant les radiateurs de chauffage sont de plus en plus répandues en Suède. Or, elles ne répondent pas toujours aux espoirs mis en elles d'une diminution de la consommation d'énergie et d'un meilleur fonctionnement des installations.

Au stade des études d'avant-projects d'installation, ou lorsqu'on remplace les robinets manuels par les vannes thermostatiques, on néglige trop souvent de tenir compte des "effects secondaires" découlant de leur automatisme: une installation de chauffage comportant des vannes thermostatiques doit être calculée en fonction de ces vannes. Ceci est surtout valable pour des installations bitubes où les différentes fonctions des circuits sont fortement dépendantes l'une de l'autre.

1. Introduction

Studies carried out at the National Swedish Institute for Building Research have shown that thermostatic radiator valves have a number of serious faults - marked hysteresis, unacceptably high conduction of heat from the valve to the temperature sensor and various production faults causing large deviations from the intended water flow rate. These findings have led to a requirement for certification. Government loans for energy conserving home improvements are now only granted for the installation of thermostatic radiator valves that are of an approved type, 5

However, the function of thermostatic radiator valves will be strongly dependent on the properties of the system in which they are to be installed. They will function quite differently in two-pipe systems with direct return, two-pipe systems with reverse return and one-pipe system. The systems themselves must also fulfill certain requirements since the end result is determined by the interaction between them and valves themselves.

This paper deals primarily with the influence of proportional deviation and the usual production faults. The results of a number of field trials are also reported.

2. Proportional deviation and differential pressure

The principle on which thermostatic radiator valves function is based implies a number of limitations and disadvantages. They are of course mechanically self-contained with a function that depends on relatively large temperature differences in the surrounding air. Manufacturers recommend that valve dimensions should be selected to give a proportional deviation (proportional band) of 2 K, which implies that a difference of 2 K must exist between set temperature and sensing element for the valve disk to lift to the extent giving the required flow at the given pressure difference. Related values of pressure drop, flow and 2 K proportional band are usually given in the form of a diagram (Fig. 1), often including values for a 1 K proportional band.

For the valves to function in this way, so that all terminal heaters have the same proportional deviation the system as a whole must fulfill certain requirements. These are discussed below as they apply to two-pipe systems with direct return.

The importance of ensuring that each radiator circuit has the differential pressure that yields the required flow is illustrated in the following example:

Two radiators are connected to the same point, one designed to give 1160 W and the other 580 W for a 20 K temperature fall. The flow rates should then be 0.014 and 0.007 l/s respectively (Fig. 2).

According to the diagram in Fig. 1 the pressure loss at the thermostatic radiator valve on the larger unit will be 1000 Pa for a proportional band of 2 K. If the pressure loss in the connecting pipes is neglected the pressure loss at the junction, point A, should be 1000 Pa. The smaller unit will have a pressure loss at the valve of 250 Pa at 0.007 l/s according to Fig. 1. The driving pressure for this circuit is, however, 1000 Pa. There is an excess of 750 Pa which according to the above quotation should be eliminated. This can be achieved either by using a separate auxiliary valve or by the thermostatic valve if it can be preset.

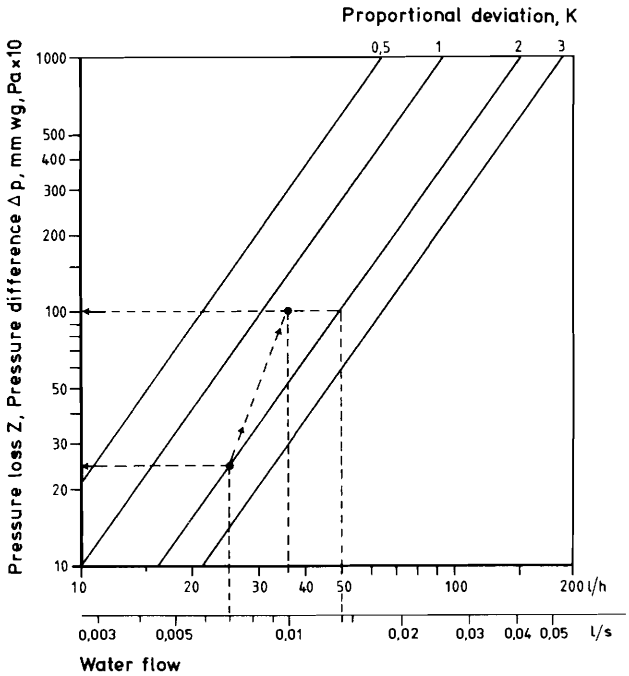

Fig. 1. Pressure/flow diagram for a thermostatic radiator valve, as given in the manufacturer's catalogue, for different proportional bands.

E.g. For a 2 K proportional band and flow-rates of 0.014 and 0.007 l/s (in the radiators shown in Fig. 2) the required driving pressures are 1000 and 250 Pa respectively.

If both radiators are connected to the same point and the excess pressure is reduced at the smaller radiator by a thermostatic valve, the flow rate will be 40% too high and the proportional band will be 1.2 K instead of the 2 K assumed. Room temperature will be 0.8 K too high.

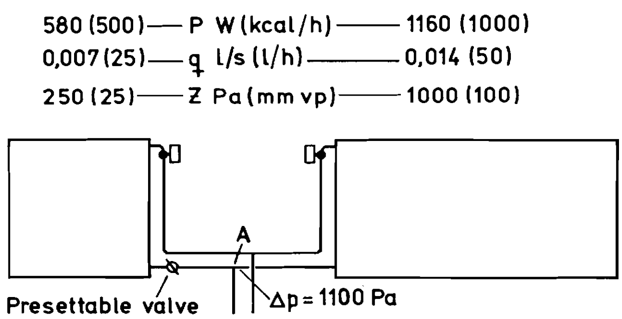

Fig. 2. Two radiators are connected to point A. If pressure losses in the pipes are neglected the available driving pressure for the smaller radiator must be the same as the pressure loss across the larger - 1000 Pa. Only if this is reduced to the required value of 250 Pa by means of an auxiliary valve will both radiators have the same proportional band and both rooms have the same equilibrium temperature. If no auxiliary valve is fitted the flow in the smaller radiator will be 40% too high as shown in Figs. 1 and 3.

Some manufacturers have claimed that such pre-setting is unnecessary as thermostatic valves are self-adjusting! Let us see what in fact happens if the excessive pressure differential at the smaller unit is reduced by the thermostatic valve alone:

Assuming that the pressure difference at A is constant the initial flow in the smaller unit will be as great as in the larger unit, that is 100% too great. Then the room temperature consequently begins to rise the thermostatic valve will constrict the flow until equilibrium is achieved with a certain flow and a raised room temperature.This can be determined by means of a matching procedure using Figs. 1 and 3. The latter shows room temperature as a function of the flow rate through the radiator for different outdoor temperatures. The design room temperature is assumed to be 20 K. It may be shown that equilibrium is achieved at 0.010 l/s, i.e. with 40% too high a flow rate and 20.8 K room temperature at ±0 K outdoor temperature. The thermostatic radiator valve at the smaller unit then has a 1.2 K proportional deviation maintaining the smaller room at a temperature 0.8 K higher than that of the larger room. The error increases at lower outdoor temperatures as may be seen in Fig. 3.

In practice the driving pressure at point A will fall below 1000 Pa. This will have the effect that the flow through the larger radiator will be too small and the room temperature consequently too low.

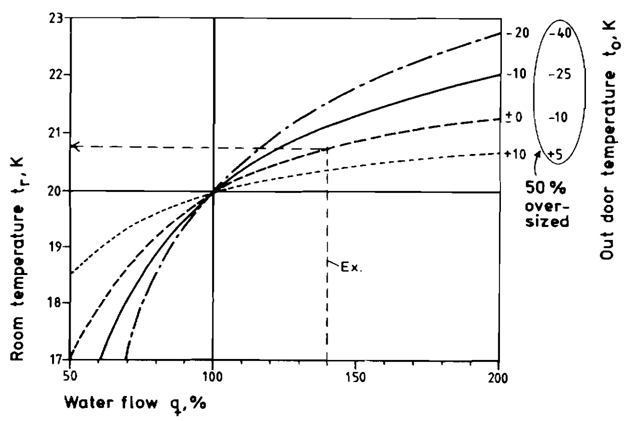

Fig. 3. The relationship between room temperature t_r and radiator flow-rate q for different outdoor temperature t_o in a system designed for 80/60 at -2 K.

E.g. If q = 140% and t_o = 0 K, t_r = 20.8 K.

It should be noted that over-sizing, which implies a lower supply temperature than here assumed, leads to smaller errors of this kind. For example, if radiators are 50% too large, t_r +20.5 K in the above example. Heat exchange with neighbouring rooms will in practice reduce somewhat the temperature deviations calculated from the diagram.

If the system is over-sized the difference in room temperature will be smaller, e.g. with 50% over-sizing 0.5 K. However, in the example the relative size of the units was 2:1. The greater the difference between them, the greater will be the difference between the resulting room temperature. A ratio 3:1 would result in a temperature of 21.5 K in the smaller room.

Multi-storey buildings

In multi-storey buildings the pressure difference will be greater the further downstream the radiators are connected to the trunk group. Assuming that the pressure difference is 6000 Pa and that two radiators, connected to the same trunkgroup as in the previously mentioned example, are designed to deliver 930 W and 465 W, flow rates will be 0.011 and 0.0055 l/s respectively. In this case even the larger radiator will have excess pressure. According to Fig. 1 the pressure difference need not be greater than 600 Pa across the larger and 150 Pa across the smaller. With an outdoor temperature of ±0 K, equilibrium will be established at 20.8 K in the larger room and 21.3 K in the smaller room. The flow rates will be no less than 50% and 100% too large, respectively.

The result will be that radiators higher up in the building will have progressively reduced flow rates. In the lower floors the flow rates will be greater than design values, in the upper flows less than design values. The lower floors "steal" heat from the upper while the smaller rooms "steal" from the larger rooms. These systems with thermostatic radiator valves must be balanced by adjusting pre-settable valves, in the same way as systems with manually regulated valves, (3, 4).

This example also shows that even if the thermostatic radiator valves are factory-adjusted to give the same room temperature the flow distribution between radiators will be incorrect.

A further source of error in unbalanced systems is that a thermostatic radiator valve when subject to local cooling can open so much that the increased flow through the radiator acts a short circuit. This can powerfully reduce the flow through other radiators on the same trunk-group, in extreme cases even cause it to cease altogether. This can be caused by such a common occurrence as an open window.

In an unbalanced system it is not possible to periodically reduce room temperatures uniformly in a building by reducing the supply temperature. This has little importance for dwellings under Swedish conditions as the energy conservation achieved each day by an 8-hour reduction of room temperatures is only 2-3% in heavy buildings and about 5% in light buildings. In schools, officies and workplaces where lower temperatures are acceptable over the weekend and during the greater part of each 24-hour period, the possible energy conservation is much greater and cannot be neglected.

In a hypotherical future energy crisis the problem must be formulated differently: how can room temperatures be uniformly reduced? With manually operated valves room temperatures can be simply, and above all, quickly reduced by reducing the supply temperature by means of a centrally placed regulating valve. Thermostatic radiator valves on the other hand, must all be reset to the maximum permitted room temperature, otherwise many dwellings and rooms will be left without any heating while those nearest the boiler will be able to maintain only marginally reduced temperatures. Several million thermostatic radiator valves will therefore have to be reset. How can such an unimaginable task be carried out in a short time?

A common method of dealing with the problem of unbalanced systems is to raise the supply temperature. This raises the temperature in the lower rooms, the thermostatic radiator valves close, thereby increasing the flow to radiators in the upper rooms and raising their room temperature. However, a completely uniform temperature throughout the building can only be achieved by means of a very large increase in supply temperature. It should be noted that raised supply temperatures lead to a raised average room temperature and increased heat consumption. A further disadvantage of raising the supply temperature is that pressure differences across the thermostatic radiator valves will increase as the pump-pressure is moved outwards towards the radiator circuits by the reduced flow in the pipe system. This leads in its turn to noise problems that must be eliminated in other ways.

3. Effect of differences due to manufacturing tolerance.

Valves are bound to differ due to unavoidable manufacturing faults, giving slightly different flow rates for the same pressure loss and setting. Studies undertaken by the National Swedish Institute for Building Research have shown that lift height of the valve disk may differ considerably between valves at the same room temperature. The variation between valves differs between manufacturers and can be several tenths of a millimeter. The valve-types investigated had a variation of ±0.1 mm for the best type and ±0.3 for the others. The lift heights is only of the order of 0.5-0.5 tenths of a millimeter with a proportional deviation of 2 K. The variation between valves is therefore of the same order of magnitude. This can lead to very large flow differences.

For example: in a thermostatic radiator valve of a certain make the lift height should be 0.4 mm for a flow of 0.01 l/s at 500 Pa pressure difference. If the lift height varies between valves by ±0.2 mm the error can be up to 50% and flow can be anything between 0.005 and 0.02 l/s. Fig. 3 shows that ±50% error in the flow leads to a room temperature deviation of -3 K or +0.8 K from 20 K with an outdoor temperature of ±0 K. Since thermostatic radiator valves are to a certain extent self-correcting the deviation will in practice be less - the valve will reduce the flow when it is too high and leads to a raised room temperature, and vice versa. However, it has been shown above that they cannot compensate fully for incorrect flow rates.

4. Calibration - balancing in the field

The two underlying reasons for incorrect flow rates dealt with above may potentiate or compensate for each others effect on room temperature. It is tempting to raise the supply temperature in order to increase the temperature of the coldest rooms. The thermostatic valves in the warmest rooms will then reduce their flow, so the differences in room temperature will be reduced. However, this is achieved at the cost of raising the average room temperature and thus of increased heat consumption. The correct measure is to recalibrate the thermostatic radiator valves in the cold rooms, and naturally those in the warm rooms too. The supply temperature need not then be increased if it was originally set correctly.

Whether thermostatic radiator valves are easier and quicker to adjust than normal valves is an interesting question. A relevant point in this connection is that it is important to know where the valves are situated on the hysteresis curve when they are calibrated, i.e. on the way up or down. The hysteresis measured in the valves studied by SIB was between 0.5 and 3 K, which implies that a calibration error or this magnitude can occur on some valves unless they are at all at the same point on the curve. This will seldom be the case as the heat demand can recently have increased in some rooms and decreased in others as a result of heat gains differing intime and space.

5. Field experience

The consequences of neglecting to balance a system have been very clearly demonstrated in a comprehensive study in Landskrona, where thermostatic radiator valves were installed in three eight-storey buildings. Room temperatures were found to be too low in the upper floors. A 6 K increase in the supply temperature did not suffice to eliminate this fault. It was also necessary to carry out a considerable amount of calibration on the thermostatic valves. The increased supply temperature caused many of the valves to close completely, leading to large differential pressures and noise generation. To eliminate these disadvantages the pumps were then fitted with variable speed regulators. It was also found that the circulation through a whole trunk of the system could be terminated completely by such a commonly occuring event as a short-circuit through a radiator caused by cold air from an open window falling on the thermostatic valve.

A spot-check in an area of three-storey dwellings fitted with thermostatic radiator valves set to a maximum of 21 K showed room temperatures between 20.5 and 22.5 K together with some extreme values (Fig. 4) around 19 K and 23-24 K, the latter caused by heat from the baking of bread. The fact that the average was 21.5 K indicates that the available pressures were greater than had been assumed.

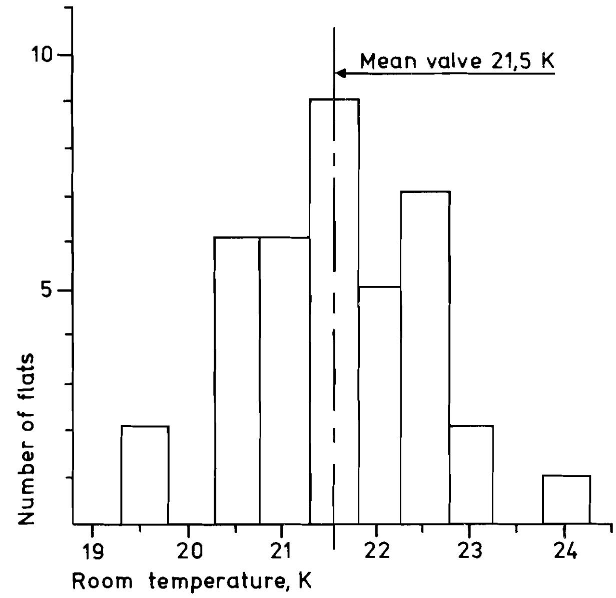

Fig. 4. Room temperature distribution in a random sample of 35 flats with thermostatic radiator valves set to close completely at a room temperature of 21 K (2).

In an area of terraced houses heating system was already adjusted, the actuator of each radiator valve was replaced with a thermostatic insert. This gave rise to the following chain reaction of events. Room temperatures bacame too low in several dwellings distant from the boiler. Raising the supply temperature did not help. Following the advice of a pump manufacturer, the circulation pump was replaced with a larger version. The temperature was still too low in a number of dwellings. The increased pump pressure gave rise to noise problems in the thermostatic radiator valves and to negative pressure in a number of the upper radiators, which therefore filled with air and became cold. In order to solve the latter problem is was considered that the expansion chamber should be raised - rather an expensive solution as it was situated on the roof of the boilerhouse.

Room temperatures were measured in a new office building before and after calibrating the thermostatic radiator valves to give 20 K according to the manufacturer's instructions. The measured values for overcast weather and -3 K outdoor temperature lay between 19 and 25 K before the calibration and 20 and 24 K afterwards. The variation was reduced to a negligible extent by calibration.

The above account applies manily to two-pipe systems with direct return. They must be balanced by presetting either the thermostatic radiator valves themselves or an auxiliary valve, and the former must be adjusted to close completely at the given maximum room temperature. Only in this way will the correct flow-distribution be achieved and running costs minimised. Only in this way will it become possible to achieve a night-time or weekend temperature set-back and to centrally control room temperatures by altering the supply temperature in resonse to the energy supply situation.

6. Two-pipe systems with reverse return

In systems where both trunks and radiators are connected with reverse return, the possibility of successfully fitting thermostatic radiator valves is much improved. They will have much greater authority and the relationship between required and available pressure differential at each valve will vary within much narrower limits than in systems with direct return. It is still necessary to be able to pre-set maximum flow rate at each valve, however, because the radiators will normally have differing flow rates and because the paired supply and return pipe runs, though equally long, have different pressure losses in supply and return will there be no excess pressure.

If thermostatic radiator valves are to be fitted to either kind of two-pipe system it must be ensured that the flow rates will not be too small where the heat demand is low as is the case in new, well insulated, buildings in Sweden. The design values of heat output from the majority of the radiators in new buildings cover a range of 300-900 W. Thus the terminal heaters must be designed for a lower temperature drop than normal. Pressure variation and accompanying noise problems can be avoided if the thermostatic radiator valves are designed as three-way valves.

7. Single-pipe systems

Single-pipe systems have a numver of advantages, among them than successive radiator circuits cannot interact hydraulically and that balancing need only be carried out for whole loops and trunk groups, provided that the terminal heaters are correctly dimensioned. Noise problems do not occur, neither is it difficult to reduce room temperatures uniformly throughout a building by reducing the supply temperatures. If the loops are loaded uniformly the pressure loss will be the same for all valves. They will therefore all have the same proportional band since all radiators have the same flow rate under normal conditions.

Flow rates will be high even if the radiators are small. The pressure loss at each radiator will be small. These two factors ensure that the thermostatic radiator valve will have great authority. It therefore appears that single-pipe systems are the most suitable for thermostatic radiator valves.

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Testing flat plate solar collectors in conditions of variable insolation

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Summary

The author discusses briefly the need for reliable performance data. Then assuming a universal acceptance of the Hottel Willier efficiency curve examines alternative test methods.

The need for a test which can be performed under any 'solar' conditions is examined and one such dynamic test is detailed. The test conditions and subsequent data manipulations are related to the various correction factors which have to be made.

Finally the paper examines the way in which some test parameters may be varied to optimise the value of the data obtained. The effects of such changes are balanced between the collector behaviour and the improvements which can be expected in the results.

Résumé

Rappelant brièvement le besoin de résultats fiables concernant l'efficacité des collecteurs plans, l'autour étudie différentes methodes d'expérimentation en prenant pour hypothèse de base la couribe d'efficacité d' Hottel Willier.

L'autour souligne la nécessité d'un type d'expérimentation qui puisse être utilisée quelque soient les conditions d'ensoleillement et, à cet effet, détaille une méthode de test dynamique.

Les conditions d'expérimentations et les manipulations de données qu'elles entrainent sont présentées en fonction des differents facteurs de correction rendus nécessaires.

Enfin l'autour discute la façon dont certain paramètres d'expérimentation peuvent être changes de manière ā optimiser la valeur des données obtenues. L'efficacité de ces variations de paramêtres en fonction du comportement des collecteurs es aussis étudiée.

Reliable performance data on solar collectors is a basic requirement of the industry and the user. Industry needs to evaluate the effects of design changes on performance and later for product control. The user requires a measure of the probable annual savings against the initial costs.

Test techniques and equipment which can satisfy these varied demands differ considerably. A research test facility has many data points and extremely high accuracy with a resulting high cost. Product control on the other hand may be simple and comparative rather than detailed and basic. The needs for commercial evaulation and for the user are rather more difficult in that both accuracy and low cost are essential.

The degree of accuracy required in commercial testing has never been satisfactorily determined, and at present it is very much a blend of what is commercially available and what the involved parties considered desirable. This is understandable for in practice the probable long term output of a solar collector system is carried out using hourly meteorological data and standardised load demand patterns.

On this basis it is only necessary to define collectors in narrow bands of usefulness. It is however commercially desirable that different test centres produce the same performance results and on a comparative basis maintain the same order of performance over any range of collectors.

The second part of the requirement is the cost. This is a two part item where the cost of installation will be recouped over many tests but the cost of carrying out the test will be direct to each test. Whilst the former depends upon the accuracy requirements and equipment used, the latter is mainly manpower and time, i.e. the test method and procedure adopted.

The N.B.S. test

The first and most basic test for Flat Plate Solar Collectors which had a detailed specification and universal appeal was that of the American Bureau of Standards. This test, based upon a series of test runs, each with different though constant input conditions (coolant temperature and insolation) allows a period for the collector to reach equilibrium, prior to taking the test data, produces extremely good results. The output is an efficiency curve based upon the Hottel Willier equation.

The curve is satisfactory for most uses, since the test technique eliminates not only variations of the coolant input temperature and insolations but also the effects of thermal mass. The equilibrium conditions allow the "instantaneous efficiency" to be calculated and for small errors to be removed by averaging.

The use of a tracking mount to the collector, or short test periods of one or two hours over midday allowed the solar input to be maintained near normal to the collector. All input radiation losses were considered to be collector losses.

Alternative test methods

The efficiency curve from the N.B.S. test had almost instant appeal but the United Kingdom along with most other maritime areas could not match the insolation stability required by the test specification.

The climate of the United Kingdom has not only a very wide variation between mean summer and mean winter insolation values but has a daily and seasonal variation of the direct radiation to indirect radiation ratio. Over the year the ratio is approximately 1.0. It can also produce cloud patterns which create an ON, OFF effect with the direct component.

The variability of the weather, and the probably protracted periods in the winter when testing out of doors would be impossible, resulted in the development of a number of alternative methods.

The continuous or dynamic method and the one described in more detail later in this paper, uses the full variable input combined with input corrections and data averaging techniques to obtain the results. Continued pressure for both general and research tests which would be independent of the weather had meanwhile generated two other alternatives.

A separated sequence which uses an external test facility to determine the 'Transmission Absorption' value, and a true indor test to determine the collector's loss coefficient. In performance terms the external work involved requires a full test facility and the indoor work, whilst reducing the need for stable insolation conditions, itself requires stable indoor conditions in terms of air temperature and wall radiation effects. Also the loss factor determined by inputting heat to the collector via the coolant is not the same as that which occurs when the coolant removes the heat from the collector.

The solar simulator is a much more complex proposition and still presents problems both in giving the correct solar spectrum and in maintaining parallelism of the resulting radiation. The need to change the radiation level at the collector creates difficulties in maintaining any set spectrum and the best answer so far requires that the simulator itself be moveable for both distance from the collector - intensity changes - and around the collector - change of angle of the radiation to the collector.

A Black Box method is at prèsent under development in which the collector is treated as a single complex element and its transfer function determined by testing, nominally under external conditions. The method requires computer facilities either on line or alternatively a high rate of data acquisition. It will if successful reduce the external test time to a level where suitable conditions could be expected to occur most of the time.

Continuous dynamic testing

Continuous or dynamic testing of a solar collector defines a method of obtaining satisfactory performance data by testing over one or two full days, accepting the insolation and environmental conditions which occur. Even so some limiting factors such as high winds and very low insolation levels do create unusable periods.

The method was considered to be close to actual operating conditions and the test loop was given a storage unit sized at 50 litres/m^2 of test collector. The storage unit is direct feed and in this differs from UK standard practice. This was necessary to prevent rapid changes of the collector output coolant reflecting too quickly at the collector coolant input. The coolant temperature's natural pattern may be varied to create additional points at the low end of the efficiency curve.

The instrumentation used complies with the accepted requirements for accuracy. The input and output temperatures to the collector plate are monitored by Grade A Calibrated Platinum Resistance Thermometers which when used with the standard correction formula give an accuracy of 0.01 degree C. The response time of the PRT's used is 3 seconds.

The system flow is measured by a turbine flow meter with pulse output and over the range used has a reading error of 0.25%. Correction for mass flow and specific heat against volume flow is made from the collector's input coolant temperature. Viscosity effects are ignored as these are smaller than the flowmeter accuracy.

The solar radiation is measured by Kipp and Zonen Solarimeters and whilst the system error is small, there is a possible error in any tilted solarimeter, which shilst unknown, may be up to $\pm$ 4%. The instrument response time is 3 seconds to 70% and 30 seconds up to 99% of the time reading. During tests the solar radiation data is available as an instantaneous value and as integrated values over the time period between successive data scans.

In the United Kingdom the input solar radiation is composed of direct and indirect radiation in almost equal parts, though wide. Daily and seasonal variations do occur. Since these two radiation components affect the collector in different ways two solarimeters are used, one for the total input, and the second, using a shadow ring, for the indirect component.

The two solarimeters are initially corrected for temperature, and for tilt angle using manufacturers' data. The two values have then to be combined, however corrections are required for ground reflectance and for the lost segment of sky arc covered by the indirect instrument's shadow ring.

The following assumptions are made:-

1. That the direct instrument sees only a segment of sky arc (due to the angle of tilt). Sees all the direct radiation and a measure of ground reflectance.
2. That the diffuse (indirect) instrument sees only a segment of the sky arc, minus a sector covered by the shadow ring together with a measure of ground reflectance.
3. The reduced values are calculated as if for a horizontal surface and then transformed to the tilt angle of the collector.
4. Because the panel efficiency curves assume that glass losses for the sun normal to the collector are part of the collector's total losses the solar angle transmission losses are calculated on the incidence angle (for each reading). The transmission at normal (0°) is divided by the transmission at the calculated angle. For angles less than 60° this may be closely approximated by the fourth root of the cosine of the angle calculated.

Test procedure

A dynamic outdoor test on a solar collector in the UK usually results in a plethora of points at the upper end of the plot and a scarcity at the lower end. Since it is impossible to obtain an accurate efficiency curve from the points at the upper end only, a reasonable number of data points at the lower efficiencies is necessary. This distribution of points is perhaps not surprising. In the morning the insolation increases rapidly and the ambient temperature only slowly. The collector efficiency is high with a low but rising T value. Over midday the insolation steadies, the coolant temperature continues to rise as does the ambient temperature. i.e. a slowly decreasing efficiency. In the afternoon whilst the insolation decreases rapidly T remains constant, resulting in a rapid loss of efficiency and relatively few data points. An increased number of data points can be acquired by steadily reducing the temperature of the coolant during this period. In practice this is difficult, however, it is felt that the problems created are more than offset by the additional number of data points acquired.

The "Classes Programme" is a means of reducing the data concentration by averaging and producing a more even distribution of points along the efficiency curve. It is a more balanced alternative to a least squares linear regression analysis on the full data set.

It uses either direct scan data or a variety of time averaged data. The first step is to remove data points which are wild together with the points closely associated with them in time. It handles the data in blocks bounded by equal steps on the efficiency graph's base line, since these are more precisely defined.

With each block a running mean is maintained and the first 'n' values are stored. In turn each successive new point is checked. If closer to the running mean than one of the existing 'n' points it replaces the point. The result is a series of 'n' points within each block, and these are used for the lease squares linear regression analysis.

Both the block size and 'n' can be chosen by the operator. The only limit is that there must be at least 2n points within any block for the block to be used in the final analysis.

This method of analysis produces good results, and a close fit in those cases where N.B.S. test results are available. In one case, where an individual collector already had two separate N.B.S. test result sets, the curve derived as above, lay between the other results.

Data scatter

Using dynamic outdoor test data corrected as previously defined, an efficiency plot will show some scatter. The degree of scatter depends upon the type of collector under test and the environmental conditions. Under stabilised test conditions, e.g. the N.B.S., the time between data scans is of no consequence but with variable conditions the time between successive data scans should be equal to the time taken by an increment of coolant to pass through the collector. Only then can we expect the altered output to reflect the total input. Further more, with this scan interval, changes to the input temperature of the coolant become less critical.

The N.B.S. test calculates, from the data taken in each scan, an instantaneous efficiency. However, where the inputs and hence the output are variable the collector's thermal mass creates two sources of data scatter.

1. Due to the transient loss or gain of input energy.
2. To an effective time shift as the input energy reacts with and moves through the collector plate.

This time shift could be calculated from the "Thermal Diffusivity" of the collector plate and since it is directly analogous to the Time constant of an electrical condensors, the delay created should be unaffected by frequency or by the level of energy within the collector. A practical approach is to use a twin plot of solar input and output temperature, from which a sensible delay time can be obtained.

Averaging

In practice the scan rate can be adjusted to the flow time of the collector though the addition of a time lag between two interwoven scans cannot be achieved with a normal data logger.

The data scatter created by the inertia effects, like the insolation variations, is random and is removed by averaging. Time averaging is perhaps the most common averaging technique which is carried out and it sometimes proves effective in reducing the scatter of data points. However it's effectiveness cannot be predicted since it depends both upon the duration of the solar variations which have occurred, the collector used and the time period chosen. Whichever averaging technique is used, all rely upon the fact that over a long enough period random variations will cancel out.

The best time average will occur when the scan rate equals the transfer rate of coolant through the collector and where an integrated total input is used with the requisite number of spot outlet temperature measurements.

Building design and air-conditioning systems for energy saving in NTT

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Summary

Nippon Telegraph and Telephone Public Corporation (NTT) attaches importance to energy saving that is a world-wide requirement due to the critical energy resources situation.

This paper presents an overall concept on the energy saving efforts made by NTT building engineering sector. The Clean Recycling Committee's activities for NTT energy saving strategy establishment, energy saving technical means in NTT building projects, such as outside air cooling, solar energy utilization etc., and air-conditioning system energy saving effect evaluation methods are introduced.

Résumé

Nippon Télégraphe et Téléphone (NTT) attache de l'importance aux economies d'énergie qui sont une nécessité du niveau mondial à cause de la situation tendue des ressources d'énergie.

Cette communication donne une vue globale de efforts en matière d'économie d'énergie qui sont faits par le secteur du bâtiment de NTT. Les activités de comité pour l'établissement de notre stratégie pour l'economie d'énergie, les mesures techniques pour l'economie d'énergie dans les projects de bâtiments, par exemple le refroidissement en utilisant l'air extérieur, la climatisation en utilisant l'énergie solaire, etc., et les méthodes d'évaluation de l'economie d'énergie sont présentés.

Introduction

Nippon Telegraph and Telephone Public Corporation (NTT) is a huge scale public enterprise responsible for every sorts of telecommunication services in Japan with 330,000 employees. It's building engineering sector maintains about 6,000 existing buildings whose total floor area is 18,210,000 square meters and constructs approximately 400 new telecommunication buildings annualy.

Obviously, such a giant corporation should thoroughly recognize the importance of energy saving that is today's worldwide requirement, and put pertinent counter meausres for it into practice.

NTT has established a committee whose responsibility is confering on energy saving strategy, applying energy saving techniques to NTT building projects, such as a cooling system using outside air for a high-rise telephone building, solar energy utilization system in an existing telephone building, etc.. NTT is also researching engineering concerned with energy saving, and establishing an energy saving effect estimation and evaluation method.

NTT energy saving strategy

NTT's energy consumption

Though telecommunications greatly contributes to the national benefit, the energy consumption in it's facilities is comparatively small, because of the electronics engineering development. Telecommunication itself can be said to be one of todays energy saving devices. For instance, it reduces the necessity for people to move about in order to accomplish information exchange, which would require much more energy consumption by public and private transportation.

However, a vast amount of energy is consumed in numerous NTT buildings all over the country. Figure 1 shows NTT's annual energy consumption in 1975.

It is estimated that 45 % of total energy consumption is for telecommunication use and 31 % of it is for air-conditioning use. Therefore, the importance of the energy conscious building design and energy saving techniques in air-conditioning system is recognized.

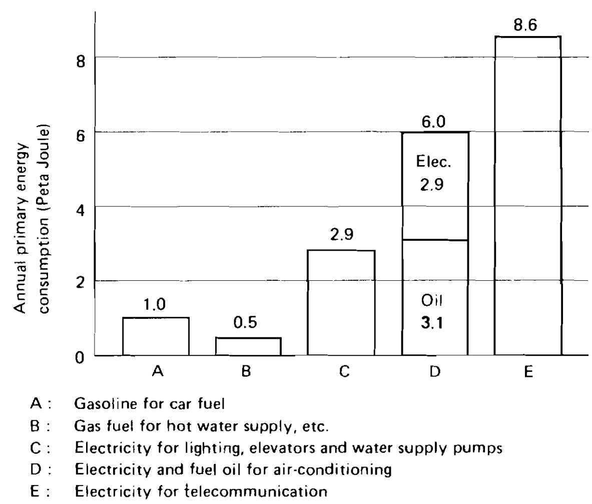

Figure 1 NTT's annual energy consumption (1975)

Committee's activities for energy saving

NTT established Clean Recycling Committee, which is responsible for making policy and for deliberation on the environment and resourses conservation problems since 1973.

The clean recycling committee consists of three ad-hoc-committees. These are waste materials ad-hoc-committee, concerned with the disposal and reuse of waste materials, material resources saving ad-hoc-committee, concerned with the saving of material resources such as paper, wood, metal, etc., and energy ad-hoc-committee. The energy ad-hoc-committee consists of new energy utilization group and energy saving group. Themes treated by energy ad-hoc-committee relating to the building engineering are energy saving measures in building and air-conditioning system design assigned by energy saving group, and solar energy utilization system development assigned by new energy utilization group. This committee's activities give the target and guide for NTT's energy saving strategy, which is directly involved in NTT's energy saving engineering.

Building energy saving technical means

NTT building engineering sector regarded the air-conditioning energy consumption reduction as one of the most important design aims before the oil crisis in 1973. For example, studies on heat recovery system started in 1968, and heat recovery system operation was started at Yokosuka telecommunication laboratory (total floor area 95,000 square meters) since 1972 and at Osaka data-communication office (total floor area 120,000 square meters) since 1974, resulting in successful effect. After the oil crisis, many energy saving technical means were undertaken, corresponding to the Clean Recycling Committee's activities. These are mentioned hereunder.

Common energy saving measures in air-conditioning

Following items are energy saving measures that can be commonly applied to new building design as well as existing building improvement. These are included in NTT's recently revised air-conditioning system design guide.

1) To prevent dust and contaminants from entering equipment rooms, it is desirable to keep air pressure inside the equipment room slightly higher than the outside air pressure. This is accomplished by forcing fresh filtered air into the air-conditioned equipment room to build up the room's interior air pressure.

Formerly, too much outside air had been introduced for this purpose. Producing a higher air pressure than necessary resulted in wasted energy consumption. NTT studied minimum outside air intake volume in various experiments and reduced it by 20 % of conventional volume. It is estimated that the air-conditioning energy consumption is reduced about 6 % with this countermeasure.

2) ON/OFF control using a thermostat should be applied to ventilating fans for electric power supply rooms that were manually operated conventionally.

3) Each air-conditioning mechanical component should be devided into several units and be controlled to obtain highest efficiency.

4) Outside air intake should be stopped during pull down and pre-heating period.

5) From 8°C to 10°C chilled water should be supplied to air handling unit coils in equipment rooms, where the sensible heat factor is nearly one, in order to prevent over-dehumidifying, and from 5°C to 7°C chilled water should be supplied to air handling unit coils in office rooms, where sensible heat factor is lower.

6) Shut out dumper should be used for internal vertical shaft to prevent heat loss by chimney effect.

It is estimated that about 13 % of the air-conditioning energy consumption is reduced by the countermeasures above items 2) - 6).

Multiple air-conditioners system

Heat from telecommunication equipments must be dissipated for the benefit of the equipment.
It is forecast that a telecommunication equipment room with heat density that may reach more than 300 X 10^4 joules per hour square meter will appear in the near future.

Telecommunication equipment is often installed in stages, a certain portion at the inauguration stage, followed by successive installations extending over about 10 years after building completion, accompanying the increase in sensible heat generated from equipment. So as to match these conditions, a new air-conditioning system was energy consciously developed, which features small capacity packaged air-conditioners being additionally installed one after another, corresponding to an actual increase in telecommunication equipment heat load in an existing building.

This system also features no air delivery duct being used. Specially developed air-conditioners, that have no dehumidifying capability, are used in telecommunication equipment rooms with high heat density. If standard packaged air-conditioners were used for such a room, electricity would be consumed for dehumidifying, which is not necessary, because latent heat load is very small in the room. This new system prevents wasteful energy consumption which could be used for dehumidifying, and is expected to provide a considerable energy saving effect. Figure 2 shows an outline of this system: Multiple Air-conditioners System.

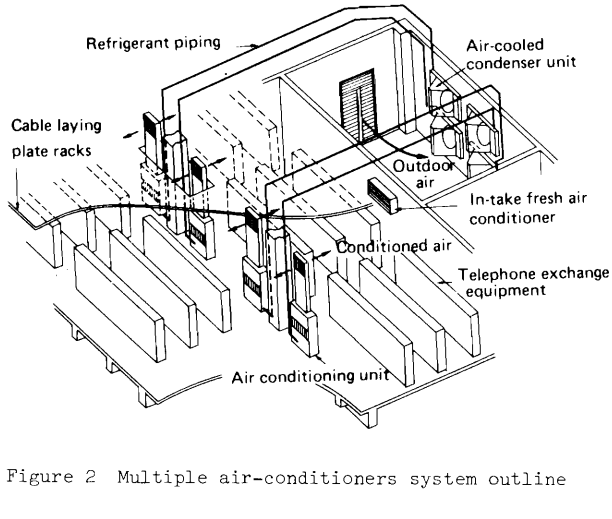

Figure 2 Multiple air-conditioners system outline

Outside air cooling system

In case the heat load from telecommunication equipments is large, cooling is required even in intermediate seasons and in winter. In such a case, using outside air for cooling provides a great energy saving effect.

Outside air cooling system was applied to the air-conditioning system for the Hiroshima second toll telephone exchange, which has 18,367 square meters total floor area. Figure 3 shows this telephone exchange office.

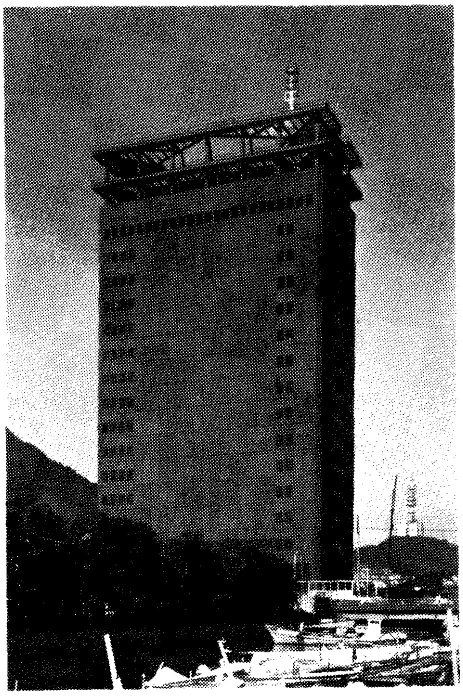

Figure 3 Hiroshima second toll telephone exchange building

Outside air is used as a cooling source in intermediate seasons and winter, instead of chilled water to reduce the chillers' energy consumption. An outline of this telephone exchange building's air handling system is shown in Figure 4.

As outside air temperature and humidity changes unexpectedly, mixing control for outside air and return air, and air supply temperature/humidity control with chilling water circulation or humidification supplement is necessary to keep appropriate room air temperature and humidity.

In the air-conditioning system in the Hiroshima second toll telephone exchange, outside air cooling system control algorithm, which was developed to match the telecommunication equipment room's thermal property, was applied to the computer control system with 16 K words memory minicomputer and real-time interface. This computer control system is also used for optimum chilling system operation. The configuration of this computer control hardware system is shown in Figure 5.

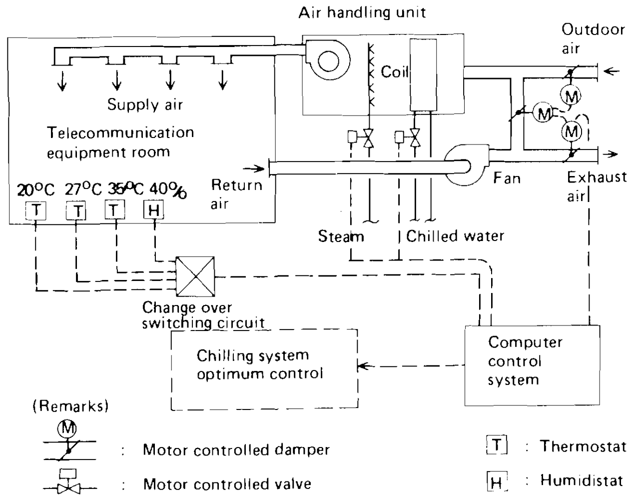

Figure 4 Air handling system for outside air cooling system

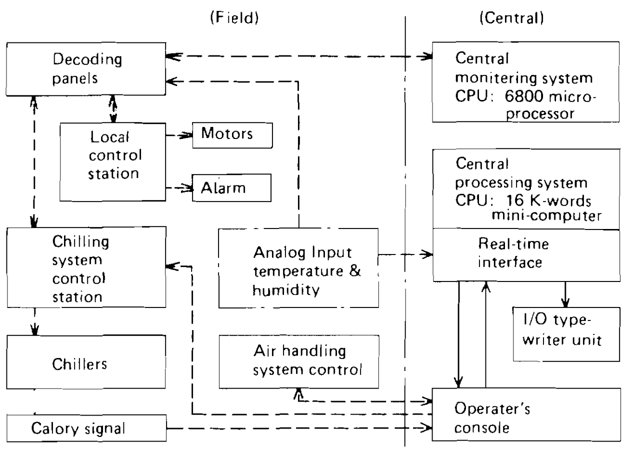

Figure 5 Configuration of computer control system

Solar heating, cooling and domestic use hot water supply

Non-depleting solar energy is expected to be used instead of conventional fossil fuels. NTT started study on solar heating, cooling and domestic use hot water supply system since 1975 and some solar projects were put into effect. Figure 6 shows Yorii telephone exchange, Saitama prefecture, Japan. Solar energy utilization system, shown in Figure 7 was adopted for this telephone exchange, which was an existing building.

This telephone exchange has 324 square meters telecommunication equipment room and 120 square meters office area. This system has been designed to utilize solar energy for 78 % of the annual cooling load and 59 % of the annual heating load.

The actual operation of this solar energy system proved that solar cooling adoption for telephone exchange building causes a considerable increase in constructing cost but solar heating and domestic use hot water supply system brings both energy saving and economical merits.

Therefore, recently NTT adopts solar heating and domestic use hot water supply where climatic conditions and building design allows such adoption.

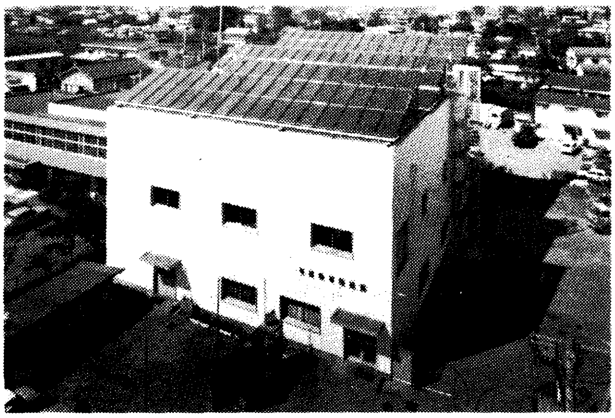

Figure 6 Yorii telephone exchange building

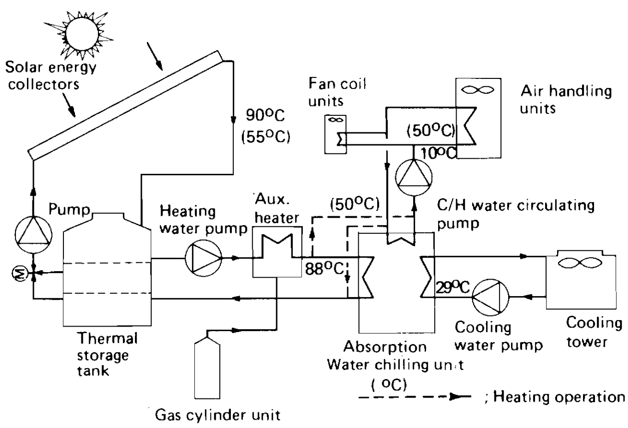

Figure 7 Yorii telephone excahnge solar energy system

Reasearch on heat storage tank

An air-conditioning system, including a heat storage tank, is very common in Japan, and is adopted for many NTT telecommunication buildings.

Conventionally, the heat storage tank, which does not have a very big capacity, is used aiming at chillers' or heat pumps efficient full load operation, preventing compressor's operational capacity to follow air-conditioning load fluctuation, and correspondence to out of schedule operation requirement.

Recently, as the importance of energy saving is stressed, heat recovery system and solar energy utilization system are frequently adopted for air-conditioning. The heat storage tank is useful for energy saving improvement, when it is combined with those systems. Moreover, when an outside air cooling system is adopted, the heat storage tank makes possible efficient chiller's operation when small capacity chilled water circulation is required to supplement outside air cooling.

In Japanese urban areas, consumed electric power reaches a peak in summer daytime, because of cooling use demand. Electric power supply utilities are obliged to install more power generating plants and operate then inefficiently. Therefore, cooling peak demand cut and night surplus electric power utilization by heat storage tank is very significant for efficient urban energy utilization.

As mentioned hereabove, today, heat storage tank utilization is regarded as a basic technique for energy saving. NTT makes much of heat storage tank's functions, and recognizes the need for developing a more accurate heat storage tank design method. So, the research on this subject such as three dimentional numerical analysis, scale model experiments and system simmulation method, is being carried out in the laboratory.

Energy saving effect evaluation method

Energy consumption computation method

It is necessory to compute energy consumption amount for evaluating energy saving effect. Two methods are applicable for it. One is using a computer method which provides strict results. The other is manual computation method which allows an easy procedure.

For the computer use method, NTT developed and owns dynamic air-conditioning load computing program AIRCON-2, air-conditioning system simulation program AIRSIM and air-conditioning energy consumption computation program AIRCON-E. These programs are presented or planned to be presented for NTT Data-Communication Service users as air-conditioning computation program series in scientific and engineering computation library DEMOS-E.

Aforesaid Hiroshima second toll telephone exchange's outside air cooling system, which has a complex control algorithm, was examined by annual air-conditioning load computation and system simulation using these programs. As a result, 35 % energy saving effect was estimated.

When a new system was developed and applied, such programs should be used to examine the system performance at the design stage. However, using these programs requires too much time and cost to expand it to all building projects.

Therefore, a simpler and easier annual energy consumption computation method is desired. From such a standpoint, NTT established an annual energy consumption manual computation method, which allows making a rough estimate of annual air-conditioning load and annual energy consumption, shown in Fig. 8. By this method, the result is obtained from three basic data elements, i.e. outside air temperature annual frequency distribution, building thermal properties and air-conditioning mechanical components energy consuming properties.

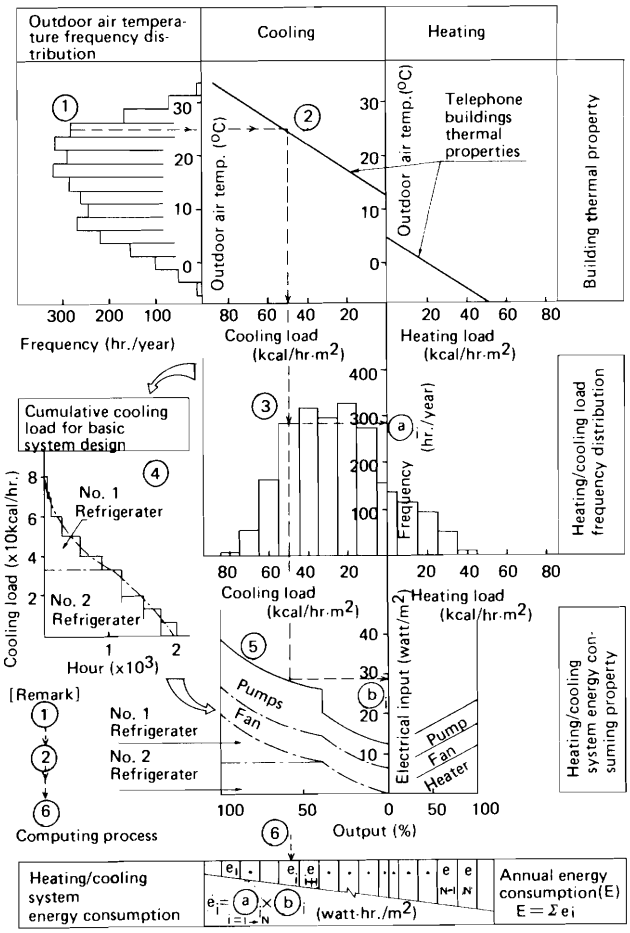

Figure 8 Annual energy consumption computation method

Energy saving effect evaluating indices

It is necessary to lay down some indices for evaluating energy saving effect. Annual energy consumption per total floor area is the most adequate index for energy saving performance synthetic evaluation. Furthermore, energy saving performance achieved by building design and air-conditioning system design should be separately evaluated.

The primary energy consumption coefficient in air-conditioning system, coefficient of building thermal load and coefficient of air-conditioning system performance were adopted as energy saving effect evaluating indices, which are defined as shown in Table 1. The numerical values that should be given for these indices are now being studied.

Table 1 Energy saving effect evaluating indices

Indices	Definition
Coefficient of primary energy consumption in air-conditioning system (Joules/sq.meter annual)	$\frac{PEC}{TFA}$
Coefficient of building thermal load (Joules/sq.meter annual)	$\frac{HL + CL}{TFA}$
Coefficient of air-conditioning system performance	$\frac{HL}{PECH}$ or $\frac{CL}{PECC}$

Note

PEC : Annual primary energy consumption in air-conditioning system (Joules)
TFA : Building total floor area (square meters)
HL : Building heating load (Joules)
CL : Building cooling load (Joules)
PECH : Primary energy consumption in heating(Joules)
PECC : Primary energy consumption in cooling(Joules)

Conclusion

Energy resources depletion is a serious problem today. NTT expends its efforts toward energy saving, considering its social responsiblity as one of the representative big businesses in Japan. This paper summerizes the NTT building engineering sector's energy saving efforts. Energy saving techniques described in this paper were confirmed to be effective through actual projects, but these techniques exhibit real values when these are widely applied. As shown in the Introduction, NTT has a great number of buildings to be maintained and many new building plans. The next problem is to diffuse the energy saving techniques more widely to building projects including present building improvement.

For this NTT is now making an energy saving design manual and studying present building improvement methods. The first stumbling steps in basic study for energy saving have already been finished. Next, the energy saving techniques diffusing step, by which substantial energy saving effect is expected, must be undertaken.

Reference

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UTILISATION DE L'ENERGIE SOLAIRE POUR LE CHAUFFAGE DES BATIMENTS.

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RESUME :

Après une brêve évocation des activités du Centre Scientifique et Technique du Bâtiment dans les domaines touchant à l'utilisation de l'énergie solaire pour le chauffage des constructions, on traite de la mise au point, par simulation sur ordinateur, d'une méthode de calcul de l'énergie récupérable par des capteurs solaires plans à eau associés à un ballon de stockage.

On indique, en conclusion, les possibilités d'extension et d'utilisation de telles méthodes pour le solaire actif et on rappelle d'autres travaux de ce type touchant au solaire passif.

SUMMARY :

After a survey of the Centre Scientifique et Technique du Bâtiment's activities in the fields relating to the uses of solar thermal energy for space heating, the improvment by simulation on computer of a method of calculation of the potential quantity of solar energy recoverable by the means of flat plate liquid-type collectors coupled with storage tank, is discussed.

In conclusion, the possibilities of utilization and extension of such methods towards active systems are pointed out ; and other parallel works relating to passive solar are mentioned.

°°°

Ces dernières années le Centre Scientifique et Technique du Bâtiment a entrepris un important programme de recherche sur les possibilités d'utilisation de l'énergie solaire pour le chauffage des bâtiments.

Ces études concernent, pour l'essentiel, les domaines suivants :

- dispositions architecturales appropriées à l'utilisation du soleil ;
- récupération des apports solaires pour le chauffage des logements, que ce soit en systèmes passifs ou actifs ;
- conception et fonctionnement des systèmes et études des stockages de chaleur ;
- qualité et rentabilité des installations.

Signalons, qu'au C.S.T.B., ces activités s'exercent au sein de la Cellule Solaire du Service Thermique et Aérauliqueet que cette Cellule est destinée à s'installer, au début de 1981, à SOPHIA-ANTIPOLIS près d'Antibes dans les Alpes-Maritimes où le Centre Scientifique et Technique du Bâtiment et le Centre National de la Recherche Scientifique créent en commun le Centre de Recherche "Bâtiments Solaires" voué aux recherches et aux expérimentations sur les emplois de l'énergie solaire dans la construction.

Un des objectifs de nos études dans ces domaines est de disposer et de fournir aux participants à l'acte de construire des méthodes de calcul de l'énergie solaire récupérable pour le chauffage des logements par différents systèmes et notamment les systèmes actifs.

Nous présentons, ici, un exemple d'étude de ce type qui porte sur le calcul de l'énergie récupérable par des capteurs solaires associés à un stockage.

Cette étude consiste à examiner les performances de deux systèmes de chauffage solaire comportant des capteurs plans à eau associés à un ballon de stockage en simulant, sur ordinateur, leur fonctionnement pendant une saison de chauffage avec des données climatiques réelles. Le schéma de principe des deux installations est représenté sur la figure 1 et on indique dans ce qui suit les caractéristiques thermiques des capteurs, du stockage, des installations de chauffage et des locaux retenues dans la simulation ainsi que les données climatiques utilisées.

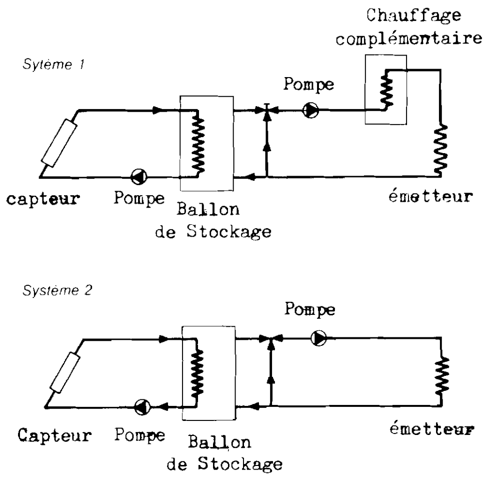


Figure 1 Schéma de principe des installations

I - CARACTERISTIQUES DES ENSEMBLES ETUDIES

1.1. Les caractéristiques thermiques des capteurs et de la boucle d'échange avec le stockage

La quantité intéressante à connaître est l'énergie effectivement cédée au stockage. Le calcul de cette énergie fait intervenir les caractéristiques du capteur, les caractéristiques de l' échangeur, les pertes de chaleur dans les tuyauteries de raccordement. On montre que la chaleur utile $\emptyset u$, cédée au ballon de stockage peut s'exprimer en fonction du rayonnement incident sur le capteur, R, de la température extérieure Te et de la température dans le ballon de stockage Tb, d'après la relation suivante

$$\emptyset u = \left[aR - b(Tb - Te)\right] S$$

où a et b sont des coefficients caractéristiques de la boucle de captation, et S la surface de captation. Le coefficient a traduit la capacité de la boucle de captation à transmettre le rayonnement solaire capté au ballon de stockage. Le coefficient b traduit les pertes du capteur et des tuyauteries de distribution.
a et b sont différents des coefficients de l'équation classique utilisée pour les capteurs seuls et font intervenir notamment le rendement de l'échangeur de chaleur éventuel.

Cette expression se met sous la forme classique :

$$\emptyset_u = a\,SR\left(1 - \frac{b}{a}\,\frac{Tb - Te}{R}\right)$$

dans laquelle :

- aSR est la puissance solaire utile, qui intégrée sur la période de chauffage donnera les apports solaires utiles,
- $\frac{b}{a}$ est un paramètre de la boucle de captation.

Dans les simulations effectuées, nous avons fait varier : aS de 5 à 50 et $\frac{b}{a}$ de 2,5 à 7,5.

1.2. Les caractéristiques thermiques du ballon

Nous avons considéré un ballon de stockage à chaleur sensible, contenant de l'eau. Dans un premier temps, le ballon a été supposé parfaitement isolé. Les dimensions sont caractérisées par le nombre r égal au rapport du volume du ballon à la surface de capteurs en m^3 par m^2. Pour un fluide de stockage différent de l'eau, on modifiera r dans le rapport des capacités thermiques. Nous avons fait varier r de 0,025 à 0,20 m^3/m^2.

1.3. Les installations de chauffage

Elles sont représentées fig. 1 (P.4). Nous avons considéré deux systèmes.
L'installation de chauffage du système 1 est une installation de chauffage central à eau chaude, l'eau de retour des convecteurs ou des radiateurs étant préchauffée dans le ballon de stockage, la chaudière assurant l'appoint.

L'installation du système 2 ne comporte pas de chaudière, et les émetteurs sont alimentés par l'eau du ballon de stockage. La température intérieure désirée est obtenue par un autre mode de chauffage, en appoint.
La puissance P des émetteurs de chaleur est donnée par la relation classique :

$$\frac{P}{P_i} = \left(\frac{Tm - Ti}{\Delta Tb}\right)^k$$

dans laquelle :

- P est la puissance des émetteurs de chaleur
- P_i est la puissance installée pour les conditions climatiques de base,
- Tm est la température moyenne des émetteurs de chaleur,
- Ti est la température intérieure du logement,
- k est un exposant fonction du type d'émetteur, pris égal à 1,35 pour les simulations

- ΔTb est la valeur de Tm-Ti dans les conditions de base, utilisée pour le calcul de l'installation.

Cette relation indique que le paramètre caractéristique de l'installation est ΔTb, qui conditionne en fait le dimensionnement des émetteurs de chaleur. Pour les simulations, nous avons pris comme valeurs de ΔTb 10, 30 et 60°C.

1.4. Description des locaux

Le local étudié a les caractéristiques suivantes :

- coefficient G........... 0,95 $W/m^3.°C$
- volume .... 200 m^3
- apports solaires internes 1,5 W/m^3

Ce local est exposé nord-sud. Seule la façade sud a des apports solaires égaux à $s\,S_v\,R_s$ où :

- R_s est le rayonnement solaire reçu sur le plan vertical sud,
- S_v la surface vitrée sur la façade sud,
- s le facteur solaire des baies.

Ce local est supposé d'inertie thermique très faible.

II DONNEES CLIMATIQUES

Les simulations ont été effectuées au pas de temps d'une heure avec les données climatiques de la saison de chauffage de l'année 1969/70 à ORLY et CARPENTRAS. ORLY est situé dans la banlieue de PARIS, CARPENTRAS dans le Sud de la FRANCE. On donne au tableau 1 la durée de la saison de chauffage, les degrés-heures base 20°C et les rayonnements reçus par les capteurs et la façade sud. On donne aussi dans ce tableau les consommations de chauffage du logement compte tenu des apports internes et des apports solaires par les baies vitres.

TABLEAU 1

	Saison de chauffage	
	ORLY (1969)	CARPENTRAS (1969)
Date	6.10 au 18.5	25.10 au 14.4
Nombre de jours	225	172
Degrés-heures	71 600	55 600
Ensoleillement (kWh/m^2) reçu :		
. par les capteurs ..	540	610
. par une façade sud .	383	491
Consommations (kWh) du logement étudié (apports internes et solaires par les baies compris)......	10 180	7 430

III SYNTHESE DES RESULTATS DES SIMULATIONS. METHODE DE CALCUL DE LA FRACTION SOLAIRE FS

L'ensemble des résultats des simulations a été traité, et on a abouti à la formule de calcul globale suivante :

$$FS = FS_0 \times C_1 + C_2$$

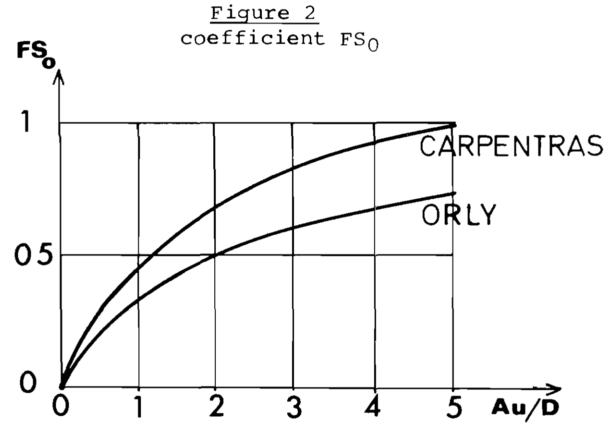
dans laquelle :

- FS est la fraction solaire, c'est-à-dire la part du chauffage assurée par l'énergie solaire,
- FS_0 est un coefficient fonction du rapport des apports solaires utiles, Au, aux déperditions du logement D. Les apports solaires utiles sont obtenus en multipliant l'énergie solaire incidente sur les capteurs, pendant la saison de chauffage par le coefficient a :

$$Au = a \times S \times E$$

où S est la surface du capteur et E l'énergie incidente par m^2, FS_0 est donné sur la figure 2 pour les deux lieux pour lesquels on a effectué les simulations.

Figure 2
coefficient FS_0



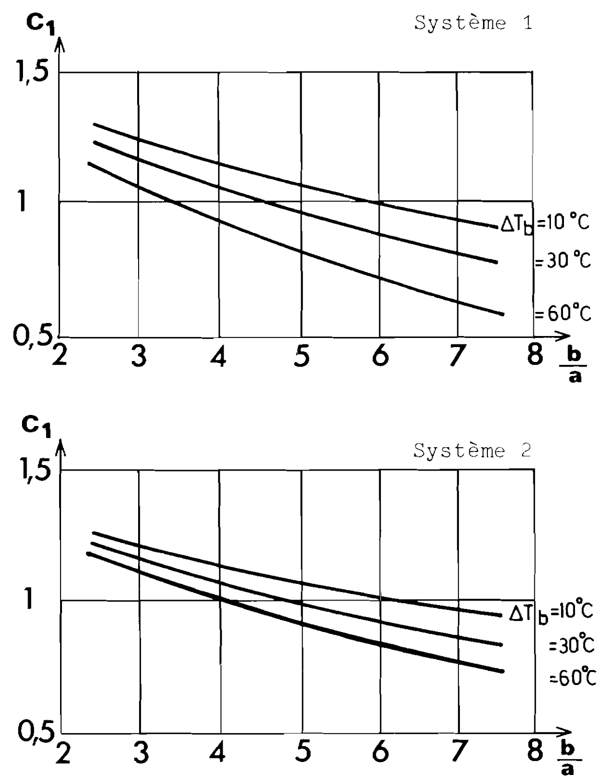
- C_1 est un coefficient de correction de pertes qui tient compte des déperditions de la boucle de captation par le coefficient b/a et de la température de fonctionnement du système de chauffage par la valeur de ΔT_b. C_1 est donné par la figure 3, suivant le système de chauffage ou fonction de b/a et de ΔT_b ;
- C_2 est un coefficient de correction du volume de stockage. Il est donné par l'expression :

$$C_2 = 0,6(r - 0,05)$$

valable pour $0,025 < r < 0,20$.

La correction est nulle pour r = 0,05, valeur pour laquelle la courbe de FS. a été établie.

Figure 3



IV CONCLUSION

Nous venons d'exposer brièvement une étude qui nous a permis de mettre au point une méthode de calcul de la part du chauffage assurée par le soleil dans une installation comprenant des capteurs plans à eau associés à un stockage de courte durée par de l'eau contenue dans des ballons.

Le calcul fait intervenir :
- les caractéristiques thermiques de la boucle de captation,
- le volume du ballon de stockage,
- le dimensionnement des émetteurs de chauffage,
- le rapport des apports solaires aux déperditions du local.

Il peut être étendu à d'autres systèmes de chauffage solaire comprenant, par exemple : un stockage par matériaux à changement de phase.

Les outils de modélisation ainsi définis nous sont également utiles dans nos études sur les systèmes de stockage intersaisonnier de chaleur dans le sol.

Pour terminer, signalons que, parallèlement à ces études sur les systèmes actifs, le C.S.T.B. vient de publier une méthode permettant de calculer l'incidence des apports solaires classiques (c'est-à-dire par les parois extérieures, principalement les vitres) sur les besoins de chauffage (1). Cette méthode, très simple puisqu'elle utilise des données climatiques annuelles, est la synthèse de calculs très élaborés, effectués au fil de l'année d'une part sur modèle analogique et d'autre part sur modèle numérique.

Nous travaillons, actuellement, à étendre cette méthode aux espaces-tampons vitrés (serres, vérandas, ...) ainsi qu'aux parois à effet de serre (murs Trombe, murs à eau), c'est-à-dire aux systèmes passifs (2).

°°°

(1) J. ANQUEZ, M. CROISET et J. LE QUERE "L'incidence des caractéristiques solaires d'un logement sur ses besoins de chauffage"
Cahiers du Centre Scientifique et Technique du Bâtiment n° 203
(Cahier n° 1596) - OCTOBRE 1979.

(2) L'Activité du C.S.T.B. en 1979
à paraître dans les Cahiers du Centre Scientifique et Technique du Bâtiment en AVRIL 1980.

Thermostatic radiator valves - functions and requirements

By Anders Svensson, Civil Engineer, The National Swedish Institute for Building Research, Gävle, Sweden.

Summary

The National Swedish Institute for Building Research (SIB) has carried out laboratory tests on the functions of thermostatic valves. A report on these tests is presented in this paper.

The paper also provides information about Swedish testing methods and rules for the type-approval of thermostatic radiator valves.

Experience from installations with thermostatic radiator valves varies; not only with regard to function and maintenance but also with regard to the amount of energy consumed. Some exampels are given.

From the experience gained a number of requirements are shown, which must be fulfilled in order to ensure good function when thermostatic radiator valves are installed.

Résumé

L'article rend comtpe d'essais conduits en laboratoire par l'Institut national suédois de recherches sur la construction et l'urbanisme (S.I.B) sur le fonctionnement de vannes thermostatiques de radiateur.

L'article fournit en outre des informations sur les méthodes de test en vigueur en Suéde et sur les régles á suivre pour obtenir l'apprabation de vannes thermostatiques équipant les radiateurs.

Les résultats de fonctionnement d'installations de chauffage équipées de vannes thermostatiques restent variables non seulement vis-á-vis de la raison d'utilisation et de la maintenance, mais encore de l'amplitude de la consommation énergétique. Des exemples sont cités dans l'article.

A la lumiére de ces expériences quelques recommandations á suivre sont indiquées pour garantir un fonctionnement satisfaisant des vannes thermostatiques.

Introduction

Research into thermostatic valves at the National Swedish Institute for Building Research (SIB) started with a commission, from the National Swedish Board of Public Building, that involved tests and theoretical studies of the control circuit; thermostatic radiator valve, radiator, pipe system and room (1), (2). The advantage of a theoretical analysis is that the influence of various alterations in the system may be studied in a simple and inexpensive way. But one disadvantage is that it may be difficult to construct theoretical models that correctly describe the various links in the system. The engineering consultants Ingenjörsfirman Orrje & Co - Scandiakonsult, Stockholm, have therefore received a grant from the Swedish Council for Building Research (BFR) for a project entitled: Computer processing of the control system: thermostatic radiator valve - radiator - room. The project, to be carried out in cooperation with SIB, thus aims at studying the control characteristics of thermostatic radiator valves by means of computer simulation. The purpose is to investigate how different constructions of such valves and the siting of the sensor, etc. influence the stability, accuracy and speed of the control system.

Laboratory tests

In the spring of 1976 SIB completed the commission from the Board of Public Building that consisted of laboratory tests, in a full-scale room, of six different thermostatic radiator valves (1).

Intentionally a difficult control case was selected, but such are not unusual within the various offices of the Board. The test room was a three-module room with a radiator under each window. Each radiator was equipped with a thermostatic valve, all set at the same temperature level.

In these tests a percentual number, here called an indicator index, was defined, and this indicates the thermostatic valves ability to compensate for variations in loading. The higher the indicator index is, the greater should be the possibility for utilization of the additional heat from the sun, etc.

The tests produced average values of the indicator index for the different types of valves of between 10 and 60 per cent, whilst the average for all types of valves was approximately 36 per cent. The best result was achieved with a thermostatic valve with a removed sensor, this depending on the fact that here the heat transfer between the valve body and the sensor was largely eliminated.

In the case of thermostatic valves with an integrated sensor, in most cases an unstable control-sequence was obtained because of this heat transfer; that is to say, oscillations were obtained that were underdamped or not damped at all. The oscilliation periods for the different types of thermostat varied from 45 to 90 minutes. In the worst case the oscillations were continuous, and in the best there was a damping of the oscillation to a stable equilibrium after approximately two hours.

It also appeared that if the load variations were so great that the thermostatic valves shut off completely, these will still open again as the impact of cold air from the window cools the sensor.

Control circuit

The factors of importance for function and economic operation depend to a certain extent on the characteristics of the thermostatic valve and also on the system of which it forms a part. The valve characteristics that influence the function are more or less obvious in the various makes of valves.

The thermostatic valve together with the radiator and the room forms a closed control circuit where the different blocks together produce a certain end-result. The four items that contribute to produce the final result are the:

- o thermostatic radiator valve
- o radiator
- o piping system
- o room

Research at Landskrona

A project has been carried out at Landskrona by the Department of Building Technology and Structural Engineering of the Lund Institute of Technology in cooperation with the National Association of Tenants' Saving and Building Societies and with grants from the Swedish Council for Building Research. The project was intended to provide an answer about the importance of the thermostatic valve in energy saving and the residents' ideas about what comfort the thermostatic valve can provide. It was also hoped to discover under what conditions the installation of thermostatic valves is justified in the exchange of radiator valves in existing houses.

The area in which the tests were carried out consists of 5 eight-storeyed multifamily houses (A-E) each containing 63 or 64 flats. The houses each consist of a basement, a ground (entrance) floor, seven floors of dwellings and an attic floor. The basement and entrance floors in the houses differ from each other but otherwise the houses are alike.

The houses are divided into two groups:

a Houses A, B and C are equipped with thermostatic valves and are therefore called thermostat houses.

b Houses D and E are equipped with manual valves, adjusted in the conventional manner and are called reference houses.

What differentiates the three thermostat houses from each other is the make of valve, but house A, especially, has 60 percent of the removed sensor against 25 per cent in houses B and C.

A final report was made in the autumn of 1979 (10). However, some preliminary results were issued at a seminar in Gävle during 1978, (6), (8), (9). It was then stated that the temperature-dependent losses for the different houses are probably equivalent and that therefore it is correct to make a comparison between the thermostat and reference houses. In other words, the reference houses really are reference houses.

Some of the other things pointed out were:

- o The difficulties of controlling the temperatures in the different houses. Measurements suggest the thermostat houses had an 0.5°C lower temperature. (Weekly measurements were made in only two of the 63 or 64 flats in each houses). The answers to questionnaires suggest that people were more satisfied with inside temperatures in the reference houses.
- o Indisputably there was a higher consumption in the thermostat houses. Night reductions of temperature took place in the reference houses. Supply temperatures have been somewhat higher in the thermostat houses.
- o It cannot be shown that the thermostatic valves, which were blocked at 22°C, were able to utilize the additional solar heat, etc. during the warming-up period. Instead they have shown themselves to be advantageous during the night hours.

Further field experience

Experience from installations with thermostatic valves varies of course, not only with regard to function and maintenance but also the heat consumption's magnitude (2), (6). The Co-operative Housing Organization of the Swedish Trade Unions (Riksbyggen), have undertaken energy-saving measures in older housing areas. The houses in the areas concerned were built during the 1940's and consist mainly of 3-storey blocks of flats. The houses had approximately the same standard of insulation.

Thermostatic valves blocked at a maximum of 21°C but otherwise adjustable to lower temperatures were installed in all houses. The houses did not have branch-regulation valves, and the old radiator valves were practically unregulatable, so the system was not preset.

There was a large spread in temperature between the different flats before the thermostatic valves were installed. The temperatures in the coldest flats were 19-20°C and in the warmest 24-25°C. These large deviations apply to houses with the largest shunt-groups. In houses with smaller shunt-groups the temperature spread was less.

The energy-saving measures for all houses in the investigation (69,?25 m^2 of flat area) showed a saving of 10.5 percent calculated on the total oil consumption. Wall and attic insulation was only carried out to a limited degree and therefore the thermostatic valves can be reckoned to account for approximately 7.5 percent of the saving calculated on the total oil consumption. At temperature measurements carried out after the valves were installed the temperature in all flats was approximately 21 ±0.5°C.

Svenska Bostäder AB has since 1976 tested thermostatic valves on radiators in newly-built house property at Husby, at north Järvafältet outside Stockholm.

The intention was to discover if thermostatic valves are of any importance for energy consumption in multi-family houses. The section selected for the experiment contained four blocks of flats with in all 116 flats. These flats were served by a heating substation. The radiator system was of a pipe-system type with a loop for each flat. The flats had a balanced ventilation.

All of the flats were equipped with manual radiator valves prepared for the connection of a thermostat unit. When the radiators were provided with thermostatic valves the whole system were preset and the control equipment was calibrated carefully. The thermostatic valves were positioned at the bottom edge of the radiator. They were blocked for a maximum temperature of 21°C.

As reference object was selected a housing section identical with regard to orientation and number of flats. The flats in this section were in fact not equipped with thermostatic units on the radiators but otherwise the same adjustments and installations were carried out as on the thermostat houses.

Readings were carried out once weekly. The results showed a clear tendency right from the start: more energy was used in the thermostat houses (about 5 percent). As nobody had expected such an effect it was decided to move the meters between the heating substations in order to be able to reveal possible errors in the meters. But the results were the same. These measurements were carried out during the six winter months 1976-77.

The investigation suggests that in this heating system, where the control equipment was of good quality and correctly maintained and the presetting was carefully calculated and carried out, no further energy saving is obtained with thermostatic radiator valves.

AB Familjebostäder has carried out experiments with thermostatic radiator valves as an alternative to traditional presetting. Experiments have been carried out on a total of 1.200 flats in the Stockholm suburbs of Västberga, Västertorp and Aspudden. Energy savings of 6-8 percent were obtained. Thermostatic radiator valves have also been installed in 115 flats at Kungsholmen, in Stockholm. In this case energy saving was found to be approximately 4 percent. In Familjebostäder' opinion the lower saving probably depends on the fact that these valves were maximized at 23°C instead of 21°C as in Västberga, Västertorp and Aspudden.

It is thought by AB Familjebostäder that thermostatic radiator valves may be an alternative to presetting in older districts where often there are no branch-valves and where the radiator valves are often difficult to preset.

Discussion of results

As appears from the above account, in some cases an energy saving has been obtained whilst in others there has been an increased consumption of energy with thermostatic radiator valves. This must of course be explicable by a careful analysis of the plant and components. But, understandably, this is an analysis that we are unable to carry out in a completely satisfactory manner as SIB did not take part in these investigations.

In some of the installations where a negative experience of thermostatic valves was obtained, these were not blocked at a predetermined maximum temperature. In other cases there was reason to believe that the systems, prior to the changeover to thermostatic valves, were preset satisfactorily. Where experience of thermostatic valves has been positive it can be stated definitely that, prior to the changeover to thermostatic valves, the installations can hardly have been preset.

But the type and make of the thermostatic valve are also important. We have in fact observed during our investigations that some valves were practically unusuable. Others were not so bad, but not until now - when official testing methods have come into use - have acceptable valves started to see the light of day.

Rules for the testing of thermostatic radiator valves

On the initiative of the Swedish National Board of Physical Planning and Building and with the financial support, among others, of Nordtest-VVS (the Nordic collaboration organ for testing), rules have been worked out at SIB for the testing of thermostatic radiator valves. These rules were first published in February 1978 (3) and issued in a revised version during the latter half of 1979. The production of these rules was made easier as the French rules were available as a prototype. In the first circulation for consideration and comment the test methods were sent to companies, public authorities and institutions. On the basis of this an SIB Bulletin was issued in 1978, M78:5 (3). The Board of Physical Planning and Building approved these rules in 1978 as the applicable testing methods for the type-approval of thermostatic radiator valves. Following this the rules were distributed through Nordtest-VVS for renewed consideration and comment.

It should be noted that the limitations and requirements that are drawn up for thermostatic valves in Sweden have been determined on functional grounds. The requirements have also been drawn up so that in most cases it is ensured that the valves on the whole are able to regulate and that the regulation is stable, that is to say without occillation. The rules apply both to valves with integrated as well as removed sensors and are intended for both one and two-pipe systems (4).

Test results

Altogether some ten types of valve have been tested at SIB in accordance with the test methods in M78:5. In the introductory phase, around the end of December 1977, it appeared that none of the more usual thermostatic valves with integrated sensor were able to fulfil all requirements. Intensive product development since then has now had the result that there are now available a number of improved thermostatic valves of approved type on the market.

Thermostatic valves and presetting

One conclusion that may be drawn is that in certain buildings thermostatic valves could replace the conventional presetting, or be the cheapest and easiest solution if there are no possibilities of presetting. In these cases the manufacturers have a great responsibility, both for the projecting and usage of the valves.

All larger radiator systems should be preset. But how is this presetting to be done when there are thermostatic valves in an installation? This would entail adjusting the pressure conditions of the system concerned in order to obtain suitable authority in the thermostatic valves. A thermostatic valve must be selected that has the correct presetting value (kv value), or preferably one that is continually adjustable.

In many cases it has been necessary to insert a pressure drop in series with the thermostatic valve (the chance of selecting valves with a suitable kv value was very small as things were). Then the thermostatic valve functions solely as an automatic maximum limiter and not as a proportional regulator.

For a single-pipe system it may be said that thermostatic valves on the radiators can compensate for excessive or too small amounts of heat from the radiators. The single-pipe system also has the advantage, among others, that the radiator circuits cannot influence each other hydraulically and that the presetting need only include loops and branches. Further, there are no problems of noise disturbance or difficulties in lowering room temperatures uniformly in buildings by lowering the inflow temperature, presuming that the radiators are correctly dimensioned. It therefore seems that the single-pipe system has favourable potentials for thermostatic radiator valves.

Requirements for good function

With the experience now gained it is possible to state a number of factors that must be fulfilled in order to ensure good function when thermostatic radiator valves are installed. These are:

- The thermostatic valve must be of the approved type.
- The thermostatic valve must be maximized at 20-21°C, which usually means that the valve is completely closed at a 2-3° higher temperature.
- Individual calibration of thermostatic valves is necessary if the correct distribution of temperature is required in different rooms and spaces.
- Airing may only be permitted for short periods unless the thermostatic valves are completely shut off.
- Shunting of inflow water must take place in order to decrease losses and to permit the thermostatic valve to operate as a post-adjuster.
- Pipe system and thermostatic valves must be adapted to each other correctly.

Design of the pipe system is important. Preferably, in the case of larger installations, the system should be provided with devices for constant pressure differences over the different branches and with a pressure-controlled speed-regulated pump.

The thermostatic valve alone does not decide the installation's function, but there are a number of associated factors. The last point listed above is one of the most important of these, and the underrating of this point is certainly a contributory reason why so many have failed with their installations.

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Solar technique in the building construction.
Aspects in the field of building construction and design.

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Summary

The basis of the study is a questionaire using poll restricted to about 300 owners of ready executed solar plants. A return ratio of 43 % was constituted. In the main, the poll covers apartment houses and other dwellings. In the field of solar plant utilization, raw-water heating is definitely in the lead. The wide spread of collector areas rangeing from 4 to 9 sqm creates serious problems in the field of building-roof design. 66 % of the total solar plant covered by the present study was installed, at a later date, in buildings already entirely, completed. It follows that difficulties deriving from ridge orientation and roof pitch take first place among the obstacles mentioned. What should be stressed here, however, is that, just 4 % of the returns experienced difficulties on account of design requirements imposed by the local authorities. No more than 2.4 % derive their difficulties from the incompatibility of their architectural plans with existing development plans.

The study comprises a documentation consisting in some 50 photographs of solar plant covered. They are provided with key-word comments. Beyond this, general proposals are made for the arrangement of small collector areas.

1. RESEARCH TASKS AND PURPOSES

The tasks of the present research are to detect and to analyze the obstacles impeding the incorporation of installations for the application of solar techniques in buildings from the point of view of both building construction and design.

Within the scope of a project sponsored by the Federal Minister of Research and Technology and aiming at the "Identification of Economic and Social Obstacles in the way of a more general Acceptance of Solar Technology" (Programme No. 4.4.1.39, Project No. ET 5008 A), the legal provisions relevant in this field were listed in detail. The essential obstacles identified in this way proved to be the so-called "design sections" as incorporated in the building regulations of the various Lands and bearing on such features as the shape and slope of the roof, the colour and the texture of the roofing material and the number and nature of the superstructures and windows featuring the roof's visual impression. It is true a statement formulated on june 14, 1977 by the Permanent Committeé of Federal and Land Section Heads for Environmental Questions provided for a broadminded, approach in the matter of the authorization of solar installations, but unfortunately this did not remedy the general situation which still causes the formative integration of solar installations to present an open problem in many cases. A closer examination of this range of problems, however, was not provided for within the scope of the above project sponsored by the Federal Ministry of Research and Technology.

Now the obstacles encountered in the field of the installation and utilization of plant for the application of solar techniques are manifold and can not be outlined by a study and comparison of legal provisions alone. These have to be completed, in the very first place, by experiences made in actual constructional practice and in actual building-consent practice. It follows that the purposes of the present study must be to define the obstacles opposing the authorization, the construction and the utilization of installations applying solar techniques under the aspects of building construction and design in general, to document examples actually carried out and to work out suggestions for a gradual removal of these obstacles.

2. EXTENT AND EXECUTION

The causes of the obstacles opposing, under the aspects of formative design, the erection of buildings equipped with installations applying solar techniques can not be identified and reconstructed unless we know the general setting providing the framework for this particular constructional process. The very first important influence exercised on the technical equipment of a building is the offer of new products. So the very first requirement is for those participating in the building process to become thoroughly acquainted with solar plant and with the building components and techniques pertaining to such plant. Beyond this, the utilization of solar energy in building construction also engenders novel effects of the regulations and processes the trade has to heed to obtain the consent tu build on the part of the authorities in question. All of these influences have effect on the execution of the work. These effects may vary in strength but, in the end, all leave traces on the building in its final state. It is these traces the present study wants to secure and analyze by covering certain data on ready erected buildings equipped with solar plant.

3. POLL

The basis of the present study is a poll restricted to owners of ready executed solar plants.
The poll provided for the distribution of a questionnaire.
This questionnaire attached special value to the securement of picture material documenting the present situation in the field of solar-plant construction.

Besides the data pertaining to the Owner, the questionnaire comprises three main fields for the collection of data on the building equipped with solar plant. The questions formulated for the purpose mainly aim at the collector part of the plant, as this part exercises most of the influence on the construction and on the outward appearance of the building, in other words on the main object of the present study. The three main fields are the following:

- Questions on the building
- Questions on the collector plant
- Questions on the planning and on the execution of this plant.

The poll was held in the summer of 1978. The laudable aid of four associations and 85 solar-component manufacturers and installation specialists permitted the identification of 312 solar-plant Owners among whom 126 replied constituting a return ratio of 43 %.

4. RESULTS

The pronounced engagement on the part of the Owners of solar plant is not only illustrated by the high return ratio reached by the questionnaires distributed but also by the fact that 57.9 % of the returns were accompanied by additional documents such as photographs, newpaper cuttings and the like. The documents themselves, some remarks added, accompanying letters and discussions prove a special pioneer spirit to reign among the people covered by this part of the poll, a spirit undaunted by the failures transpiring here and there.

In the main, the poll covers apartment houses and other dwellings. In the field of solar-plant utilization, raw-water heating is definitely in the lead (refer to Table 1). In 29.4 % of the cases investigated, the solar plant serves more than one purpose.

Utilization	Percentage of total plant covered
Raw-water heating	
Space heating	20,6 %
Swimming-pool heating	23,0 %

Table 1 : Solar-plant utilization

The use the solar plant is provided for is matched by the size of the collector area. Here, installations of an area of some 7 sqm are predominant (refer to Table 2).

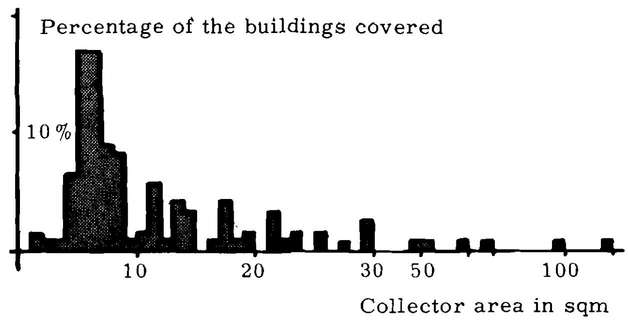


Table 2 : Distribution of collector areas by size

Table 3 summarizes the distribution of the solar plant investigated by the year of their purchase. It gives a fine impression of the rate this plant soared at in the first years this new technology became available.

Year of construction	Percentage of total solar plant
1975	0,8 %
1976	11,5 %
1977	
1978	32,0 %

Table 3 : Year of construction of the solar plant (up to and including june, 1978)

4.1 Obstacles

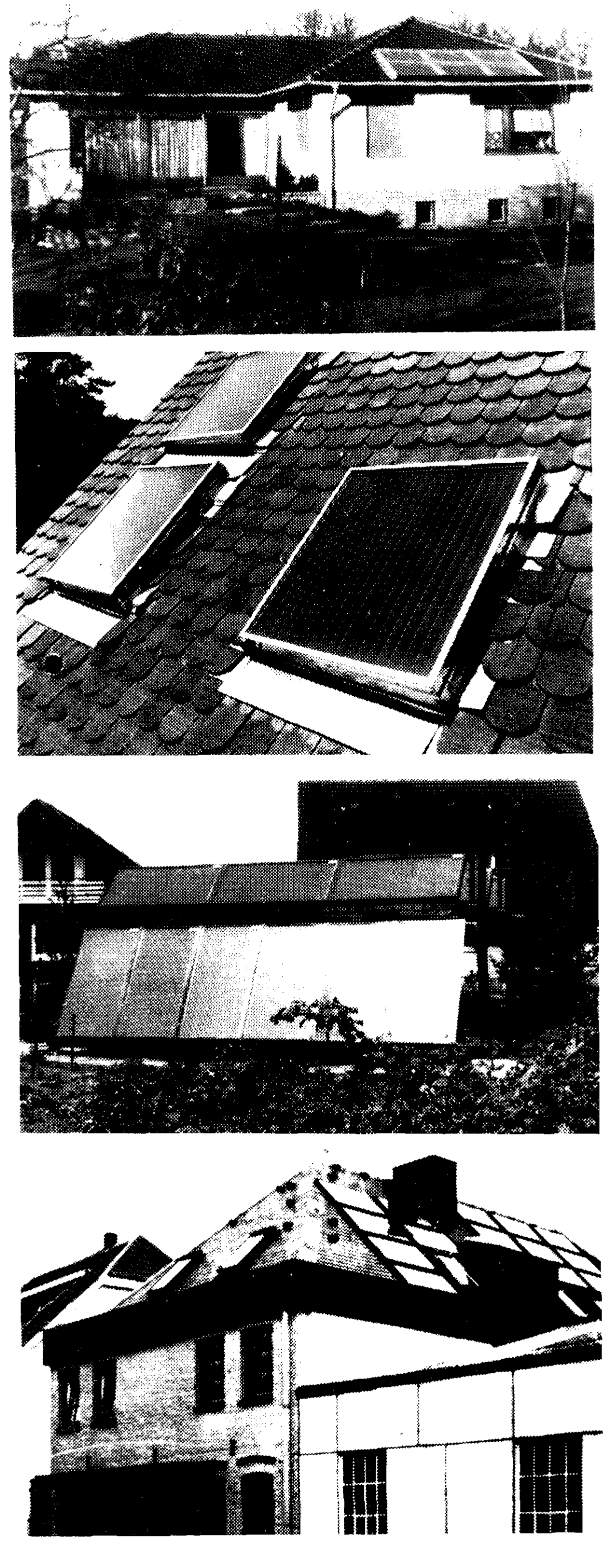
The wide spread of collector areas rangeing from 4 to 9 sqm creates serious problems in the field of building-roof design, as these relatively small areas do not allow of a generous conversion of complete roofing levels into collector areas. 65.9 % of the total solar plant covered by the present study was installed, at a later date, in buildings already entirely completed. This inevitably leads to the difficulties necessarily resulting from ridge orientations and roof-pitch values deviating from optimum conditions. In the case of those encountering these obstacles, the ratio between ulterior installation on the one hand and installation in a newly erected building on the other is even in the order of 3 : 1. It follows that difficulties deriving from ridge orientation and roof pitch take first place among the obstacles mentioned. What should be stressed here, however, is that, quite contrary to expectations, just 4 % of the returns experienced difficulties on account of design requirements imposed by the local authorities. No more than 2.4 % derive their difficulties from the incompatibility of their architectural plans with existing development plans.

Nor were these results modified to any essential degree by an additional investigation of building-consent problems as covered, on a Federal level, by the Ministry of Research and Technology and the Ministry of Building Construction.
When reviewing the questionnaires and also the letters returned by Owners facing such building-consent difficulties it strikes the eye that, in the matter of requests for a deviation from design regulations or development plans, these often seek to get their way with remarkable obstinacy and, in some cases, in several courts.
In all probability, this scant inclination to compromise on the part of Owners is caused by a partial or total lack of knowledge in the matter of the losses of energy to be expected, for instance in case of a deviation from optimum collector orientation. In many cases, the efforts made by Owners to obtain special consents or exceptions from the rule are out of all proportion to the profit involved. Similar efforts and expenses, however, for the conception of alternative plans providing, for instance, for a shift of the collector plant to the house front or some other place, are never made. The cause of this probably lies in the fact that, on the one hand, architects are seldom reverted to for the integration of solar plant into a building and that, on the other, examples are frequently interpreted too rigidly for an acceptable solution to be found.

4.2 Documentation

The study comprises a documentation consisting in some 50 photographs of solar plant covered. They are provided with key-word comments. This collection offers a cross section of the outward appearance of the solar plant erected to date. What strikes the eye is that, for the better part, collectors are integrated from a purely technical point of view unter complete neglect of formative integration.

Fig. 4:
4 examples for unsatisfactory design and construction.



Sunlight collectors are positioned almost exclusively on the roof of the building without heed to the latter's geometrical nature which, in some cases, just does not allow of any compatibility with rectangular collector areas. A complete lack of interest in questions of membering, structure and shape usually results in a veritable rag-rug pattern. Better possibilities for a formative integration of such predominatingly small collector areas are offered, on the contrary, by smaller surface-stressed building components such as garage roofs, balcony parapets, window parapets and the like. Alternatives to the plant illustrated by the documentation are indicated in keywords. Beyond this, general proposals are made for the arrangement of small collector areas.

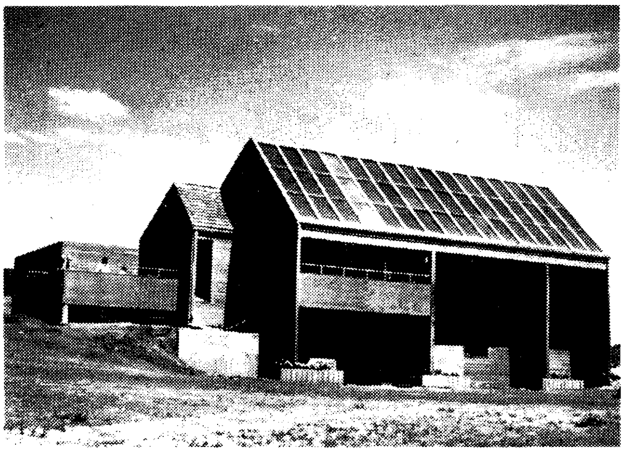


Fig. 6:
Solar house of the university of Colorado, USA

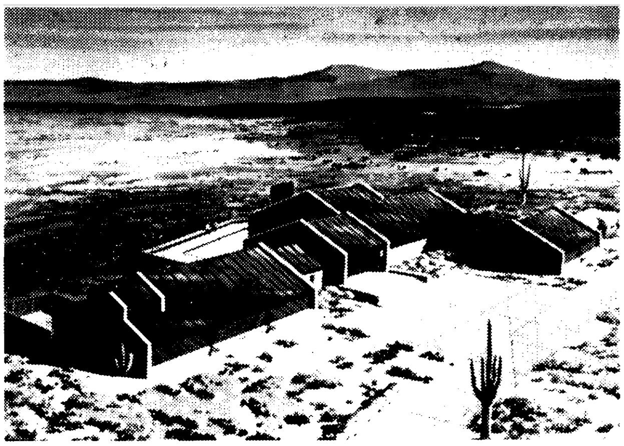


Fig. 7:
Solar house in Tucson, USA

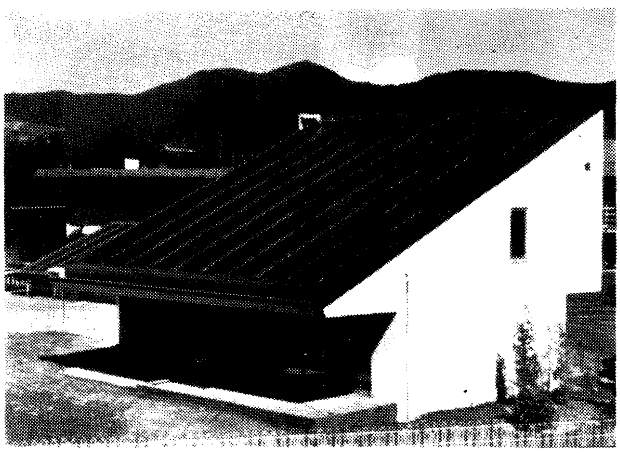


Fig. 8:
Experimental house, Japon

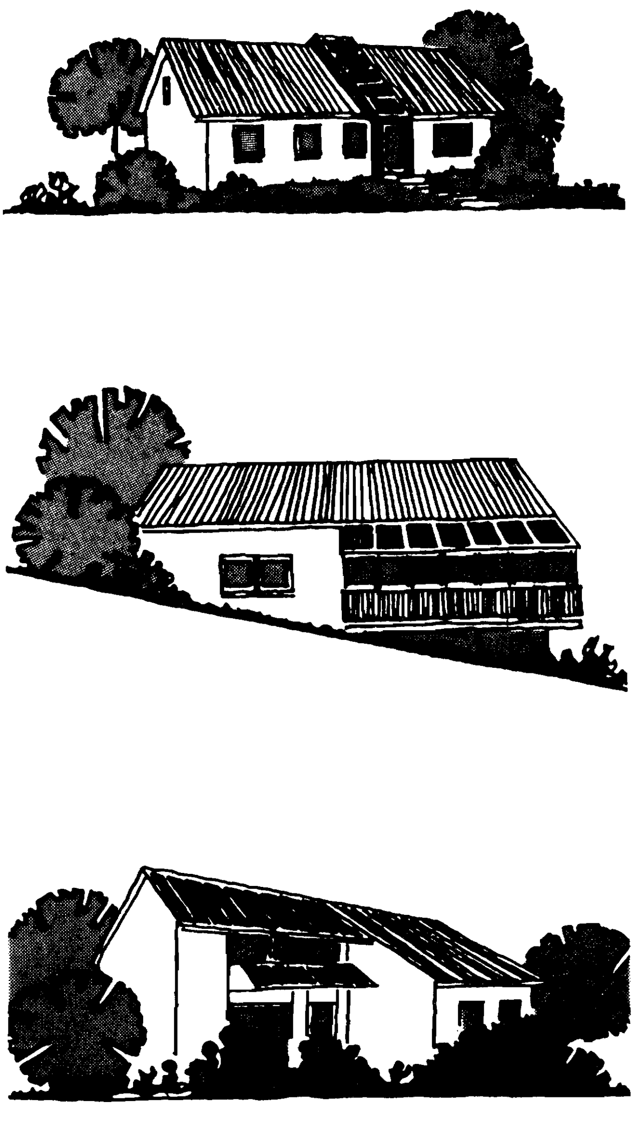


Fig. 5 :
Possibilities for the integration of solar-collectors

4.3 Suggestions

It would be desirable for general directives for the consent to the execution of solar plant to be worked out for the subordinate authorities so as to restrict the incertainties now governing their decisions and - more important still - to prevent existing regulations from beeing interpreted, in cases of doubt, more narrowly than their true scope allows of.

It is feared, however, that a complete release from Owner's present duty to seek the prior approval of the authorities as contemplated by some Lands for single- and two-family homes today, might well produce negative effects on both the formative and the functional design of these buildings as, in this case, the designing expert, the architect, would find his possibilities to take influence even more restricted than they already are.

SUBJECT SUJET 3C

Housing sociology. Human requirements. Basic needs related to family and national resources

Exigences humaines. Sociologie de l'habitation. Besoins élémentaires concernant les ressources de la famille et de la nation.

SOCIOLOGICAL RESEARCH FOR PLANNING AND DESIGN

by Stefan Dahlgren, National Swedish Building Research Institute

Introduction

Housing sociology is by no means a new field in building research, and many of the research institutions have long been concerned with sociological research projects. In CIB, too, the subject is no novelty but it has featured to but a small extent in the international collaboration organized by that body. A short survey of the growth of housing sociology and its current policy would therefore seem to be in place here.

CIB collaboration in the area of behavioural science has earlier been organized mainly by the Working Commission W 45, Human Requirements. For the last two years or so there has been a separate working group with the designation Housing Sociology (W 69). In this survey I shall give a number of examples of the sociological projects that are being carried on at the building research institutes that are participating in this Commission.

This area of research is a very extensive one and a balanced account of it is out of the question. It is also very difficult to formulate an acceptable definition of the field. However, housing sociology is not concerned solely with examining and determining needs of various kinds, and the name adopted for this session is therefore to some extent misleading. I shall return to this point later on.

The following presentation is naturally based on experience within Scandinavian sociology, with influence mainly from the Anglo-Saxon world. Experience of research in housing sociology in developing countries will be dealt with in separate papers.

Contributions of sociology

It is, of course, difficult to describe the contributions and importance of sociological research to the design of the dwelling, physical planning and the supply of housing in general, but I belive that five main areas can be identified which have been developed in different ways.

The *first* of these is *the relationship between the countryside and the town*. This was an extremely early theoretical interest in both sociology and social anthropology, the basic concepts having been formulated already at the end of the last century. It was held that there were wide differences in social conditions and relations. Early theoreticians in the field include Tönnies, Simmel and Durkheim; later on Redfield, the anthropologist, and Wirth the sociologist, made important contributions.

The relatively minor role of the antagonistic urban/rural concept in the last two decades is presumably due in some measure to the fact that some of the differences in living conditions between urban and rural areas in the industrialized part of the world began to disappear owing to, for example, a tendency towards similarty in the conditions in production and distribution and to the effect of the mass-media. The problem has simply become less relevant. The antagonistic concept has also been strongly criticised, it being maintained that there are other problems that are important and that happen to coincide with urban types.

Instead we have two offshoots of different character, namely the occurrence of the concept of «suburbanism» and a new pair of antagonists, centre and periphery, founded on a perspective of power and resources. The former offshoot is characterized by the concentration of the suburban residents on the private sphere, family life and the neighbourhood, and is typical of the metropolises of the Western world. The latter offshoot is applicable to the conditions in both developed and developing countries, and is concerned with analyses of the difference in power over, and disposal of resources of various kinds that exists between, for example, rural communities and industrial centres or between the concentration of government agencies in the city and the dependence of other parts of the country on their decisions.

Closely associated with these concepts on differences between the urban and rural areas, though with a greater emphasis on practical planning, was the garden city movement in England, with its beginnings around the turn of the century (Howard), and the theoreticians such as Mumford, the town planning ideologist. The garden city in England was intended to combine the best of the urban and the rural life styles. Mumford derived his inspiration from an earlier and as it were, more rural economic system. As a contrast to the present-day mass production and metropolitan society, with its entirely impersonal relationships, Mumford juxtaposes medieval society, with its principal virtues of direct interpersonal relations and a life style that is, to use a modern expression, ecologically better adapted.

Mumfords ideas on social philosophy had important implications for the *second* main area of sociological influence, namely, *neighbourhood planning*, which developed rapidly in the forties. Neighbourhood planning might indeed be said to be the first and the most large-scale attempt to apply any form for sociological principles to planning. On the basis of investigations in New York, Perry, an American, had as early as 1929 proposed that between 4000 and 8000 inhabitants was a suitable population for a neighbourhood unit on social and functional grounds, including the size of the schools.

There were a number of reasons for the rapid gain in popularity of the neighbourhood concept. In the first place, the ideas that it embraced were not new ones. Opinion had already been prepared for them by Howard and Geddes. Second, in many countries the ideas were consistent with the new approach to housing policy, governed as it was by the accent on post-war reconstruction and with the aspirations for a more democratic urban culture, favouring a greater measure of direct citizen participation and repudiating guidance from the top. Thirdly, the ideas were conceivably in keeping with the search for a social approach to town planning, which was one of the chief principles of functionalism.

It is interesting to note that neighbourhood planning was introduced and implemented on a large scale without the possibilities of carrying it through first being checked with smaller projects. In other words, gigantic experiments with people were carried out without adequate verification of the hypotheses. Perhaps Mumford's historical parallels were considered to serve as sufficiently convincing proof.

Neighbourhood planning and its sequelae had their foundation in more or less well developed physical determinism; thus, social behaviour is governed by the design of the physical environment. For most non-sociologists this principal trend of housing sociology is in fact the *real* housing sociology. Many studies carried out in the forties, fifties and sixties were concerned with attempts to establish the influence of the physical environment on social life – the effect of size on the neighbourhood, the effect of the relative position and the height of the buildings, and of various types of building for example, one- and two-family houses and apartment blocks. It is true that some relationships could be demonstrated, but in most cases the theory was insufficiently developed and the «measuring instruments» – interviews and observations – were too crude for the results to be productive.

As a consequence of more advanced theory, and development of method we now have a more refined view of these problems – that is to say, of the relationship between the physical environment and social life. This new approach is referred to as «environmental sociology» or «environmental psychology», depending on which aspect of behavioural science it is desired to emphasize. The aspect of social anthropology also enter the picture.

One example of the new standpoint is that the physical environment is perceived as a «filter» capable of blocking or of allowing the passage of certain activities (Michelson); the origins of the activities themselves must be sought elsewhere than in the psysical environment. There would also appear to be a two-way relationship between the inhabitant and the environment; it is not seen chiefly as a physical phenomenon but rather as a bearer of symbolic and cultural values, which may change or be modified from time to time. Perhaps the most familiar results of the development of theory in this new trend is the concept of the behavioural setting (Barker). Briefly, it implies that behaviour in a given environment is influenced to a large degree by a combination of physical characteristics and of social norms concerning what kind of behaviour is appropriate to this environment. A large number of behavioural settings may be identified and the concept is also applicable to planning, since it is to some extent possible to predict probable behaviour in a given environment.

A *third* important area of housing sociology was the research of the Chicago school on the *internal differentiation of the town*. These «social ecologists» derived their data from large American towns and attempted to formulate general conclusions concerning social patterns in the urban environment. Familiar names and models for this differentiation are Burgess' concentric zone theory, Hoyt's sector theory and the multiple nuclei theory. Their results have had important implications for practical town planning, and it has been possible to apply the experience to such diverse areas as the importance of the transport network, the adaptation of ethnic groups and the development of land prices.

The problems of segregation are considered to have increased rather than diminished over the years, and the methods and concepts adopted are largely the same as those formulated by the Chicago school. More recent contributions in this field include detailed studies of the development and survival of subcultures, a discussion on the positive effects of social segregation as regards support for group affinity and identification, and conflicts resulting from too heterogeneous population.

The *fourth* principal area is the study of *dwelling habits*. There sociology has perhaps had the most important implications for the development of investigatory methods. The emphasis has been on survey technique – that is to say, the standardized interview according to a prescribed schedule and, to some extent, sampling methods. Theory derives from another source, namely, architectural functionalism, with its conviction that daily life in the home can be analyzed and divided into units whose design can be optimized in relation to specific needs.

The *fifth* and last principal field I would like to mention might be designated *sociopolitical investigation*. This research, whose purpose was to furnish a basis for sociopolitical measures, was started in the first decade of this century and was being carried out extensively in many countries in the inter-war years. Perhaps the most large-scale single example is An American Dilemma, by Myrdal and others. The studies for the most part took the form of statistical descriptions with a well defined practical goal – for example, to provide a picture of housing conditions.

Sociopolitical investigations are now being carried out in many countries with growing enthusiasm. The inclusion of measurements of the level of living represents a new approach. Another novel feature is the linking of different aspects of welfare, the data usually being collected through interviews of individuals and households. The most common point of departure is an analysis of resources in which a comparison is made of the access that various population groups have to utilities and amenities of various kinds – for example, income, dwelling standard, education and health. The measures relating to housing policy, and the associated investigations and research, are no longer concerned solely with families having several children, but also with a number of other groups, expecially the handicapped and the elderly, with particular requirements.

Among the lines of research that are of current interest there are a couple that are not so clearly linked with earlier more well-defined research in housing sociology.

Since the end of the sixties a new school with many ramifications has developed – particularly in France – which to a greater og less extent rejects what is justified in the existence of a separate urban sociology. Instead, it is maintained that what is being studied in these branches of sociology

where the town or the residential area is the physical unit, is rather a reflection of what is happening in society in general; it is true that social problems concern individuals or distinct social groups, which have a physical location, but from this no inference can be drawn as to the effect of the environment. The development and the internal differentiation of the town, and also the relationship between urban and rural areas, should be seen from a macrosociological perspective. The best known advocate of this policy outside France is Castells. Other research workers belonging to this group are Pahl and Harloe in England and Szelenyi in Poland.
Perhaps partly as a consequence of this and similar views the interest of many sociologists is shifting to the planning process. This has been happening to a large extent over the last decade, when the object has been to examine and develop forms for citizen influence outside the elected political bodies.

Research in housing sociology at institutions affiliated to CIB

The surveys of earlier and current research in the field of housing sociology that had been prepared by the members of the CIB Working Commission W 69 (Housing Sociology) reflect the same variability of approach and theoretical orientation in housing sociology as that outlined in the above survey. Some examples of the research problems in the countries represented in Working Commission W 69 will be briefly outlined.
In British building research, as in many other places, work at the end of the forties and during the fifties was concerned mainly with studies of dwelling use and the requirements as to the internal and external design of the dwelling. During the sixties and seventies more attention was given to town planning, and today the emphasis is on problems of topical interest to the municipal housing authorities, – for example, surveys of the housing standard of a municipality, analysis of the extent to which the local supply of housing is meeting the demand, and definition of the demands on the dwelling made by, for example, the elderly and the handicapped. A factor of major importance is the extent to which the research results can be immediately applied.
At the Belgian Institut de Logement work is being conducted in three main areas, besides the supply of information to the public and authorities. These areas are the definition of the requirements of certain population groups as regards the dwelling, studies of the various parties concerned in the housing production process – the contractors, architects and proprietors – and the evaluation of dwellings and housing districts. Among the population groups whose housing demands have received particular attention on various grounds are the elderly and the handicapped and students, mine workers and immigrants.
In the French CSTB a group of sociologists and psychologists are studying the prerequisites for planning and design on the basis of a combination of psychoanalytical and macrosociological theory.
The work consists partly of projects concerned with development of theory, where interest is focused on man's relationship to the environment, and partly with application, including studies on leisure housing («l'autre habitat»), the environment in new towns, residents of one-family dwellings and the experience of noise in the dwelling.
In Polish research on housing sociology three main areas may be distinguished, namely studies of stratification and spatial differentiation, residential areas and use of the dwelling.
Differences in the housing standards of various population groups are regarded as an index of social stratification. One aspect of this is the spatial distribution of dwellings with different standards; the investigations are concerned with both the objective conditions and the subjective experience of the attractiveness of different residential areas.
The studies on residential areas and the dwelling are obviously carried out with a view to furnishing a better foundation for the specification of design standards and recommendations, but also from a more theoretical standpoint, in which interest centres on the development of neighbourhood contacts and on the conditions within the family, such as the roles and status of its members.
In the Scandinavian countries, the Netherlands, and some other countries the sociologists at the building research institutions are at present devoting much attention to studies of living standards and problems concerned with citizen participation. Besides these topics the research on design problems, long regarded as important, are being continued – with, for example, investigations on dwelling habits.

Needs as a common factor of research topics

The variability of the lines of research outlined above is an outcome of the diversity of the theoretical and methodological approaches. A further factor may well be their association with different kinds of social anomalies and different applications in practical planning and design. While this variability may perhaps ensure that none of the important problems is forgotten, it inevitably complicates the choice of research projects and to decide priorities. (It also makes it difficult to choose topics for international collaboration – for example within CIB.)
Basic needs of different combinations are a common point of departure for research intended to lead up to proposals for regulations and recommendations. In this context it is appropriate to consider whether the concept of «needs» is in fact a suitable point of departure.
During the sixties Maslow's so-called hierarchy of needs gained wide currency among social scientists, and was used both as theoretical basis for explanations and as a point of departure in a discussion of a choice of research projects. Both the designation of this long established CIB Working Commission Human Requirements (W 45) and the title of the sector of the congress to which this essay belongs (Housing Sociology. Human requirements. Basic needs related to family and national resources) is presumably linked with Maslow's needs model.
The model implies, briefly, that, while it is true that man strives to satisfy his needs, he does not do so haphazardly.

The needs assume a definite order, thus forming a hierarchy with the following five basic needs.

1. Physilological needs
2. Safety needs
3. Love needs
4. Esteem needs
5. Needs for self-actualization

For a particular type of need to be satisfied the types lower down in the hieararchy must be satisfied first.
The wide and continued acceptance of the model is due in some measure to the fact that it is easy to apply to the predominant approach in physical planning and housing design, namely architectural functionalism, the fundamental idea of which is, that life in the dwelling or in the residential area can be broken down into separate units, or functions. It is easy to match the needs of Maslow's model to these functions.
The model has been criticized on the grounds that the hierarchy is too mechanical and too individualistic; society and social phenomena are disregarded. These objections cast doubt on the general validity of the model.
The general level of the model, also presents problems in any attempt to operationalize its content, and it is obviously in this process that the model's shortcomings will be most clearly apparent. Any layman with social ambitions will have his view of what he would like to fit into such a model. Agreement will certainly be closest as regards the fundamental physiological needs, but then opinions will probably diverge concerning the more concrete implications of the needs, and their order of priority. In the context of housing planning, moreover there is the difficulty of applying the model in decisions on design.
A kind of «needs model» is also the basis for social policy, the housing policy component of which will govern planning and housing research, and be noted by the building research institute in most countries where such research is pursued. Here, it is not, of course, a question of a coherent scientific theory, but of more or less well defined conceptions of the citizens needs, desires and demands (which can to some extent in fact be influenced by the results of the research.) These conceptions are, however, in the first place normative, and based on a definite conception of society – that is to say, how it is considered that society should be.
There are, in fact, few researchers today who would maintain that science should also specify the goals of society, as Auguste Comte, the father of sociology, did 150 years ago, and as was also held by George Lundberg, the American sociologist, in the forties. It would seem that the researchers should not specify any *definitive* requirements, even as regards apparently simple factors such as to light intensity and noise level; it being considered that the levels aimed at must be political decisions hinging on, for example, what a particular country considers it can afford. This does not mean, however, that the researcher passively turns out results; his contribution will, of course, include a critical examination of decisions and their prerequisites.
A pure needs model as a point of departure for the formulation of research goals is of doubtful value. It is obvious that there are major difficulties in deciding what are generally valid needs – perhaps less so in the case of the so-called basic physiological needs. Another disadvantage of the concept of a needs model is the temptation to assume that the more one gets of something the more satisfied one will be. This is by no means the case and it can lead to aggravation of the effects of other anomalies.
Elements of some kind of needs model might be recognized in any research project whose results are intended to serve as a basis for concrete decisions and modifications – for example, as regards planning and design in the field of building research.
There is, however, a world of difference between, on the one hand, determining precise and constant needs which will serve as a basis for deciding on research projects aimed at determining limiting values, latitudes and requirements and, on the other hand, accepting that there are certain fundamental and general human needs but that these are too obvious and vague to suffice for the formulation of concrete research projects. A thorough discussion of this problem in scientific theory does not, however, fall within the scope of this paper.

The applicability of housing sociology

An important problem in housing sociology is how to apply the results to practical planning and to determine the extent to which research tasks can be related to design specifications.

A number of reasons for adopting as a goal the development of a better basis for design may be proposed. One of them is the incontestable fact that in physical planning certain decisions relating to design must be taken, and for this the designers need guide-lines. This is no less true where there is a well developed exploitation of user or citizen influence. Faced with the diversity of available alternatives, even the user himself, in making his final decision, requires guidance and a knowledge of what can reasonably be demanded. The comprehensive research on planning processes is no guarantee that good solutions will be found.
Another reason may be that an established research tradition and fund of knowledge constitute important resources which cannot be left unexploited without strong motive.

There are also arguments *against* a one-sided concentration of design questions. As mentioned earlier, many sociologists consider that the physical environment is not a very important factor in the creation of existing social problems; sociological research should therefore be focused on other fields, and in particular the power structure of society.
Nor are the problems of housing policy concerned primarily with the question of deciding between one type of buildings or another, but with providing housing for the citizens in general and for various groups of them, such as the elderly and families with small financial resources.
One important question is, of course, whether it is possible to decide what is a suitable design of the environment on the basis of previous research in the field of housing sociology. As intimated above, most building research institutes have

come into existence because the central and local governments assumed responsibility for guaranteeing housing supply[1]).

Essentially, the task of the institutes was thus to solve problems of quality versus cost. Of the various lines of sociology that have been described above it is research directly linked with the problems of dwelling design that has been the concern of the institutes in Scandinavia and other countries. This work has consisted in evaluation studies of dwellings and residential areas, and attempts, under laboratory-like conditions, to find acceptable solutions for particular spaces in the dwelling or details of equipment and fittings.

The inside of the dwelling presents only a comparatively simple problem. Research in many countries has given us guide-lines for good dwellings (in the sense that evaluation studies have shown the dwellings to be acceptable to the residents.) The guide-lines are usually based in the first place on functionalistic analysis and presumably, to only a small extent on genuine theories of behavioural science. Because so little research has yet been performed with these points of departure, it is uncertain whether it can yield proposals for different dwellings.

As regards results that have a bearing on the achievement of desirable standards in residential areas and the built environment in general I would like to propose the following points (to stress that this is largely a personal interpretation no references are given):

* Small scale. (Not too large apartment blocks, a reasonable number of inhabitants, a moderate of rate of expansion.)
* Preservation of local culture and tradition. (Links with earlier ways of life and types of community should not be severed too abruptly.)
* Variability. (The buildings should not be uniform and present an impression of sterility.)
* Freedom of action. (The environment should not be «programmed» down to the smallest detail when the area is brought into use.)
* Reasonable services. (A newly built area must always have a reasonable standard of public and commercial services so that it does not fall behind the older areas where such services have had a long time to develop.)

Most people, however, are convinced that to achieve all this would cost too much money and could give rise to conflicts over limited resources. It is often stressed, moreover, that such qualities can be imcompatible with strong power and capital interests. (Herein lies the reason for the interest in the study of the planning process.)

Despite efforts in that direction, there are, unfortunately, few systematic surveys yielding concrete conclusions on how research results in housing sociology should be applied to design. In a recently published work under the direction of Christopher Alexander, the American architect, the goal has been to provide a generally valid and well documented basis for the design of a large number of different environments. This is done in a number of *patterns* which describe a social or a town planning problem and also indicate the design that should alleviate, if not actually solve, it.

»Each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice» (p. X)

«Each solution is stated in such a way that it gives the essential field of relationships needed to solve the problem but in a very general and abstract way – so that you can solve the problem for yourself, in your own way, by adapting it to your preferences, and the local conditions at the place where you are making it.» (p. XIII).

This work has been criticised for dealing too lightly with many social problems and because Alexander and his co-authors seem to be unaware that there are many problems in society that have no real connection with the physical design. However, true this criticism may be, the work represents a laudable and most ambitious attempt to contribute to the solution of many of the questions with which we are grappling. And the proposals that the book offers for further research on design or for verification of the author's statements could provide lengthy research programmes for several institutes.

Neither the proposals for conclusions that I have offered here nor the patient work of Alexander and his collaborators in developing models for environmental design are the outcome of research in any particular branch of housing sociology but rather the product of combinations of ideas resulting from various lines of research.

Conclusions

I have stressed three points in this paper. The first is that the field which we label «housing sociology» is very diversified and has in fact existed as long as there has been urban planning and social policy activities in the present-day sense, and furthermore that sociology has made substantial contributions to these activities.

My second point, which in a way is a reflection of the diversity, is that the wide-spread concept of «needs» should not be emphasized too much in research. It is only one of many research approaches in the behavioural sciences and by no means the dominant and probably not the most useful one in housing or urban sociology.

My third point is, that even if sociologists over the years have done a lot to provide planners, politicians, and the general public with knowledge useful for housing and urban planning, there have not been enough efforts to make the research results useful for practical purposes.

And this point is, in my opinion, the reason why CIB should engage itself in housing sociology. There are already several organizations of the international level, where social scien-

[1]) This applies not only to social housing but to all forms of public involvement in planning and housing construction through, for examples, standardization, financing and physical planning.

tists discuss problems connected with, for example, environment, urbanization, and planning. The question is, what can CIB add to make more international co-operation worthwhile? The fact that many building research institutions were established as a result of a wider public engagement in housing makes it more probable that these institutions and their researchers have closer contacts with current planning and design problems than the university researchers usually have. This presumably better knowledge of the demands of the practitioners could be made use of also for the international exchange of information to help fill in the gap between theoretical knowledge and practical use.
I do not belive that social scientists at universities are sitting in ivory towers or similar edifices, but I imagine that there is a greater probability that social scientists at the building research institutions have more experience of what is required for practical purposes. They may also take advantage of a close collaboration with colleagues from other disciplines, since many institutes are organized along interdisciplinary lines.
My conclusion from this is that the CIB Commission for Housing Sociology (W69) should concentrate on the possibilities of utilization of research and not on development of theory, which as far as international co-operation is concerned, conveniently could be left to organizations like the International Sociological Association. We shall definitely not reject theoretical work but the goal must be to stimulate more systematic use of research results in design and planning.
When discussing the CIB activities in the social and behavioural sciences there are also some internal organizational problems to consider. One of these is the scope of W69 in relation to W45 (Human Requirements). In order to facilitate discussions on this subject the following list has been prepared in collaboration with D. P. Wyon, whose work at the Swedish institute falls under the heading of W45. I want to stress that items only are examples of the division of interest between Commissions and that the list is by no means complete.

Suggested examples of division between W45 Human Requirements (of the physical environment) and W69 Housing sociology

W45	Borderline – dual interest	W69
Room temperature	Heating systems	Sources of heat, energy
Humidity	Sources of humidity	Kitchens, laundry design
Air velocity	Ceiling height	Visual space
Thermal radiation	Room size, crowding	Room dimensions
Heat balance of body	Clothing	Fashion, washability
Metabolic rate	Eating habits, routine	Dietary costums
Heat balance outdoors	Outdoor activities	Outdoor facilities, journeys
Wind chill	Wind engineering	Housing area design
Lighting	Daylighting, sunshine	View of sunlit, foreground
Windows (thermal)	Windows (view in/out)	Windows (shape, appearance)
Windows (ventilation)	Windows (escape)	Fire escapes
Windows (noise level)	Windows (noise information)	Window siting
Noise level (nuisance)	External noise sources	Traffic, industrial areas
Noise level (privacy)	Noise from neighbours	Neighbourhood studies
Noise level (irritation)	Internal sources of noise	Household equipment
Ventilation rate	Smell	Personal hygiene
Air pollution indoors	Allergy, health	Health services
Dust	Parasites	Cleaning methods
Chemical pollutants	Sources of pollution	Choice of furnishings
Radon problem	Radiation risks	Choice of building materials
Ionisation	Static electricity	Electrical safety
Physical stressors	«Stress» diseases	Psycho-social stressors
Personal arousal	Aggression	Riots, unrest, political activities
Physical conditions for motivation	Initiative, creativity	Hobbies, sports, education
Physical conditions for rest	Recreational activities	Safety, defensible space
Physical conditions for sleep	Sleep evaluation	Psycho-social causes for insomnia

One conclusion that may be drawn from these examples is that there is no hard and fast division, but rather a gradation of emphasis between W45 and W69. The crucial difference is in approach. Scientists connected to either group, be they psychologists, sociologists, physiologists or ethnologists, may study the same problem but they do this from different angels and, mostly, with the help of quite different methods. There is, however, one self-evident difference; in W45 the focus is on the individual while in W69 the focus is on social groups of different kinds and on society as a whole.

HOUSING SOCIOLOGY. HUMAN REQUIREMENTS. BASIC NEEDS RELATED TO FAMILIY AND NATIONAL RESOURCES

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Summary

In this paper we have discussed certain problems of housing sociology as they are experienced by two European sociologists working in a developing country.
It is stated that the pressure towards doing practical, relevant research is experienced more strongly, and that one feels more obliged to the country's political ideology than what is the case in Europe. In a country with scarce national resources the choice of topics for research has to be evaluated in relation to these resources.
Other topics discussed include the production of knowledge as basis for planning, both on a general level concernig national housing development, and on a more detailed level relating local culture to house designs. The choice between basing design of houses on existing local culture or on political ideology and values is identified as a problem.
As an important topic for sociological work, the implementation process is discussed. It is pointed out that in order to initiate a process of social change it is not sufficient to inform people about the knowledge needed to improve on's house. First of all it is a prerequisite that people want to continue to stay in the village where they are presently living. Further one has to show that it is possible to improve on's lot by taking up the knowledge presented.

The authors of this paper have spent two years in Tanzania. The period from 1974 to 1979. We both worked at the National Building Reseach Unit in Dar-es-Salaam, (BRU). BRU will be presented in a paper by Director Mtui at this seminar. This paper is based on our experiences from Tanzania.
When you come to a developing country as an expatriate most often you are full of enthusiasm and idealism, perhaps especially so if you are a social scientist. You think that now you are going to do really important research, because so little in the field of research has been done before. After some time of orientation you centainly will face the question: important research for whom? For yourself and your own interest or for poor people in the country you are living in as an upper class member? In many cases it is possible to combine the two aspects. However, there should be no doubt about which should be given priority in a building research institution in a developing country. Another related question was: should we do research which perhaps could have an impact on the long term basis, or should we do research which could have consequences for the people living in the country today? As sociologists at BRU it was fairly easy to answer these questions.
The objectives of the unit are closely tied to the national housing policies, which may be summarized to the following: To improve the standards of housing in the country within a limited number of years. The government gave rather high priority to housing. Thus to the sociologist, as well as the technical research staff, the task was to provide the necessary basis of knowledge to reach an ambitious goal in housing development.
This strong pressure on improving housing conditions fast, also implied a responsibility for the unit to participate actively in implementing research results. To us as sociologists this opened for a field of research which is not so often identified as a research topic in European building research, i.e. the process of implementation.

National resources

To work within sociology in a poor country like Tanzania, puts you under quite different constraint than if you for instance work in Norway.
First of all the economic situation defines limits for what kind of research results that can be utilized on a broad basis. Even if housing is given high priority by the government and a relatively high proportion of the total investments are made within this sector – in 1976 it was 9,5 per cent – the absolute monetary value is small. The per capita investment in housing were shs. 30/– in 1976. Almost two thirds of this amount is made up of nonmonetary activity, i.e. self help construction.
The income level in Tanzania is low. The following income distribution for private households is taken from Sabri, Schmetzer, Rastad and Guntvedt: «Reducing Housing Costs».

Table 1. *Monthly cash income in private households in urban/rural area. Percentage distribution. (Data from »1969 HBS» upgraded to represent 1976 level.)*

Monthly income T.Shs.	Percentage of household		
	Urban	Rural	Total
0 – 333	20	88	85
334 – 666	37	9	10
667 – 999	15	2	3
1000 – 1999	17	1	1
2000 – and above	11	–	1
Total	100	100	100

The data are old – from the «1969 Household Budget Survey» – but were still chosen after comparison with other available sources. The figures in the table are up-graded to represent 1976 level.
The most striking feature of this distribution is that 88 per cent of the rural, and 85 per cent of all households have a monthly cash income below shs. 333/–. There is of course a close connection between this income group and the average per capita investments in housing mentioned above.
The information we have given on income and economy are neither precise nor up to date. However, certain developments in the later years have probably contributed to make the situation even more difficult. Most important are the rise in oil prices, the war with Uganda, and the floods in 1978/79.
The population of Tanzania is rather heterogenous. It is composed of more than 120 peoples, with differences in language, mode of living, culture, and of course housing. However, there is one general trait of great impact; between 90 and 95 per cent of the population live in rural areas. As can be understood from table 1., the rural population lives partly outside the monetary sector. Maybe it can be described as being in a transition from a non-monetary to a monetary economy. In fact the same goes for a considerable part of the urban population.
Because the rural population represents such a majority, and as the government's policy is to prevent a movement from the countryside into the towns, this population also is the main target for housing development.
What we have mentioned above is a very limited, and of course incomplete, description of what access for resources one can calculate with. What is important, however, is to evaluate the choice of research topics in relation to these resources. As sociologists being responsible for, among other things, looking into what is called «human requirements» it becomes necessary to reconsider the concept.
The meaning of the concept «human requirements» ought to be considered in the light of what resources for change or development that are available. In the Tanzanian case it is tempting to suggest a somewhat crude conclusion: A *sophisticated* understanding or interest in «human requirement» have to give way for the urgent need to improve durability, lay-out and hygienic standards in rural houses. Presently the dominating human requirement is to solve these problems.
Basically one has to accept the housing situation as it is today, and suggest small and cheap solutions for improvement.

Basis for national planning

Both for planning housing development in general, and for designing houses it is quite necessary to have information on the actual situation in the different parts of the country. In a big country like Tanzania with many different peoples with their specific cultures, and with great variations in climatic conditions, architects designing houses ought to have information on the way of living in these different environments. Planners and administrators are also in need of information on this, and in addition, they need information on the actual housing situation, the building materials being used etc.
At the general level, one of the tasks of BRU was to provide such kind of information. This was done by more intensive studies in spesific areas, and by co-operation with the Bureau of Statistics. A small Unit like BRU could not afford to do nationwide representative surveys. Therefore, it was a must to co-operate with the Bureau of Statistics and try to get the Bureau to include some questions on housing in some of their surveys. Such questions were included both in a Household Budget Survey, and in the Census 1978.
Information on population growth, household economy, density in housing, use of materials, etc. was needed for two purposes: 1) As a basis for discussing how far an improvement of the housing conditions were possible, or in other words, it made it possible to put down more realistic targets for what kind of improvements that could be achieved. 2) Secondly this knowledge can be connected to the present capacity for production of crucial building materials, and the possibilities for expanding this production.

Basic needs – local culture-political ideology

We think that the basic needs in most cases are universal, and will not comment further on this concept. But the ways in which needs are satisfied differ a lot from society to society. Descriptive we can define culture as the ways in which needs are satisfied. In our job descriptions it was stated that we should study the local culture, and that the design of new houses should be based on such studies. One other research aim would then be: how are needs – related to housing – satisfied in different local communities in Tanzania. In order to answer this we have to describe how the houses are used. Examples of this are Karin Boalts: «Village Housing in Tanzania», and Helland, Kimati and Poonja: «Housing Development in Kilimanjaro». In the Kilimanjaro-study we tried to describe the development of the housing situation in the Kilimanjaro region during the past fifty years, and to look into how needs were satisfied during the different phases of the development.
The aim of the Kilimanjaro-study was not only to describe the use of the houses, but also to describe the development of the housing situation in the region which today has the best housing condition. In that way we hoped that other regions could learn something from the experiences in Kilimanjaro. This study demonstrates the importance of having a realistic view on human needs when you are trying to improve the housing condition. In Kilimanjaro during the night it can be very cold. The traditional house of the region was a small one-roomed

house where the cattle also stayed during the night together with children and adults. In this way it was a warm house, but not so hygienic. In the next phase of the housing development the cattle were taken out of the house and they built rectangular, nice plastered houses which also were plastered white inside. A traditional fireplace inside the house would make the nice, white walls black and the fireplace was therefore moved away from the house. The consequence of all this was that the house became a very cold house. One could question what would be most hygienic or best for the health of the people to have the cattle and the fireplace inside the house or to have a nicer and better and colder house. One relevant question would be: what contributed most to infant mortality, the unhygienic condition of having the cattle inside the house where the children slept or the cold during the nights. This is an example of an improvement in one field which leads to a derogation in another field.

In another project in an urban area we planned to study the whole building process. Because of practical and organisational problems with the infrastructure in the area not all the phases of the project were realized as planned.

In the first phase we interviewed a sample of people who had been allocated a plot in a World Bank financed Site and-Service project. We got information on their family situation, finanscial situation etc., and their preferences and wishes in regard to the house they wanted to build.

On the background of this information the architects designed different house types which were offered free of charge to the house-builders.

In the next phase we wanted to study the actual building of the houses, to see how much and what kind of work they were able to do themselves, and to what degree they got help from family-members and friends, and to what degree they had to hire labour. This information is important for estimating the cash money involved in building a house. Another question was: How did they get the different building materials which could be a scarcety in Tanzania.

In the last phase of the project we wanted to study how the new houses were functioning. How were they used, and did they satisfy the household's needs. In this way the architects could get feed-back on their type-drawings and eventually improve them.

One experience from this project was that the formal procedures involved in building a house in the surveyed areas, were an important hindrance. Thus, a special study of these procedures was undertaken in co-operation with different offices involved in plot allocation, issuing Right of Occupancy, granting loans, building permits etc.

In the study of how houses are used you have to use observation as a method together with for instance questionnaires and you can also do surveys. Especially if you use observation as a method one prerequisite is to know the culture and the meaning of the different behaviour you will observe. This makes it quite necessary to work together with the local sociologists in these kind of studies. This also indicates the importance of training local sociologists, in contrast to a different policy of using expatriates in research like this.

In this area of research, of describing the use of the houses and where you base the new design of the houses on this description, it is a question if this is the correct or right approach. Should the needs be satisfied in the same way as before or would it be better for the society to try to design the houses in different ways so that the needs are satisfied in also a different way? This is a question of basing the implementation of research on local culture and tradition or to base it on political ideology and values.

As there is a dynamic relationship between housing and social life, there is a reciprocal influence between them. Therefore it is possible to influence the social structure by careful planning of the physical environment.

This is perhaps not a relevant question in many other developing countries, but in Tanzania it was a very pertinent question. The reason for this is that Tanzania has a very clear socialistic settlement policy. The people should live in villages where the villages should be self-sufficient and self-reliant and there should be a collective way of living in these villages. This way of life is in contrast to the way of living of many peoples in Tanzania. Some peoples base their way of living on the family and not on the villages. The question then was for the sociologists to contribute and try to implement into housing designs the local culture or the policy of the country. Most often our solution to this question was to prefer the political idelology and the political solutions and to help architects with designs which suited these pursuits in the same way as we also took into consideration local culture so that the political solutions would have a chance to survive the resistance which would have been very strong if we had not taken local culture into consideration. One example of this is that in the political ideology of Tanzania men and women are equal. In the culture of many peoples in Tanzania men are superior to women in most respects. This is also the case in the use of the houses.

The practical question then was: How should the houses be designed: With the man as a superior creature with his own house, or with the man living as an equal member in the same house as the rest of the household?

Implementation

The choice of solution to the conflict between putting emphasis on local culture or political ideology is of course influenced by the obvious necessity of getting fast results – and by the scarcity of resources. Still, however, knowledge about and respect for local culture is a necessity for reaching any goals for housing development. This becomes very clear when one faces the problems of implementing better housing in rural areas.

We have already identified the process of implementation as a topic for sociological research in a developing country. There is always a time-lag between the development of knowledge and its practical application. In Europe this time-lag is strongly reduced as far as technical knowledge is concerned, due to the close co-operation between the research institutions and the users. This is not so in a country like Tanzania. While the users of knowledge in Europe most often are well developed companies and organisations which may have the same expertise as the research institutions, the most important potential users in Tanzania is the rural population.

In general we can say that the aim of doing research on implementation is to establish the experience necessary to initiate a process of change that eventually will carry itself into the future. To reach this goal one of the practical tasks is to convince people that it is possible to improve ones lot by taking up the knowledge presented.

The first prerequisite for getting people to build better houses is, however, that they want to stay, at least for a certain number of years, in the village they are living in.

The whole of Tanzania's rural sector is undergoing great changes in many aspects, housing being one of them. Over the past few years, the Government has made great efforts to have the people settled into villages. In some places it has been necessary to move the people from one area to another, sometimes causing them to leave behind their immovable properties like houses and permanent crops. In other places there has been no need for movement except that the people have been asked to lead «Ujamaa» way of life. On the whole the movement of the people into villages has been successful although with some few exceptions.

In some areas where resettlement has been experienced, some complaints have been heard that the people were asked to move into villages which were not properly planned, let alone those who moved into totally new areas and later to do the planning themselves. This has in some cases resulted in moving the people into yet, other hopefully better places.

Apart from being economically disruptive, this process makes the people loose confidence, and that air of uncertainty discourages them from building permanent houses.

Before we can except the people to build permanent houses they have to be sure that they want to live in and regard the villages as their permanent homes. For promotion of house-building the decision of settling down is very important. However, Housing Campaigns planned by the Government are aimed at motivating and encouraging the people in villages to build better and permanent houses. Although such housing campaigns would probably not affect people who are not sure about settling down in the village they live in, they do help to restore the confidence in people who might have had unpleasant experiences during their moving into new villages. All the same if housing information only reaches a few people in such villages the campaign may be justified since there is a hope that these few people who build better and more permanent houses will influence the rest. However, in places where people still resist to settle down in the villages other types of campaigns which would help them to settle down should be conducted before launching housing campaigns. Furthermore, this shows that the results of campaigns on housing or other specific measures to get people to improve their houses, are very much dependant upon other – political and social factors, which have to be taken into consideration if good results are to be achieved.

Fortunately in most villages there is a strong motivation among people to improve their housing. But in a village with 400 families, one will have to make a plan which implies that some get a house next year and others in ten years. If only individual resources were put into the project this would not be so much of a problem. But as the villages are based on a certain degree of collective production which ultimately will have to be put into a housing project, you will face problems of solidarity or loyalty conflicts because people's loyalty traditonally may be stronger towards the family than to the village cooperative.

There is no reason to believe that general information campaigns alone will be sufficient to make people spend money on building a soil-cement foundation for their new house. Maybe you can convince some people that they would get a better house in this way. But still few of them will act according to your advice before they are convinced that it is *possible* to use this knowledge. By stressing the actual possibility to use knowledge we want to point out the financial, practical and organisational difficulties. Granted that if a man accepts that a foundation and a non-leaking roof will improve his house, and he wants this improvement, he will still ask: How do I get money, cement, timber, ironsheets, nails? Seemingly these problems are not the responsibility of a building research unit, but if on's research results are to be implemented one has to look into them.

In Tanzania there is a National Housing Bank, which in fact controls rather large sums of money. The problems has been to find ways of channeling this money into rural housing in such a way that it also satisfies the bank's need for security.

One way of showing that improved housing is possible is to start demonstration projects where all aspects of the building process are included.

An important problem concerns how far one should control and protect such a project. Ta have a demonstration effect the project must be successful. But if it, in order to achieve success, is made too artifical, it may loose its convincing value, and it will also be difficult for the house-builders to continue the process when the experts retreat from the project.

One of the initial problems is to decide upon what region and village that should be granted the favour of being the site for such a project. In Tanzania we again experienced some degree of conflict between political ideology and professional judgment. While the ideology focuses on developing the least developed areas, it is possible that in order to secure a good result one will have to choose the already rather well off villages. It is possible that starting with the least developed areas your efforts will not be successful.

One task for the sociologist here was to develop criteria for selecting places where an information or implementation project could have a chance to continue after the experts have left. For this purpose a simple form for describing villages were developed. This form could be used by anyone who made a first visit to a place that requested some kind of assistance from the Unit. Thus, in principle, it was possible to optimize the use of the Unit's scarce resources.

A systematic follow-in of the project is needed in order to be able to utilize the experiences and eventually transfer organisational models to other projects. In general, a careful evaluation is crucial for future application of results.

Some of the problems mentioned may seem self-evident and obvious. Even though they are usually not considered when projects are launched. An example can be taken from an evaluation made on a «Nyumba Bora» (better housing) seminar. In the report it was pointed out several reasons for the seminar not being a full success. Some critics of this report claimed that it did not present anything new. All the problems mentioned could have been foreseen and thus taken care of.

We quite agree on this «criticism», but would like to add that because of the sociologist's background in information theory and organisational theory he could have told beforehand what to the other professionals became obvious afterwards.

Socio-cultural and Economical Factors Effecting The Spatial Arrangement of Dwellings in Turkey

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SUMMARY:

This paper aims at emphasizing the need for research on user requirements in the field of housing in developing countries, due to their special socio-economic conditions, with special reference to Turkey.

To serve to this aim, firstly, the present socio-economical structure of Turkey will be analyzed shortly, giving the specific characteristics of main socio-economic groups. Secondly, the examples of dwellings belonging to each group will be given, dealing with in detail the squatter housing. The technical measures and design criteria proposed for low-cost housing are presented finally, in the conclusion.

SOMMAIRE

Cette étude vise à souligner le besoin d'une recherche concernant les éxigence des usagéres à la champ du 'logement' dans les pays 'presque-développés' à cause de leurs conditions socieaux-écenomiques spéciaux comme la Turquie.

Pour remplir ce but, premierement, on doit faire l'analyse des présents structures socieaux-economiques de la Turguie, uraiment des characteristics specifics des groupes socieaux-economiques principeaux. Secondement des exampl es de logements de chaque groupe, surtout le details des 'bidonuilles' sont donnes . Les mesures techniques et les criteria concermant les projects pour les logements sont presentes enfin, à la conclusion.

Introduction:

Turkey s a country which bears some characteristics of its own from the point of view of its geographical location, socio-economic and cultural structure. The unique characteristics of its geographical location which is 'binding, Europe and Asia in other words, East and West to each other, is also reflected in its socio-economic and cultural structure: The Western technologies, Western way of thinking and living which have been being introduced to the country, through the process of "getting industrialized" are added on the Eastern cultural foundation. Within this framework, the three factors shaping the country's social economical and cultural characteristics are the followings:

- Transition from 'agricultural economy' to 'industrialized economy',
- Transition from Eastern culture to Western culture,
- A dense migration from rural areas to urban areas.

As a result of these three factors, three main socio-economic groups exist in Turkey:

- Rural Group
- Urban Group
- Transition Group

The first two groups are quite static with respect to their social, economical and cultural structures. The rural groups has deep-rooted traditions, customs, thinking and living styles and a socio-economic structure in which the rate of mobility is very low and the limits of any possible changes are determined by this existing structure.

Since the educational possibilities presented to rural area are quite low both in quantity and quality, the only means of learning and knowing the outer world is mass media and the relations kept with the fellow country men who had migrated to urban area.

The socio-economic conditions and characteristics, customs, traditions, value judgements and living styles of urban group are wholly different from the rural group. It has much wider possibilities of education telecommunication,transportation etc. through which 'Western' culture with all its respects and technologies of every sort are introduced easily. This group, also, has a dynamism the limits of which are determined within the existing social economical and cultural set-up and is not in the form of passing from one culture to another.

The third group is the 'Transition Group' who migrates from rural to urban areas, due to the upset of the population-land equilibrium in rural areas (the push factor) and the possibilities, mainly economical, the urban area offer. (the 'pull factor). This group is in the state of breaking off a deep-rooted socio-economic and cultural structure and directed towards a totally different one. Transition group being heterogeneous and dynamic, has a high rate of mobility in locational, social and economical sense.

The characteristics of socio-economic and cultural structures of societies, are reflected through the physical structure. Since family is the unit of society, the effects of societiés' social, economical and cultural characteristics are best observed in the dwelling family lives in. Therefore,production and formation of and the spatial organization in the dwellings, the relationships among and, distribution of the activities to the spaces, choice and use of the equip ment, fitment and furniture required by these activities are the indicators of users needs and requirement shaped by the socio-economic characteristics of the society to which users belong. This is valid for Turkey, also. Within this framework, the examples of dwellings belonging to each group mentioned above, are given and elucidated in the next chapter.

Dwelling types with respect to socio-economic groups:
Rural Housing

Among the rural group, the extended-family type is dominant. The average family size is quite large. Women work both on land and at home. Since rate of social and economical mobility is very low,it is very rare that a family changes its dwelling during the family cycle . Dwellings are either built by the family itself at one time, or bought as a finished product from the owners who had already migrated to urban areas. Homeownership is dominant. Rate of childbirth is very high. No of persons/room changes from 1-2 upto 6-8 ccording to the size and economic state of the family. However, on the whole, dwellings with 3-4-5 rooms are in majority where each family has a separate room due to extended family type. Areas of rooms are , generally, large since the spaces are not specialized with respect to functions.

The definitions of 'kitchen' and ' living room' implies the same space among the rural peoples "We live in the room where we cook' or 'we cook in the room where we live' are the answers obtained for the question "Where is your living room" or "where is your kitchen?" Mostly there is no space specialized as ' kitchen'. The 'sofa' is an entrance hall to the dwelling, functioning also as circulation and storage space for kitchen equipments, food articles and where dish and clothes washing and cooking is done especially in the warm seosons of the year. In the cold seasons, living,sleeping, cooking, eating,etc., take place in the rooms. If there is any separate space called 'kitchen' it is the place where many different activities including, storing the surplus of the agricultural products. Existence of a separate space serving as 'bathroom' is hardly observed. If there is any, it is less than 1 m2. The hadds and face dlearing is done in 'sofa', in the rooms or in the garden, when the reason is adequate. Body clearing is mostly, done in the multipurpose cupboards in the rooms, called 'gusülhane' where water ewers or buckets are kept and floor beds are stored during daytime. Running water system is very scarce, water is provided from a well in the garden, from a stream flowing nearby, but mostly from the village fountain. The most sophisticated equipment used for water heating is 'bath stove' which is very rare.

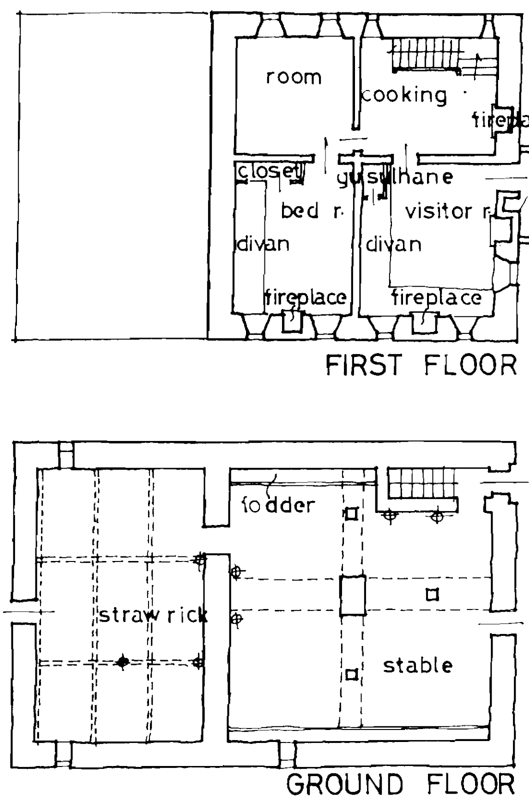

Fig. 1: An Example From Rural Housing

The rural family has a closed economy, peoples' consumption basing, mostly, on the house products, Bread, macaroni, yoghurt, etc. are made by the women, mostly in gardens in summer and inside the dwelling during winter. The equipments used for cooking and heating are various: fireplace, furnace, maltese, stove and very rarely kitchen stove. The kinds of fuel used are, fire wood, coal and mostly dried dung.

Storage spaces are vital components of a rural dwelling necessary for food items equiring, mostly, yearly or seasonal storing, for fodder and for the surplus of what is produced and for fuel. Use of refrigerator as a food storage is very rare since, there is no electricity in most of the rural areas instead larders or flyproof food cupboards with wire screening are widely used.

One of the most common characteristics of rural type of living is the dense and integrated use of garden with dwelling. Especially during the warm seasons of the year, sofa and kitchen are integrated with garden most of the activities are brought outdoors. In another sense, garden has an economic character, since some kinds of vegetables are grown and cattles, sheeps, goats, poultry and pets are kept there.

Urban Housing:

Among the urban group, nuclear type of family is dominant. Average family size is small. Most of the women work especially at public sector. Rate of childbirth is low due to women working and economic limitations. Social and locational mobility follow the trend of family's economic conditions. In the urban area, districts, mostly, express the status fact r and locational mobility takes place parallel with the status change and improvement in economic conditions. Since housing supply is in the form of finished products with rigid plan types, urban family has to change dwellings as its needs and requirements change through the family cycle, if it is affordable. Consequently, the rental tenure is, in general, dominant. In dwellings, spaces are highly specialized with respect to functions, such as studying room, children's room, etc. The dwellings are equipped with all sorts of substructure, heated through either central or local heating. Urban people make use of the facilities urban life offers, widely. Therefore, food stock of daily, weekly or at most monthly is required, need for space for food storage lessening gradually. On the other hand, there arises need for space for durable consumption goods such as refrigerator, cooking unit with oven, washing machine, etc. In the urban areas, balconies replace the garden in the multi-storey housing, and the scale of individual outdoor space changes to 'common recreationalareas.'

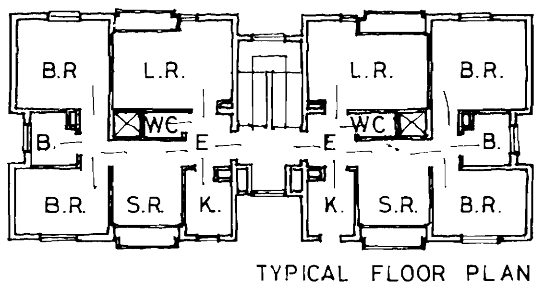

Fig. 2: An Example From Urban Housing

Squatter Housing:

Transition group undergoes a process, which is symbolized by ' squatter housing'. This process begins with leaving the rural area for the urban area continues towards 'getting urbanized'. It is an event of breaking with the rural area and gradually, getting integrated with urban area and bears a character of a process consisted of stages following each other in a time dimension and each stage is reflected through the planning and spatial organization of migrant's dwelling. These stages are the following.

1. Head of the family migrates to urban area first and tries many jobs. Throughout this stage, migrant has to maintain his connections with rural area open until he provides a stable income through the job he obtains in urban area. During this period, he lives either in one room of a squatter dwelling as a renter or stays in one room of a relative's home.

2. In this stage, head of the family finds a suitable job with stable income and brings rest of the family to urban area. Now that he is with his family, he needs a house therefore a squatter house is rented and other member(s) of the family seek for and get jobs in order to support the family budget.

3. The main character of this period is the increase in the locational mobility of the family being parallel to the improvement in economic conditions.

4. With the head of the family finding a suitable, continuous job with sufficient income, the conditions for the family to own a squatter dwelling become ready, through one of the following ways:

. Family builds up a squatter dwelling either alone or by the help of foremen.

. Family buys a squatter dwelling either from its builder or a developer.

The stage which is of utmost importance to the professionals - architects - is this last one since it is the period that family's own dwelling exists and begins to live with it throughout the family cycle, reflecting the distinct character of 'dymamism' of the transition group (which is infact a result of people's economic struggle during the process of gettin urbanized) as flexibility in the planning of dwellings.

The quality of 'flexibility' yields for, mainly, two different approaches of planning:

. A core or a single space (room) is taken as a planning unit. Vertical and horizontal additions are made following the trend of economic dynamism and changing needs of the family.

. The dwelling as a whole is considered as 'planning unit'. First the size and form of the dwelling is determined. The decisions about how to divide inside the shell and for which purposes the spaces will be used, are given later.

Within the framework given above the characteristics of 'transition group'- people which shape the spatial organization in the dwellings are that:

. They are at the young and active age group equipped with necessary energy to achieve the economic struggle in the urban area and to adapt themselves to the urban living style.

. The'nuclear family' type is most common among this group which implies that all stages of family cycle are to be gone through in the urban area which is'a world of strangers' for migrants.

. They have to prove to rural area where they come from that their relations are still lasting, by performing the main traditional behaviours towards which the rural area is most sensitive.

. Majority of the transition-group people receive some sort of an aid from rural area in the form 'aid in kind' and/or 'cash'. In return, theyserve the rural area as 'connection and reference point' where information about urban area is obtained and where it is possible to stay for nothing during the visits to urban area.

. Rate of childbirth is lower than the rural area.

. Women have to work outside the dwelling, mostly in housework, in order to support the family budget and this factor acts a certain role in having less children.

. They are much more informed about and aware of the changes and novelties than rural area people through the increasing possibilities of mass media, education, leisure time activities and the consumption goods which are presented by the urban area.

. Integration of migrant with urban way of living takes place first through materialistic ways. Social integration progresses at a slower pace.

. The family has to produce some of the food still at home therefore keep poultry and grow some vegetables in the garden as a supplement to the family budget.

The squatter dwelling has some characteristics that make it different from the dwellings of two other groups mentioned:

. Since the land is not so abundant as in rural area use of space must. be economical. Apart from that, there are many cases that the migrant has to pay for the plot. Consequently, the dwelling and the garden are small in area.

. Since the family structure is 'nuclear' family size is small and multi-purpose there is no need to have many rooms, especially in the first phases of family cycle.

. As the family size gets bigger and the economical state of the family improves, rooms are added and the spaces become 'specialized' gradually. This is also an indication of 'getting urbanized.'

. Garden keeps its importance in the lives of transition group people as it has been in rural area, although it gets smaller gradually, as the family requires more rooms.

. Provision of the squatter dwellings with running water and electricity is rare. Therefore, water is taken from neighbourhood tap, mostly. There are also cases that the electricity is taken illicity from the city electric line.

. Daily and weekly food stock is required, mostly. Seasonal food stock is required for the items sent or bought from or made in rural area during the visits. As the family's economical state improves rate of using the ready-made products urban life offers, increases.

. Other items requiring storage space are furniture and belongings due to:

. Lack of sufficient useful space (use of floor beds only at night)

. Investments made for durable or semi-durable consumption goods as means of 'status' and for preparing 'trousseau' for children.

. Furnitures are also used multi - purposely especially in the early phases of transition process due to very limited economical possibilities. This aspect play role in increasing the need for storage space in the dwelling.

. Towards the end of the transition process, as the people get more unified with urban life, they loose their character of dynamism and this reflects in their dwellings as 'decrease in flexibility'.

An Example of Squatter Housing:

The author is carrying on an individual research on "spatial organization of the squatter dwellings with respect to changing needs and requirements of users" The example given below is one of the squatter housing visited during this research with two years' interval, in 1977 and in 1979.

It belongs to a very low income family of 5, 3 of them being children. In 1977, a grandfather was with the family, since he has passed away in 1978, the family is at present, 'nuclear type'. Head of the family came to Ankara, 12 years ago, rented a room of a squatter dwelling, found his present job and constructed his dwelling by himself within one year, and brought the rest of family to Ankara in 1969. They have been living in the same dwelling since then.

First, the two rooms (Fig 3.s.l) were built, both of them serving as multi-purpose spaces. The space serving as 'entrance and cooking niche' at present were added in 1973. (Fig. 3 - S.2). The changes realized in between 1977-79 are (Fig. 3 - S.3):

1. Changing the location of the stairs and adding a concrete pathway leading to the dwelling,
2. Construction of a concrete slab on coloumns at the floor level of dwelling, making use of the slope of the plot, using the space underneath as fuel storage by removing the soil,
3. Changing the places of window and door at the 'entrance and cooking niche.

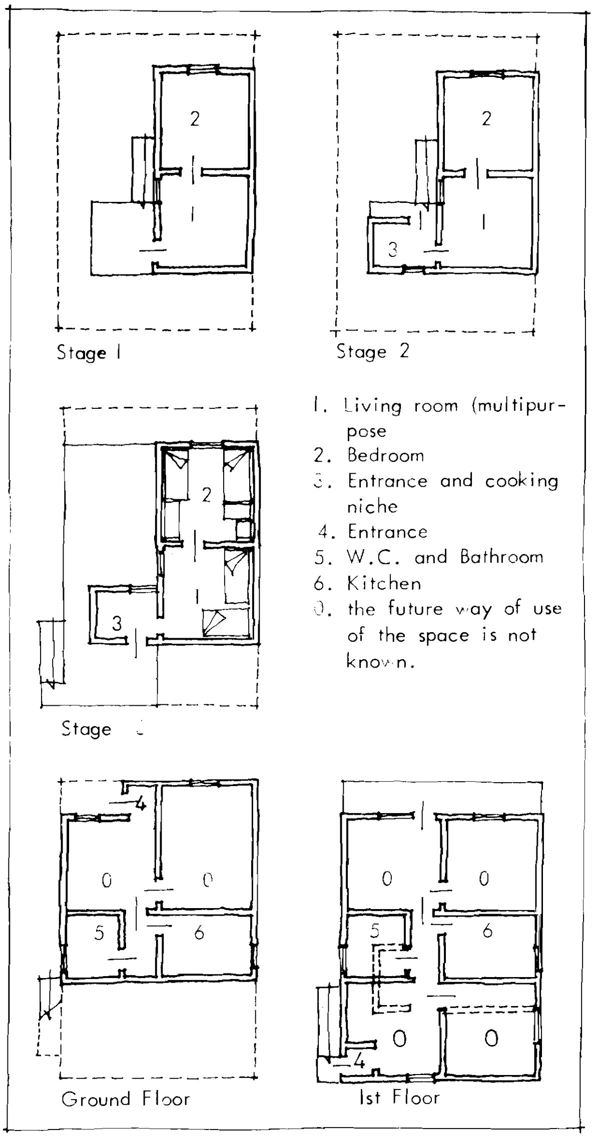

Fig. 3: Evolution of A Squatter Dwelling.

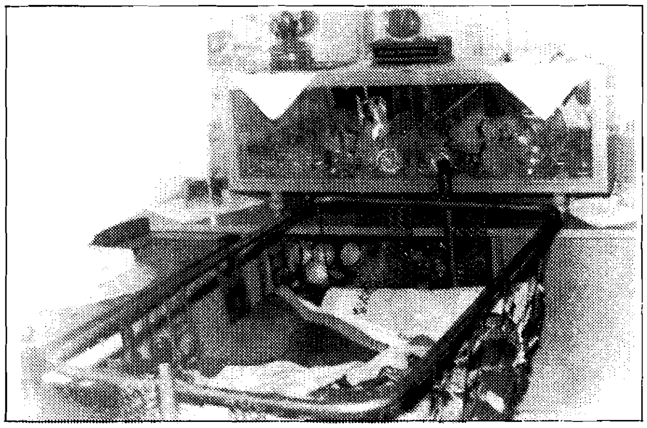

Fig. 4: Use of a bedroom also for childcare and exposing the status symbol - Bufet

Fig. 5: Squatter family having lunch on round floor table.

These are the preparations made for the additions planned to be realized when the head of the family gets retired and has his 'retiring gratuity' next year. He thinks to largen his dwelling by adding new rooms on the concrete slab and to change the present fuel storage space into a new dwelling by dividing it into rooms and rent it. (Fig. 3 - S.4) At present, all of the rooms are 'multi-purpose'. (Fig. 3-S.3) One of the rooms (Fig. 3-S.3-2) serves as 'bed room' for parents the spaces underneath the beds are used as storage space for yearly and seasonal food stock, floor beds and refrigerator are also kept there. The other room (Fig. 3-S.3-I) is used for the activities such as children's sleeping, studying, entertaining visitors, eating, clothes washing and body cleaning in winter, etc. The other space (Fig. 3-S.3-I) functions as entrance, cooking niche and the place where dish and clothes washing and body cleaning take place in summer. W.C. is in the garden, there exists no running-water system, water is provided from the well in the garden, electiricity is taken from a neighbour's line.

Low-cost housing:

In Turkey, 60-70 % of the population of the three biggest cities, is living in 'squatter-housing'. As a counter-solution, low-cost urban housing was developed. This kind of housing is realized, mostly, through the credits and funds provided and operated by housing corporations, 'Social Security Organization' and other public bodies. Since the funds and credits available are always limited, the current approach to low-cost housing is largely, cost-oriented, the economies being tried to be achieved by reduction of floor areas, use of cheap materials etc. wherever possible and the 'rigid' design solutions are arrived in the conventional way through concepts of conventional urban dwellings whereas this approach has no 'flexibility' since the 'dynamic' character and needs of 'transition group' people are not considered at all.

The photos were taken by the author during related research.

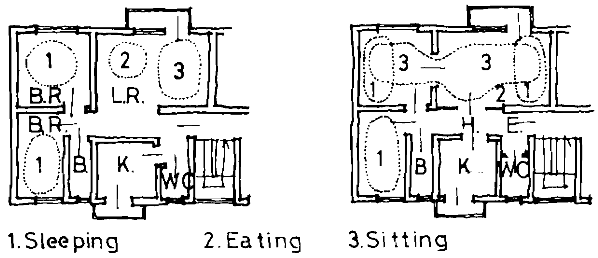

Fig. 6: An Example From Low-Cost Housing and Changes Made By The User

The results have been such that:

1. The transition group people do not want and can not afford to buy these houses with 'rijid' plan types supplied as 'finished-products'.

2. The 'transition group' people buy these houses if they can afford, more with speculative purposes. They continue living in squatter-housing where they organize the spaces in accordance with their needs and sell the low-cost housing to urban people.

3. The 'transition group' people buy these houses and change them according to their needs and reguirements.

Conclusion:

Migration from rural to urban areas and consequently 'squatter-settlements' are the events dictated by the socio-economic conditions of the country. As long as these conditions last, these events will continue to exist. Therefore, 'what has to be done?

It is proposed that:

. The 'squatter-housing' should be accepted as a 'solution' realized by individuals, as long as public sector can not provide the 'transition group' people with adeguate housing systems.

. Within the above framework, financial and technical subsidies should be provided by public sector for the improvement of squatter-housing and housing production techniques that would offer solutions detailed simply enough to be used by the users easily in realizing the changes they want to make in their dwellings, should be developed.

. In the low-cost housing developments that would be realized by public sector, technical organizational and planning stipulations should be determined in order to provide that the users'participation at every level of 'housing process'.

. The standards for low-cost housing should be determined through research on the evolution of aspirations, potentials, needs and requirements of 'transition group' people, that would reflect in planning.

. The design solutions with rigid plan types should be given up and at least one of planning approaches that is dominant among squatter-housing, taking the dwelling as a planning unit' (p. 5) should be adopted in realizing the low-cost housing, technical and organizational approaches and measures should be provided, accordingly.

. Typification of building elements in accordance with the needs and possibilities of the country and users, in the light of above mentioned proposals, should be provided instead of typification of dwelling plans.

The low-cost housing realized and supplied in its present form is far from being a counter-solution to squatter-housing and a means of lightening the housing problem of Turkey, as claimed. On the contrary, it results in adding to the loss of country's limited sources by not serving adequately to the group it should serve.

Within the framework of proposals given above the key to the right approach of planning and use of low-cost housing is multi-disciplinary research on needs and requirements of 'transition-group' people which should lead to performance criteria of spaces, material, building elements. In this respect, the building research institutions or establishments in developing countries are greatly responsible for undertaking and encouraging basic and developing research projects on this subject.

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Measuring Adaptability Between Activities and Spaces in Dwelling Units

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Summary

In this paper, a mathematical approach for the measurement of adaptability between activities and spaces in dwelling units is presented.

In the first and second parts, the problem is defined and the mathematical model, which is used in the measurement of the adaptability has been explained. The third part is devoted to the development and the computerization of the model in order to apply it to the dwelling units. In the following parts, the proposed model has been applied to six different types of dwelling units and the results are discussed according to the layout characteristics of dwelling units and the different family sizes.

Sommaire

Dans ce travail on a voulu de présenter une approche mathématique de mésurement d'adaptabilité, au point de vue de l'éspace et les activités.

Dans le premier et la seconde parties se trouvent la détermination du problème, et la présentation du model de mésurement mathématique. Dans la troisième partie, on a presenté le developpement du modèle par l'informatique en but de l'emploie dans les unités d'habitations. Dans les parties précédentes vous pouvez trouvez les essais du modèle dans les unités d'habitation de six types differentes avec le discutions de l'organisation des plans au point de vue des charactéristiques privés et la grandeur des familles.

Introduction

Adaptability is an important property which effects the planning decisions in housing. To shelter families with different structures (life styles and sizes), the houses need a great ability of adaptation. The problem needs special attention in Countries like Turkey where the housing problem is severe and the requirements of the users are greatly variable and changeable depending on the rapid change of the cultural and social system of the community.

The adaptability concept must also envelope the changeable uses during short time periods, the occupation of the same space of the house by different activities at different hours of the day.

The aim of this study is to adapt and develop a mathematical model used to measure adaptability to houses and to measure the adaptability of houses built by mass-production.

The mathematical model used:

Necessarily, before explaining the model the term adaptability will be defined. As in Fawcett's definition, in this model, adaptability is equivalent to the ability to maintain compatibility as the activities change (1).

In measuring the adaptability of a building Fawcett introduces two different approaches. In the first approach -the loose-fit- a given set of activities and spaces are matched in such a way that there is only a one to one correspondence between activity and space. In the second approach -the microstates- this correspondence is between a group of activities and a group of spaces.

In approach introduced in this paper it is assumed that an activity or a group of activities can take place in one space.

The calculation process of the microstates approach and the approach developed in this paper is similar to the loose-fit approach. Therefore the loose-fit approach will be examined briefly.

To explain the loose-fit method theoretically it is accepted that a part of the activities of the set of activities accomodated in a building feasibly can take place in many different spaces in the building, while the other part may only be feasible in one space.

In the method, the amount of uncertainity -the measure of adaptability- is calculated by the entropy of the probability distribution which is based on the Information Theory.

The application of the method may be summarized by the following headings:

- o Obtaining the feasibility matrix
- o Obtaining the potential solutions of activity - space allocations and the full allocation matrix
- o Obtaining the probability distribution matrix and consequently measuring the amount of uncertainity.

Obtaining the feasibility matrix:

In principle, it is always possible to determine whether or not an activity is feasible in a space. The problem is how to establish an overall feasibility matrix from many attributes of activites' demands and spaces' supplies. Each attribute can be considered as a filter with which an activity -to- space match must be tested, Figure (1). Consequently, if the activity is possible in the space f_{ij} is one if not, f_{ij} is zero, Figure (2).

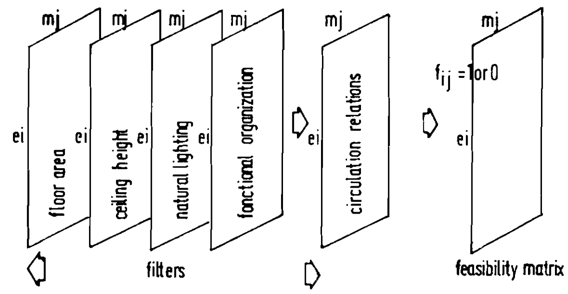

Figure 1. Obtaining the feasibility matrix.

	M_1	M_2	. . .	M_j
E_1	f_{11}	f_{12}		f_{1j}
E_2	f_{21}	f_{22}		f_{2j}
.				
.				
.				
E_i	f_{i1}	f_{i2}		f_{ij}

f_{ij} = 1 or 0

Figure 2. Feasibility matrix.

Obtaining the potential solutions of activity - space allocations and the full allocation matrix:

By the help of the feasibility matrix, the potential solutions of activity-space allocations may be obtained in which every activity is located to a space, and no space has more than one activity in it, Figure (3).

	m_1	m_2	m_3	m_4	
e_1	1	1	0	0	1) $(e_1,m_1),(e_2,m_2),(e_3,m_3),(e_4,m_4)$
e_2	0	1	1	0	2) $(e_1,m_1),(e_2,m_3),(e_3,m_4),(e_4,m_2)$
e_3	0	0	1	1	3) $(e_1,m_1),(e_2,m_2),(e_3,m_4),(e_4,m_3)$
e_4	1	1	1	1	4) $(e_1,m_2),(e_2,m_3),(e_3,m_4),(e_4,m_1)$

Figure 3. Enumeration of the full-allocations.

After obtaining the possible activity-space allocations, it is possible to enumerate the proportion of times each of the feasible spaces open to a given activity is used. This is the allocation matrix, Figure (4).

Obtaining the probability distribution and consequently measuring the amount of uncertainity:

If the full allocation matrix is expressed as a fraction of the total number of full allocations, this fractional matrix is the desired distribution matrix, Figure (4).

If the probability distribution across the spaces h_j (j=1,2,....) is p_j (j=1,2,....), then the probability of the distribution can be measured by the equation of (1):

$$S = (P_1,P_2....) = -k \sum_j P_j \log P_j \qquad (1)$$

The base of the logaritm is optional, normally it is 2. In the given example the entropy is S = 4.622.

	m_1	m_2	m_3	m_4
e_1	3	1	0	0
e_2	0	2	2	0
e_3	0	0	1	3
e_4	1	1	1	1

	m_1	m_2	m_3	m_4	
e_1	3/4	1/4	0	0	
e_2	0	2/4	2/4	0	
e_3	0	0	1/4	3/4	
e_4	1/4	1/4	1/4	1/4	$P_i(J)$

Figure 4. The allocation and the distribution matrices.

The development of the model

In analysing the adaptability of the house, there are two variables; the first variable is the changing activity patterns and the second variable is the family sizes. The method which is used in this study is developed in order to include the both variables mentioned above.

In this study, the activities which can take place in the dwelling units were analysed at the spatial behaviour scale (2).

The activities at this scale were determined as:

1. Living and resting
2. Dining
3. Food preperation
4. Sleeping
5. Working-Studying
6. Washing (self and other)
7. Toilet
8. Entering and leaving the dwelling.

One of the principles of the loose-fit approach is that only one activity can take place in one space, although even if analysed in the spatial behaviour scale it is possible that more than one activity is available in one space. To avoid this handicap of the approach the possible activities which can take place together in one space were determined by the help of the activity relation matrix Figure(5). The combinations of the activities which can occur together changes by cultural and social differences of the families at a macro scale and by the different hours of the day in a micro scale. If two activities can take place together in one space the relation in the matrix is shown by 1 if not by 0. By the help of this matrix all possible combinations of 2, 3 and 4 activities were enumerated. Consequently, by using the whole set of activities available in a dwelling unit all the possible combinations of the activities and activity groups were determined by exhaustive enumeration. By this method, 203 different activity patterns were obtained (Table 1). To obtain the number of possible microstates of activities in a given schedule has also been studied by Fawcett in a theoretical way (3).

	1	2	3	4	5	6	7	8
1		1	1	1	1	0	0	1
2			1	1	1	0	0	1
3				1	1	0	0	1
4					1	0	0	1
5						0	0	1
6							1	0
7								0
8								

Figure 5. Relationships between activities.

1.1	1.1,2	1.1,2,5
2.2	2.1,5	2.4,1,2
3.4	3.1,(2+5)	3.4,(1+2),5
4.5	4.2,(1+5)	4.4,2,(1+5)
5.1+2	5.5,(1+2)	5.4,1,(2+5)
6.1+4	6.1,4	6.4,(1+4),2
7.1+5	7.4,5	7.4,(1+4),5
8.2+4	8.4,(1+2)	8.4,(2+4),5
9.2+5	9.4,(1+5)	9.4,(2+4),1
10.4+5	10.4,(2+5)	10.4,(4+5),1
11.1+2+4	11.4,(1+2+5)	11.4,(4+5),2
12.1+2+5	12.4,4	12.4,4,1
13.1+4+5	13.4,(1+4)	13.4,4,2
14.2+4+5	14.4,(2+4)	14.4,4,5
15.1+2+4+5	15.4,(4+5)	15.4,4,(1+2)
	16.4,(1+4+5)	16.4,4,(1+5)
	17.4,(1+2+4)	17.4,4,(2+5)
	18.4,(2+4+5)	18.4,4,4
	19.4,(1+2+5)	19.4,4,(1+4)
		20.4,4,(2+4)
		21.4,4,(4+5)
		22.4,(1+4),(2+4)
		23.4,(1+4),(4+5)
		24.4,(2+4),(4+5)
		25.4,4,(1+2+4)
		26.4,4,(1+4+5)
		27.4,4,(2+4+5)
		28.4,4,(1+2+4+5)

1. Sitting-resting
2. Dining
3. Food preparation
4. Sleeping
5. Studying-working
6. Washing
7. Toilet
8. Entering and leaving

Table 2. Additional activities or activity groups.

1. 1,2,3,4,5,6,7,8
2. (1-2), 3,4,5,6,7,8
3. (1-3), 2.4.5,6,7,8
4. (1-4), 2,3,5,6,7,8
5. (1-5), 2,3,4,6,7,8
6. (1-8), 2,3,4,5,6,7
7. (2-3), 1,4,5,6,7,8
8. (2-4), 1,3,5,6,7,8
9. (2-5), 1,3,4,6,7,8
10. (2-8), 1,3,4,5,6,7
11. (3-4), 1,2,5,6,7,8
12. (3-5),1,2,4,6,7,8
13. (3-8), 1,2,4,5,6,7
14. (4-5), 1,2,3,6,7,8
15. (4-8), 1,2,3,5,6,7
16. (5-8), 1,2,3,4,6,7
17. (1-2), (3-4), 5,6,7,8
18. " , (3-5), 4,6,7,8
19. " , (3-8), 4,5,6,7
20. " , (4-5), 3,6,7,8
21. " , (4-8), 3,5,6,7
22. " , (5-8), 3,4,6,7
23. (1-3), (2-4), 5,6,7,8
24. " , (2-5), 4, 6,7,8
25. " , (2-8), 4,5,6,7
26. " , (4-5), 2,6,7,8
27. " , (4-8), 2,5,6,7
28. " , (5-8), 2,4,6,7
29. (1-4), (2-3), 5,6,7,8
30. " , (2-5), 3, 6,7,8
31. " , (2-8), 3,5,6,7
32. " , (3-5), 2,6,7,8
33. " , (3-8), 2,5,6,7
34. " , (5-8), 2,3,6,7
35. (1-5), (2-3), 4,6,7,8
36. " , (2-4), 3,6,7,8
37. " , (2-8), 3,4,6,7
38. " , (3-4), 2,6,7,8
39. (1-5), (3-8), 2,4,6,7
40. " , (4-8), 2,3,6,7
41. (1-8), (2-3), 4,5,6,7
42. " , (2-4), 3,5,6,7
43. " , (2-5), 3,4,6,7
44. " , (3-4), 2,5,6,7
45. " , (3-5), 2,4,6,7
46. " , (4-5), 2,3,6,7
47. (2-3), (4-5), 1,6,7,8
48. " , (4-8), 1,5,6,7
49. " , (5-8), 1,4,6,7
50. (2-4), (3-5), 1,6,7,8
51. " , (3-8), 1,5,6,7
52. " , (5-8), 1,3,6,7
53. (2-5), (3-4), 1,6,7,8
54. " , (3-8), 1,4,6,7
55. " , (4-8), 1,3,6,7
56. (2-8), (3-4), 1,5,6,7
57. " , (3-5), 1,4,6,7
58. " , (4-5), 1,3,6,7
59. (3-4), (5-8), 1,2,6,7
60. (3-5), (4-8), 1,2,6,7
61. (3-8), (4-5), 1,2,6,7
62. (1-2), (3-4), (5-8),6.7
63. (1-2), (3-5), (4-8), 6,7
64. (1-2), (3-8), (4-5), 6,7
65. (1-3), (2-4), (5-8), 6,7
66. (1-3), (2-5), (4-8), 6.7
67. (1-3), (2-8), (4-5), 6.7
68. (1-4), (2-3), (5-8), 6,7
69. (1-4), (2-5), (3-8), 6,7
70. (1-4), (2-8), (3-5), 6,7
71. (1-5), (2-3), (4-8), 6,7
72. (1-5), (2-4), (3-8), 6,7
73. (1-5), (2-8), (3-4), 6,7
74. (1-8), (2-3), (4-5), 6,7
75. (1-8), (2-4), (3-5), 6,7
76. (1-8). (2-5). (3-4). 6,7
77. (1-2), (3-4-5), 6,7,8
78. (1-2), (3-4-8), 5,6,7
79. (1-2), (3-5-8), 4,6,7
80. (1-2), (4-5-8), 3,6,7
81. (1-3), (2-4-5), 6,7,8
82. (1-3), (2-4-8), 5,6,7
83. (1-3), (2-5-8), 4,6,7
84. (1-3), (4-5-8), 2,6,7
85. (1-4), (2-3-5), 6,7,8
86. (1-4), (2-3-8), 5,6,7
87. (1-4), (2-5-8), 3,6,7
88. (1-4), (3-5-8), 2,6,7
89. (1-5), (2-3-4), 6,7,8
90. (1-5), (2-3-8), 4,6,7
91. (1-5), (2-4-8), 3.6,7
92. (1-5), (3-4-8), 2,6,7
93. (1-8), (2-3-4), 5,6,7
94. (1-8), (2-3-5), 4,6,7
95. (1-8), (2-4-5), 3,6,7
96. (1-8), (3-4-5), 2,6,7
97. (2-3), (1-4-5), 6,7,8
98. (2-3). (1-4-8), 5,6,7
99. (2-3), (4-5-8), 1,6,7
100. (2-3), (1-5-8), 4,6,7
101. (2-4), (1-3-5), 6,7,8
102. (2-4), (1-3-8), 5,6,7
103. (2-4), (1-5-8), 3,6,7
104. (2-4), (3-5-8), 1,6,7
105. (2-5), (1-3-4), 6,7,8
106. (2-5), (1-3-8), 4,6,7
107. (2-5), (1-4-8), 3,6,7
108. (2-5), (3-4-8), 1,6,7
109. (2-8), (1-3-4), 5,6,7
110. (2-8), (1-3-5), 4,6,7
111. (2-8), (1-4-5), 3,6,7
112. (2-8), (3-4-5), 1,6,7
113. (3-4), (1-2-5), 6,7,8
114. (3-4), (1-2-8), 5,6,7
115. (3-4), (1-5-8), 2,6,7
116. (3-4), (2-5-8), 1,6,7
117. (3-5), (1-2-4), 6,7,8
118. (3-5), (1-2-8), 4,6,7
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121. (3-8), (1-2-4), 5,6,7
122. (3-8), (1-2-5), 4,6,7
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166. (2-4-8), 1,3,5,6,7
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170. (3-5-8), 1,2,4,6,7
171. (4-5-8), 1,2,3,6,7
172. (1-2-3), (4-5-8), 6,7
173. (1-2-4), (3-5-8), 6,7
174. (1-2-5), (3-4-8). 6,7
175. (1-2-8), (3-4-5), 6,7
176. (1-3-4), (2-5-8). 6,7
177. (1-3-5),(2-4-8), 6,7
178. (1-3-8), (2-4-5), 6,7
179. (1-4-5), (2-3-8), 6,7
180. (1-4-8), (2-3-5), 6,7
181. (1-5-8), (2-3-4), 6,7
182. (1-2-3-4), 5,6,7,8
83. (1-2-3-5), 4,6,7,8
184. (1-2-3-8), 4,5,6,7
185. (1-2-4-5), 3,6,7,8
186. (1-2-4-8), 3,5,6,7
187. (1-2-5-8), 3,4,6,7
188. (1-3-4-5), 2,6,7,8
189. (1-3-4-8), 2,5,6 7
190. (1-3-5-8), 2,4,6,7
191. (1-4-5-8), 2,3,6,7
192. (2-3-4-5), 1,6,7,8
193. (2-3-4-8), 1,5,6,7
194. (2-3-5-8), 1,4,6,7
195. (2-4-5-8), 1,3,6,7
196. (3-4-5-8), 1,2,6,7
197. (1-2-3-4-5), 6,7,8
198. (1-2-3-4-8), 5,6,7
199. (1-2-3-5-8), 4,6,7
200. (1-2-4-5-8), 3,6,7
201. (1-3-4-5-8), 2,6,7
202. (2-3-4-5-8), 1,6,7
203. (1-2-3-4-5-8), 6,7

Table 1. General activity patterns.

If the number of spaces and the number of activities and/or activity groups in an activity pattern is concerned there are three different relations:

- o In the first case, the total number of the activities and/or activity groups of the activity pattern is more than the number of spaces available in a dwelling. In this case, there is no probability to locate all the activities or activity groups in the existing physical schedule.
- o The second case is that the total number of activities and/or activity groups of the activity pattern is equal to the number of spaces. In this case it is possible to measure the adaptability of the building.
- o The third case is that the total number of activities and/or activity groups of the activity pattern is less than the number of spaces avilable in the dwelling. In this case, this means that the building can accomodate more activities and/or activity groups than the applied activity pattern contains.

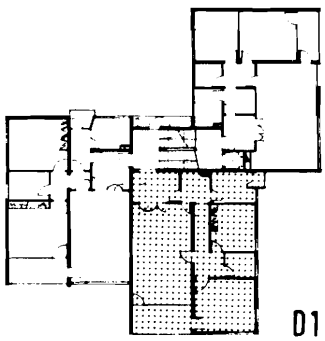

Figure 6. The plan of the dwelling unit D1.

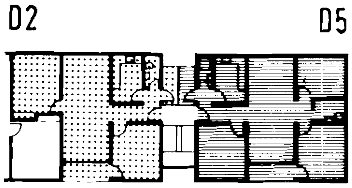

Figure 7. The plans of the dwelling units D2,D5.

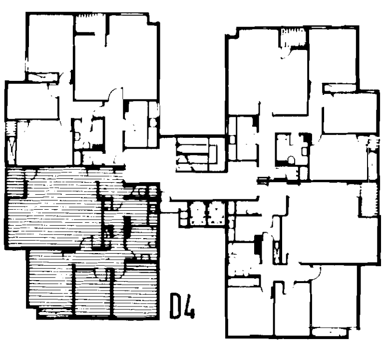

Figure 8. The plan of the dwelling unit D4.

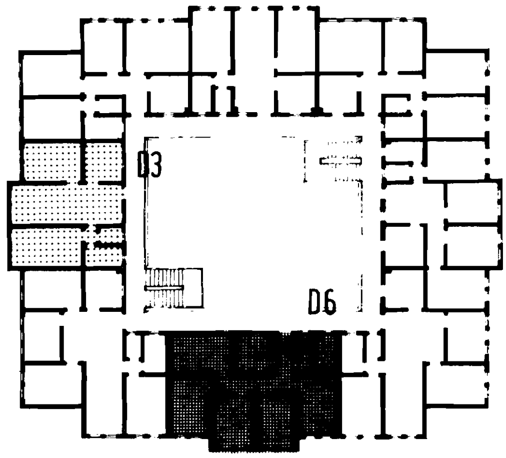

Figure 9. The plans of the dwelling units D3,D6.

Therefore, it was concluded that measuring the adaptability of a dwelling by using only the activity patterns which have the same number of elements as the number of spaces available the number of applicable activity patterns were reduced and the real usage of the dwelling was not expressed thoroughly.

In the first part of this study, if the number of the elements of the activity pattern was less than the number of available spaces of the dwelling, this was modified by adding new sleeping activities for one, two and three children. Consequently the family size was also expressed in the measurement of adaptability (4).

In the second part of the study, the approach was developed to cover different life styles. Therefore, a group of secondary resting, living, sleeping, dining and working activities and activity groups obtained by their combinations were added. These additional activities and activity groups are shown in Table (2).

As a result of the difficulties in allocating all the possible states of full allocations and obtaining the allocation matrices and the great amount of activity patterns used in measuring the adaptability it was decided to computerize the approach. The computer program developed performs the following operations: Selecting the appropriate activity patterns related to the characteristics of the dwelling, enumerating the full allocations, generating the allocation matrix and the distribution matrix, and consequently computing the adaptability. The input data for the computer program is as follows:

Data related to general activity patterns in dwelling units;

- o the activity pattern matrix,
- o the activity or activity groups that is to be added to the activity patterns.

Data related to a given dwelling

- o the number of spaces of the dwelling,
- o the general feasibility matrix of the activity-space relations.

The output of the computer program is as follows;

- o the number of the applied activity pattern,
- o the activities and/or activity groups which form the activity pattern,
- o the special feasibility matrix of the applied activity pattern,
- o the full allocations of the applied activity pattern,
- o the probability distribution matrix,
- o the entropy value of the activity pattern,
- o the total number of applied activity patterns for each type of family,
- o the total amount of entropy for each type of-family,
- o the average entropy for each type of family.

Principles in the application of the method:

The first four examples D_1, D_2, D_4, D_5 (shown in Figure 6, 7, 8) were selected from a mass-production scheme realized by a National Bank specialized in financing housing schemes. The other two examples D_3, D_6 (shown in Figure 9) are selected from a group of apartments built as one of the first examples of mass-production housing in Istanbul. The types chosen are examples which are differentiated by their number of rooms and/or the relation characteristics and/or the sizes and equipments of the rooms.

Conclusions:

The results of the application of the methcd is shown in Table 3. In the first, second and third column, the total number of applied activity patterns, the total adaptability and the average adaptability of each dwelling unit are listed in the forth, fifth and sixth columns.

The minimum and maximum values obtained for each dwelling unit are listed in the seventh and eighth column. The hypothetical maximum adaptability which is obtained by all the possible combinations of activity-space allocations excluding the space pairs of food preparation-kitchen, toileting-bathroom is listed in the last column.

The dwellings can be evaluated according to the number of applied activity patterns or their total adaptability. In the first case the behaviour of the dwelling with respect to different life-styles can be investigated. In the second case the adaptability of the dwelling for a given activity pattern can be examined.

The total number of activity patterns and the total adaptability for each dwelling unit is shown in Figure 10 and Figure 11 successively.

DWELLING TYPE		FAMILY SIZE	FOR EACH FAMILY SIZE: TOTAL NUMBER OF APPLIED ACTIVITY PATTERNS	TOTAL ADAPTABILITY	AVERAGE ADAPTABILITY (aa)	TOTAL NUMBER OF APPLIED ACTIVITY PATTERNS	TOTAL ADAPTABILITY	AVERAGE ADAPTABILITY	OBTAINED MINIMUM ADAPTABILITY	OBTAINED MAXIMUM ADAPTABILITY	HYPOTHETICAL MAXIMUM ADAPTABILITY
D1	FAMILY WITH	NO CHILDREN	51	86	1.68	99	146	1.47	0.00	2.00	4.75
		1-2 CHILDREN	32	44	1.36						
		2-4 CHILDREN	16	16	1.00						
D2	FAMILY WITH	NO CHILDREN	84	105	1.25	136	179.72	1.32	0.00	3.42	4.75
		1-2 CHILDREN	36	51	1.42						
		2-4 CHILDREN	16	24	1.50						
D3	FAMILY WITH	NO CHILDREN	107	76	0.71	162	104	0.64	0.00	2.00	4.75
		1-2 CHILDREN	39	28	0.71						
		2-4 CHILDREN	16	0	0.00						
D4	FAMILY WITH	NO CHILDREN	18	82	4.56	78	277	3.5[illegible]	0.00	4.56	8.00
		1-2 CHILDREN	24	79	3.29						
		2-4 CHILDREN	28	88	3.14						
		3-6 CHILDREN	8	28	3.50						
D5	FAMILY WITH	NO CHILDREN	101	380	3.76	324	1232	3.80	0.00	6.03	8.00
		1-2 CHILDREN	103	394	3.83						
		2-4 CHILDREN	104	390	3.75						
		3-6 CHILDREN	16	68	4.23						
D6	FAMILY WITH	NO CHILDREN	42	495	11.79	254	2995	11.[illegible]	11.79	11.79	11.79
		1-2 CHILDREN	64	755	11.79						
		2-4 CHILDREN	108	1273	11.79						
		3-6 CHILDREN	40	472	11.79						

Table 3. The results obtained from the applications

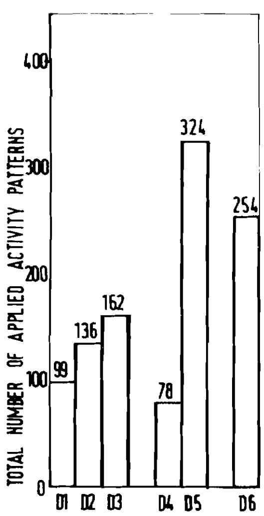

Figure 10.
Total activity patterns.

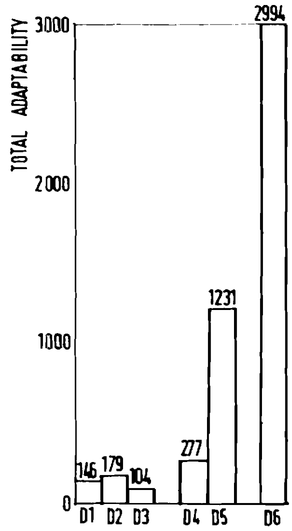

Figure 11.
Total adaptability levels.

The dwelling D1, D2, D3 which have 3 rooms have different layouts. In the dwelling D1 two rooms are grouped with a bathroom unit. In D2 the rooms are not grouped unlike D1.D3 has no entrance hall and one of the rooms is grouped with the bathroom.

If the total adaptability of the dwelling are studied, the adaptability reaches the highest level at the dwelling unit D2.D3 has the lowest value,hence, the entrance is combined with one of the rooms and another room is grouped with the bathroom.

The dwellings D4, D5 which have 4 rooms also have different layouts. Three rooms are grouped with the bathroom in the dwelling D4. Instead of three rooms in dwelling D5 two rooms are grouped with the bathroom unit, and one of the rooms has a direct access from the entrance hall. Therefore it was possible to apply a higher number of activity patterns on D5 then on the dwelling D4 and relatively the total adaptability was also higher in D5.

The dwelling unit D6 has five rooms and all of the rooms are similar in size, shape and relation with each other. Therefore the total adaptability reaches the highest level at the dwelling D6. Although the number of rooms of D6 is more than D5 the total number of applied activity patterns are less.

Consequently, the number of the applicable activity patterns and the adaptation level increases with the number of rooms and decreases with the specialization of rooms.

The total number of the applicable activity patterns for each family size are shown diagrammatically in Figure 12. It can be seen that the relation between the applied activity patterns and the family sizes is dependent on the number of rooms of the dwellings. The highest rate of the application of the activity patterns in the dwellings with three rooms is when the family has no children and this rate decreases with the increase of the family size. In the dwellings with four and five rooms the relation of the number of applicable patterns and family size, is maximum when the family has 2-4 children and decreases when the family size increases or decreases.

Consequently, the maximum values of applicable activity patterns can determine the most suitable family sizes for each dwelling unit.

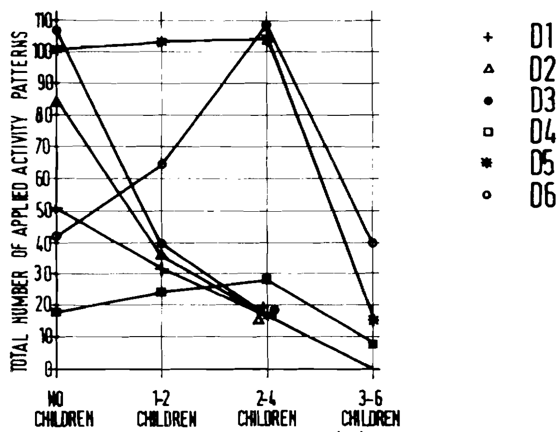

Figure 12. Total number of activity patterns related to family sizes.

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Standards for low income housing
- a new type of standard may make more informed choices possible

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Danish Building Research Institute

Resumé: Il-y-a besoin d'un grand nombre de normes internationales et nationales dans le domaine de "low income housing". Les nouvelles normes doivent être basée sur les réalitées dans les differents pays en voie de development et doivent en consequence être flexible donnent des possibilitées de choix.

Summary: There is a need for a great number of international and national standards within the field of low income housing. The new standards must be based on what is reality in the different developing countries and they must, consequently, be flexible and give options for choice.

A recent survey has shown that there are no international standards for low income housing - and only a very few even at the national level.

It is of course necessary that daily work with low income housing in developing countries be based on some kind of standards, but the "standards" commonly in use are too often unsuitable, for example because they have been taken over from other countries without being adapted to local conditions. Sometimes the "standards" thus adopted in developing countries are still in force long after they have been acknowledged as obsolete in their country of origin. To make matters worse the "standards" are as a rule too rigid.

Initiatives at the international level are gaining momentum

The United Nations has for some time been active in the field of standards for low income housing. As it is not the job of UN to set official standards, the recommen-

CONDITIONS FOR CHOICE OF BUILDING TECHNOLOGIES

Type of domain	Scale of project	Type of construction	Type of buildings
Metropolitan region	Goverment as continuous client	Dams	Dwellings
Capital	Long-range plan	Harbours	Kindergarten
City	Large project	Roads	Schools
Town	Medium-size project	Railways	Shops
Village	Small project	Buildings	Prayer places
Hamlet	(Maintenance/ repair)	Sewerage	Sport . .
Farm	(Rehabilitation)	Water supply	Factories
		Electricity supply	Hospitals
			Offices
			Colleges
			Nursing homes
			Depots/stores
			Barracks
			Cinemas
			⋮
			etc.

Type of housing	Type of country	Population increase	(vacant)
Luxury	Small/big	10 % yearly	
Upper middle-income	Warm/cold	8	
Middle-income	Dry/humid	6	
Under-middle	Mountainous/ flat	4	
Low-cost	Continental/ island	3.5	
Shelter	Rich/poor	3	
Site and services	Liberal economy /planned econ	2.5	
"No cost"		2	
		1.5	
		1	
		0.8	
		0.6	
		0.4	
		Negative	

Checking (✓) in a standard survey which contains lists of conditions relating to projects may provide a basis for an informed choice of for example building technology.

POSSIBLE BUILDING TECHNOLOGIES

OFF SITE

Degree of "mechanization"	Type of design	Type of labour	(vacant)
Labour-intensive	No design	Owner	
Artisanal	Individual design	Unskilled	
Rationalized traditional	Type design	Specialist worker	
Partial prefabrication	System building	Artisan	
Full prefabrication	Catalogue building	Engineer	
Automation	Computerized "tailor made"	Robot	

ON SITE

Water supply	Sanitation	Structures (example: walls)	(vacant)
Collected rain water	Defecation on fields, in lakes or streams	Mud/thatch/ twigs-and-poles /bamboo	
Lakes, streams	Bucket latrines	Stabilized soil blocks/sawn timber	
Wells	Latrines (pit-, compost-, etc)	Fired bricks/ concrete blocks/ wood frames	
Pumping wells	Septic tanks	Wall panels of wood, metal, concrete etc.	
Piped water	Communal sewerage system		
Desalinization	Electrical toilet		

Checking (✓) in a standard survey may indicate a desired building technology. The lists in the top part of the survey relate to off site parameters, those in the bottom part to on site parameters.

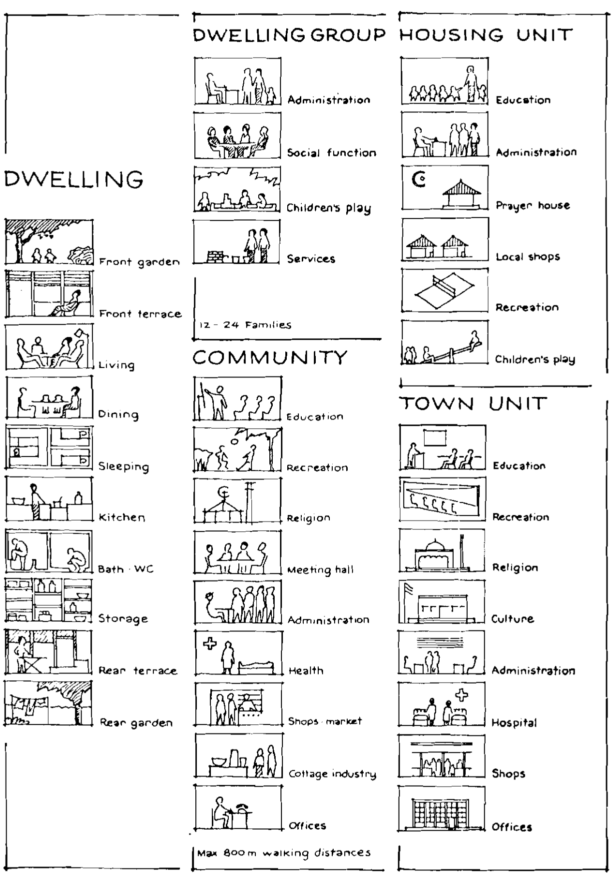
dations often take the form of Guidelines. Several such guidelines have already been published and more are underway. Lately UN has organized meetings and seminars on standards for human settlements, building regulations, etc.
In ISO, the International Standards Organization, the interest in doing an effort in the field of standards for low income housing has resulted in the establishing of an ad hoc group attached to ISO Technical Division 3. The ad hoc group is expected to submit a draft report mid 1980.
Also in CIB there are actions focused on the field of low income housing. Thus CIB W63, Low Cost Housing, is conducting a seminar by correspondance on the subject.

New procedures in standardization work are necessary
The initiatives which have been taken will undoubtedly lead to the creation of more national and international standards for low income housing.

It is however a difficulty that standardization work takes time, often 1-3 years for a national standard and even longer for some international standards.
As there are so extremely few standards for low income housing, the developing countries can quite simply not afford to wait for a sufficient stock of standards to be developed according to the old procedures. Too many millions of low income dwellings would be built to the old, obsolete and rigid "standards" while waiting!

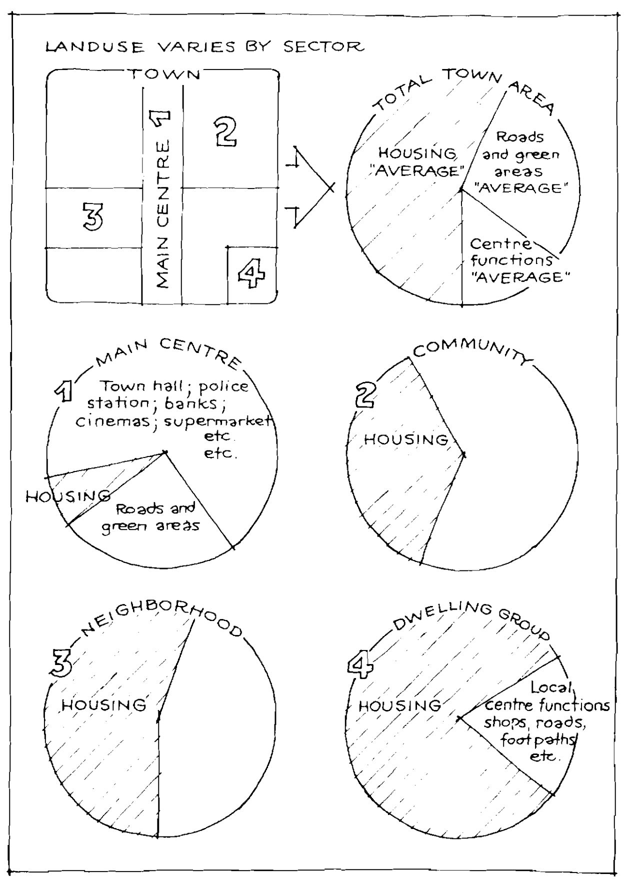
New standards must be flexible
At the same time as the new standards must be developed more quickly, they must become more flexible. Conditions in developing countries vary enormously from country to country - in big countries even from region to region. This makes it necessary that standards should be flexible - they should as a matter of fact be able to correspond to wide-ranging conditions and also to the changes which occur with time.

HOUSING IS MORE THAN HOUSES



A standard survey as suggested here may list the facilities etc. which are necessary for housing projects of varying sizes. Incidentally, there are no standard definitions of "dwelling group", "housing unit" etc.

AN "AVERAGE" MAY BE MISLEADING



A standard survey may clarify how landuse varies by sector. Another similar survey may clarify how housing densities will vary as widely as the areas taken up by housing.

Recent research seems to prove that new flexible standards also should allow that a final choice or decision be made as late as possible in connection with an actual project. Only when enough is known about the conditions for the project in hand standards should be set.

Surveys as tools for informed choices

The considerations in the two proceeding chapters lead towards what may be termed a new breed of standards. Before the standard proper comes the preliminary standard, and before that comes necessarily a survey of possibilities.

Such surveys could be established much more quickly than a standard, because there need be no long discussions about the setting of any specific standards level to be imposed.

If such surveys are given the status of a standard they may become very efficient tools for more informed choices. They would present comprehensive and possibly systematic surveys of relevant possibilities - as rather an opposite to the imposition of rigid, specific standard values.

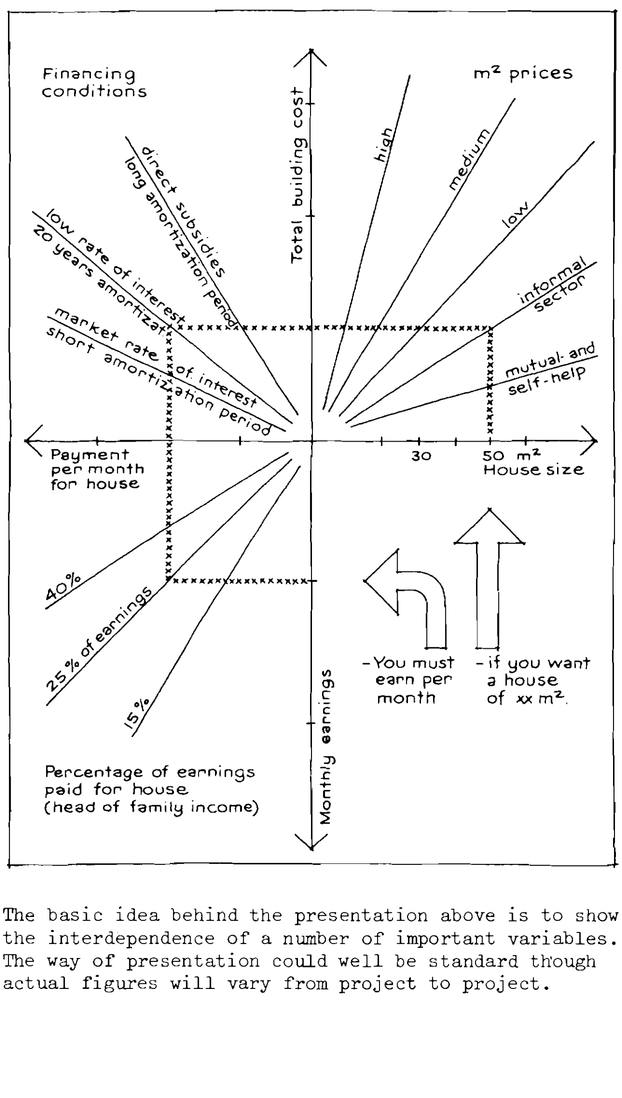
Standard Surveys as suggested here would, incidentally, have many traits in common with the proposals by CIB W60 (Performance Concept in Building) for how to express performance values in banded levels.

Standard surveys must be easy to grasp

In connection with any building scheme there are scores of decisions to be made. If such - more informed - decisions are to be made on the basis of surveys, these must be easy to read and understand. A technique for making surveys - and other forms of standards - more easy to comprehend needs further development. Not least because some of the new standards must reach a much wider clientele than the old "standards".

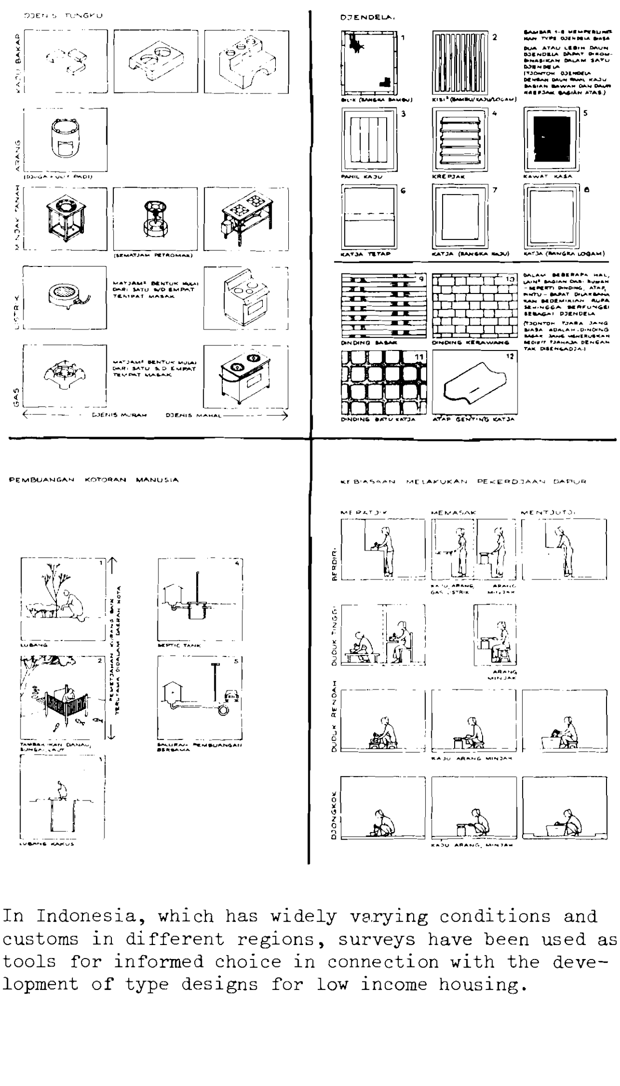
This paper is accompanied by a series of examples of surveys which certainly need further elaboration, but which try to present some lists of options and conditions relevant to low income housing in a novel way more easy to grasp.

RENT - FINANCING - PRICE - HOUSE SIZE



The basic idea behind the presentation above is to show the interdependence of a number of important variables. The way of presentation could well be standard though actual figures will vary from project to project.

EXAMPLES OF SURVEYS FROM INDONESIA



In Indonesia, which has widely varying conditions and customs in different regions, surveys have been used as tools for informed choice in connection with the development of type designs for low income housing.

A Model for the Analysis of Bioclimatic User Requirements

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Summary

One of the most important functions of a building is to answer the bioclimatic requirements of the user. It is known that elements of the indoor climate effect each other as well as the bioclimatic, visual, olifactory, bioclimatic acoustical user requirements. Satisfaction of one user requirement may affect another negatively as it is usually in the case of economic requirements. Requirements of users related to an indoor space are dependant on the users, their characteristics defined by their psychological, physiological, socio economical, cultural backgrounds, their activities, the time and period of those activities, the related equipment and furniture.

The characteristics of an indoor space are dependant on the use, outdoor conditions (climatic lighting etc) and the characteristics of the building envelope. The aim of all design procedures is to create an indoor space that would satisfy the user's requirements.

In this paper a model that will allow the designers to consider the user's requirements with special reference to the bioclimatic requirements in relation to the outdoor conditions, building shell and the other user requirements will be presented. The use of the model is analogous to solving an equation where the givens are the user's spatial requirements, outdoor conditions; those are used to calculate the characteristics of the building envelope, that would satisfy the user's requirements.

Sommaire

La plupart des fonctions importantes d'un batiment est de remplir les exigences bioclimatique des utilisateurs. Comme il est bien connu, les eléments de climat interieur effectuent l'un l'autre, comme ils effectuent les exigences bioclimatiques, visuelles, olfactives, acoustiques, des utilisateurs. Satisfaction d'une exigence d'utilisateur peut affecter un autre dans un sens negatif comme dans le cas des exigences economiques. Ayant rapport sont dépendent aux utilisateurs, et leurs characteristiques défini par leurs situations psycholigiques, physiologiques, socio-economiques, culturel, leurs activités, le temps, et la période de cette activité, les équipements rapportés et les mobilier.

Les characteristiques de space interior sont dépendent a l'usage, conditions exterieur (climatique éclairage....) et aux characteristiques d'envelope du batiment le but principal dans la réalisation d'un batiment est d'assurer des conditions optimales d'environnement intérieur qui doivent satisfaire les exigences de l'utilisateur.

Dans ce travail, un model, qui va laisser les dessinateurs à considerer les exigences des utilisateurs avec un rapport spécial aux exigences bioclimatique aux rélations des conditions extérieurs, d'envelope du batiment et des autres exigences des utilisateurs a été presenté. L'usage de ce model est analogue à la solution d'une equation oủ les données sont exigences d'espace, des utilisateurs et les conditions exterieur; de sorte qu'on peut calculer les characteristiques des murs exterieurs pour viser à satisfaire les exigences des utilisateurs.

Introduction

The buildings aim to satisfy the users' requirements whether these are the bioclimatic, visual, antropometric or economic requirements. For a healthy construction process, and a functional building the requirements have to be identified in the planning, programming and design stages. Both in determining the building demand in macro scale and the user requirements in micro scale, a great number of studies are made. In the recent years the determination of the user's requirements and their reflection on the design of the physical environment has gained importance. To-day identification of the user requirements and their translation to performance criteria has become a system whose value is proven. Therefore numerous check lists are prepared to be used in the initial design stage and evaluation of existing buildings. The aim of this study is to establish a model that would be used as a checklist in determination of the user's requirements in the initial design stage.

User's characteristics

The user's characteristics can be identified systematically by a thorough scrutiny of the characteristics, such as the sociological, economical, cultural, physical and etnical characteristics. Buildings have to relate to the user's requirements that are mostly formed by the personal characteristics and the environment Personal characteristics are the product of social, economic, cultural geographical environment and hereditary factors.

a) Physiological characteristics, age, sex, weight, height, motor development, characteristics related to sight, hearing, smelling, testing and touching (development of senses), nervous, hormone systems and physical development.

b) Psychological characteristics, behaviour patterns, value judgement, adaptation, social relations, sensous and mental development

c) Socio economic characteristics, family size and construction, ethnic group, mobility religion, sect, regional characteristics, family income

d) Cultural characteristics, education, regional behavior patterns, customs etc.

Environmental factors and personal characteristics define human needs:

a) Physiological needs; are those necessary to be done to continue living, like eating, drinking, sleeping. Those are activities that are performed by everyone but there are differences in the manner of performing them.

b) Psychological needs are those needed to make people happy eg reading books, talking laughing, watching TV

c) Socio economic needs are those related to social status and work such as working, gathering, talking.

d) Cultural needs are dependent on the socio economic structure such as reading, meeting, educating, learning.

The activities that are products of those needs show great differences due to socio economic conditions and personal characteristics. The set of needs resulting from activities related to human needs are user requirements. In the design of indoor and outdoor spaces activities and requirements related to activities must be identified.

Some activities can exist completely free from space while some activities are related to spaces. The space to be designed has to be correlated to activities and requirements. This process is the first stage of design. At this stage a model of five factors can be used. The factors that make the pentagon are users, activities, time, space and equipment.(Fig I)

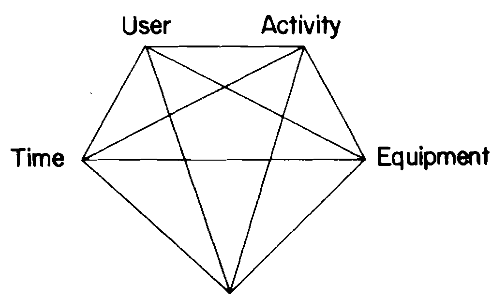

Fig: I- Relationship of User, Activity, Time, Equipment, Space

a) Users

The specification of the characteristics of the users and their activities related to space effect the usability and functionality of space.

The number of users, age group, sex, physiological characteristics, psychological, sociological, economic and cultural conditions are important in terms of its effects to design decisions. The workers in a factory, the residents in a house, the students and teachers in a school are the actual users, but in most cases the goals and requirements of the administrations and organisations are reflected in buildings rather than the real users.

Activities

In the definition of a space and identification of user requirements the most relevant criterium is user activities. The definition of these activities in terms of users is a necessity to serve the aim of designing the most comfortable, safe, productive indoorspace. By including mental activies to the definition of an activity, all the user requirements related to activities can be identified.

Activities can be classified as those related to physiological processes, such as breathing, talking, seeing, listening, smelling, tasting, feeling, feeling cold, perspiring, sleeping, resting, getting ill, hurting, moving, walking, eating, as activities related to an aim such as cooking, carrying, lifting, openning, shutting, taking, storing listening; as those related to a mental process, such as realising, recognising, thinking, choosing, expressing oneself, creating, getting bored, controling, orienting one self. Another classification classifies activities under the heading of resting, eating, drinking, hygiene, production, putting on and taking off, cleaning, repairing, culture, education, recreation and administration. Another classification mentions private, semi private, semi public, and public activities.

Time

After the determination of the user and activities, the time, period, frequency and the sequence of activities are identified. A certain period of time is analysed. The year, season, month, day and hour are relevant criteria in terms of activities.

Equipment

The equipment needed for certain activities such as water systems, gas, electricity, appliances or furniture should be identified. The characteristics, dimensions, side products of the appliances and furniture should be mentioned.

Space

The characteristics and the activities of the users identify their needs. A space is defined by the surrounding surfaces. The fact that a space can satisfy user requirements is dependant on the properties of the building shell. The aim is to define the building shell that provides comfortable conditions and to prepare the performance specifications for the product. The user's have a set of requirements related to space. The space which is the product of the building shell and the outdoor conditions has to correlate to the requirements of the users. The aim of the design process is to equate the indoor conditions to the comfort conditions needed by the users.

Spatial User Requirements

The users with their activities and equipment have a set of spatial requirements. The space has to have a set of properties so that they can continue their activities in a comfortable environment in a most productive way. These requirements are the antropometrical, visual, olifactory, bioclimatic, acoustical requirements. The safety, functionality, economy, privacy requirements should be mentioned as well as the hygenic requirements. (Fig 2)

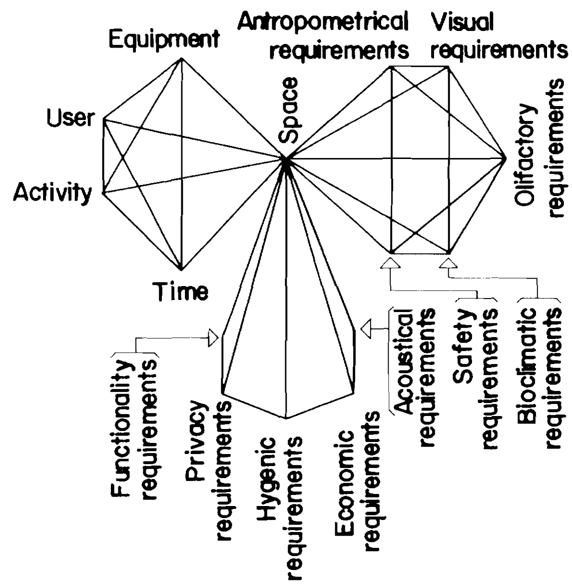

Fig: 2- All the Spatial requirements of the User

Spatial Characteristics of the Indoor Space

The spatial characteristics are defined by the outdoor conditions and the properties of the building shell. The location, orientation, form, opennings, dimensions, indoor partitions, materials and their physical properties, the outdoor climatic conditions. The boundaries of the built environment identify the indoor conditions. (Fig 3)

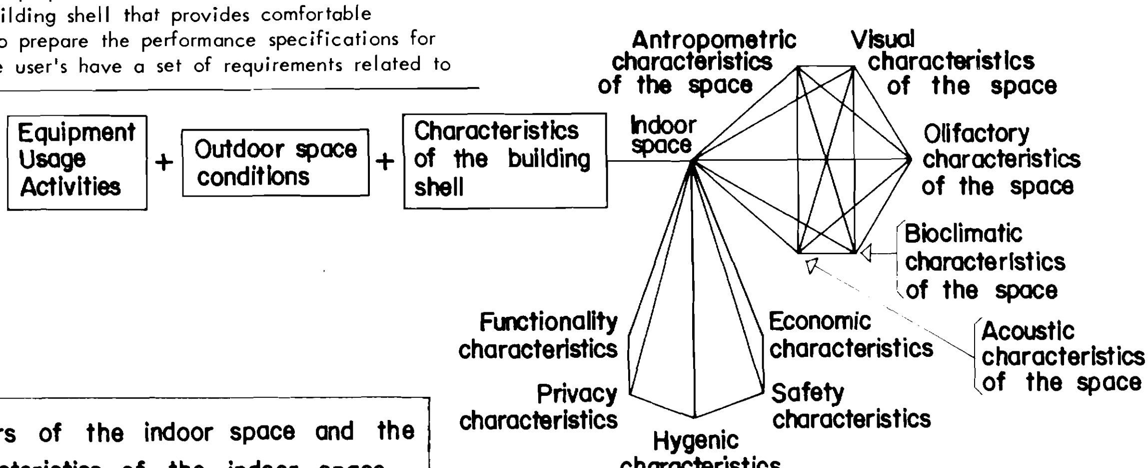

Fig: 3- Factors of the indoor space and the Characteristics of the indoor space

The Use of the Model

There is a constant relation between activity user, time, equipment and space factors. In the model , all the users, the individual activities of the users in relation to the equipment has to be analysed and the design could be done accordingly. In using the model a time section is chosen and characteristics of the users using the space at that time section are identified. The activities of the user, the time, frequencey, period of the activities together with the equipment and infrastructure are analysed. The requirements related to this process are identified. According to the users and their activities the visual, bioclimatic, acoustical requirements vary and effect each other. For example the clothing and the activity level of a user in a gymnasium identify the bioclimatic requirements within this space but while doing this the bioclimatic requirements can not be considered apart from the visual requirements and ventilation requirements. Thus all the factors in the user activity, equipment time the spatial requirements. (Fig 4)

If the model is to be used for analysing a house, a typical family is chosen and the family members of that typical family are marked on a table in terms of their activities for a chosen time eg 24 hours. Thus the primary data for design is collected.

Identification of the Bioclimatic User Requirements

As an example of using the model, bioclimatic user requirements will be analysed. The bioclimatic user requirements are related to the mean radiant temperature, air temperature humidity and air movement. The clothing and the activity level effect the comfort conditions of the users. When the indoor climate of a space which is the product of the outdoor climatic conditions and the properties of the building shell is the equated to the comfort conditions the indoor space becomes bioclimatically comfortable. Such a model , establishing a one to one correlation between the user's characteristics and bioclimatic requirement possibilizes the design of a building which is sensitive to user's requirements. (Fig 5)

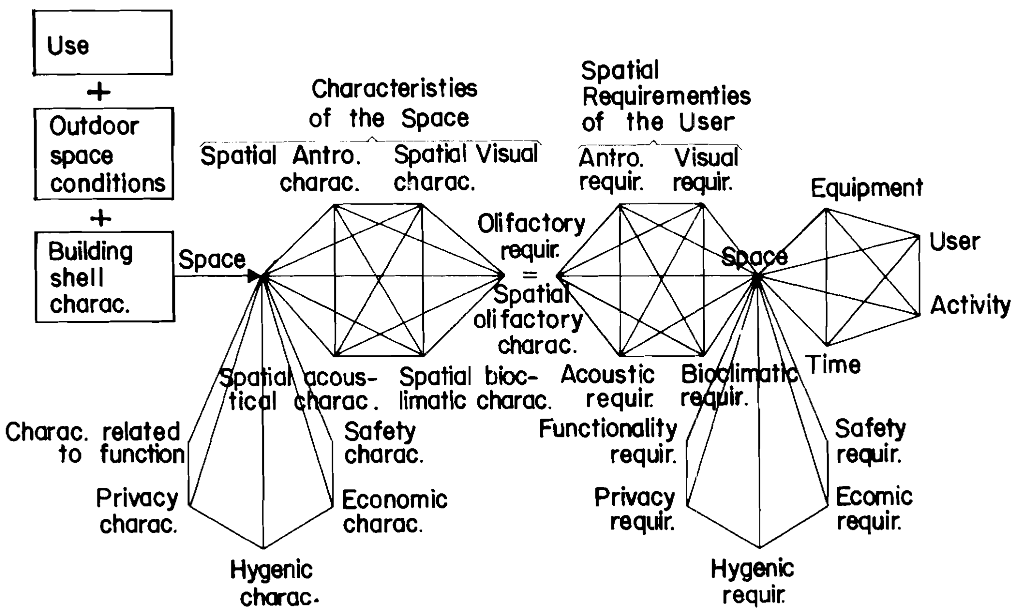

Fig: 4 - Spatial user requirements - equality of indoor space characteristies

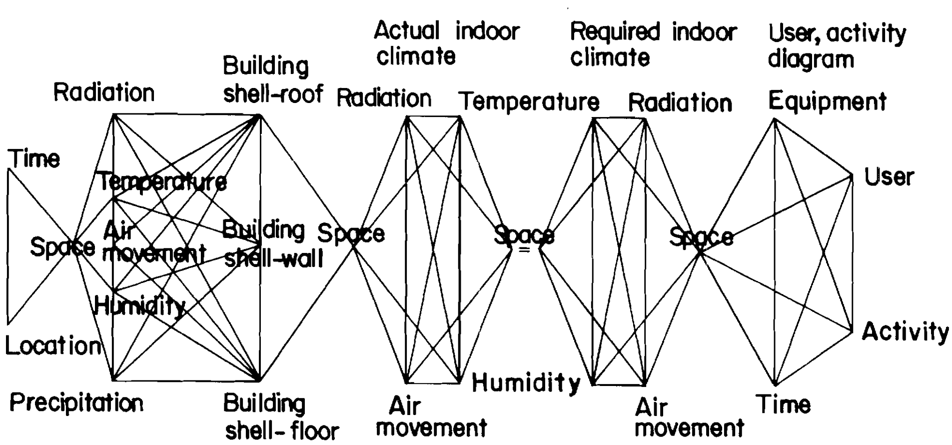

Fig: 5 - Climatic data, building shell and dichotomy of actual and required indoor climate

The geography and topography of a location, shape the climatic conditions of a certain location. The outdoor climatic conditions effect the indoor climate through the orientation, location, openning, materials, thermal characteristics, form and dimensions of a building. The diagram simplifies this correlation and acts as a check list. For specific dates the conditions of the actual indoor climate can be calculated as well as the bioclimatic requirements. Thus these two can be equated through the manipulation of the design of the building shell. By the alteration of the dimensions, orientation opennings, material and the thermal characteristics of the materials the indoor conditions can be held within the boundaries of confort. (Fig 6)

The outdoor conditions are related to time and location. The concept of the building shell is divided into components and the properties are identified interms of their effecting the indoor climate.

Conclusion

The aim of this model is to provide an easy means to the designers so that they can see the effect of various building elements on the bioclimatic comfort conditions. The user requirements can be analysed with ease in terms of their effect on the design of the indoor conditions through the building shell. In order to design bioclimatially comfortable spaces the user requirements have to be considered in the primary design stages.

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1. Location
2. Time
3. Space
4. Solar Radiation
4a. Short wave direct radiation
4b. Short wave diffuse radiation
4c. Short wave reflected radiation
4d. Long wave direct radiation
4e. Long wave diffuse radiation
4f. Long wave reflected radiation
5. Air Temperature
5a. Air temperature at agiven level
5c. Soil temperature
6. Humidity
6a. Humidity level
6b. Fogginess
6c. Cloudiness
7. Air movement
7a. Air pollution
7b. Wind velocity
7c. Wind direction
7d. Wind velocity gradient
8. Precipitation
8a. Precipitation duration and amount
8b. Snow amount
8c. Evapoaration
9. Pressure
10. Building shape
11. Orientation
12. Materials and surface properties
12a. Absorbtion
12b. Emmissivity
12c. Film Resistance
12d. Film Coefficient
13. Thermal Properties
13a. Insulation resistance
13b. Thermal conducitivity
13c. Thermal Transmittance
13d. Thermal Resistance
13e. Insulation Capacity
13f. Time lag.
14. Dimensions
15. Opennings
16. Location
17. Mean radiant temperature
18. Air temperature
19. Humidity (vapour pressure, relative humidity)
20. Air movement
21. Equipment
22. Activity
23. User
24. Time
25. Space

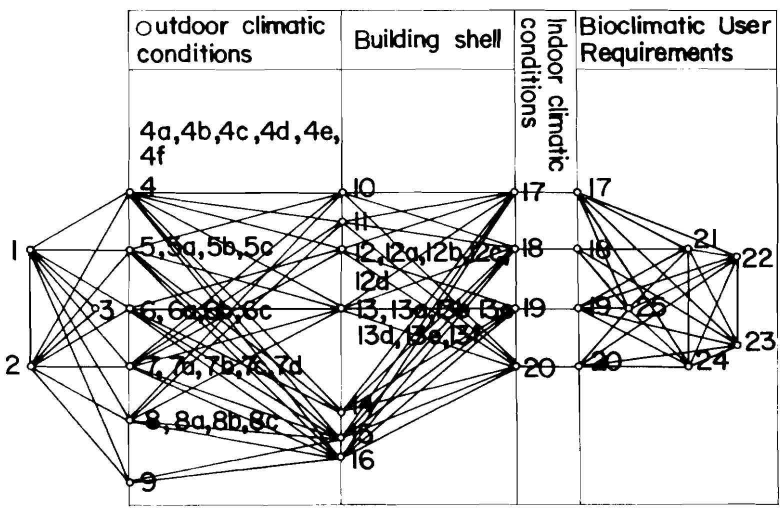

Fig: 6 - Relationship of outdoor space characteristies Building Shell, Indoor climatic conditions and Bioclimatic user requirements

Le changement de logement en temps de crise économique

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Résumé

Le changement du logement en temps de crise économique.

Il est fait appel aux résultats de deux enquêtes en profondeur menées en France par J.Palmade pour susciter un débat sur les deux questions suivantes : comment réagiraient les gens à une mobilité forcée ? quelles sont leurs attitudes face au changement social ?

Il semble que ni les ouvriers ni les employés obligés de changer de logement pour des raisons économiques ne trouverons de compensation affective à la perte de leur lieu de vie antérieure. Certains en seront malheureux, d'autres seront plus ou moins indifférents à leur nouveau logement. Pour ces derniers cela n'a pas de sens de considérer le logement comme autre chose qu'un moyen. Et pourtant pour la plupart des gens sans doute un bon logement doit-il être quelque chose de plus, un abri, une protection de l'intégrité personnelle menacée par le changement dans la société.

L'exposé suggère qu'une action des pouvoirs publics dans ce contexte pourrait en atténuer les conséquences pénibles.

Summary

Housing moves in the wake of economic crisis.

The results of two in depth surveys by J.P. Palmade in France are questionned in order to raise two discussion topics : how shall people respond to compelled housing moves ? And how do they react to social change?

It seems likely that on the whole workers or employees who have been compelled to move for economic reasons will not find their new housing to be the comforting place that deserves to be called home. Some will be fairly unhappy about it; some will be more or less detached. The more so, the more they will have a strictly rational view of their housing which will mean no more to them than any piece of mechanical equipment. Yet for the greater number a good house should be more than that and should provide a shelter to the threatened identity of individuals who feel deeply concerned by impending changes in their society. It is suggested that some public action could be taken in order to alleviate such a situation.

Introduction

Les restrusturations industrielles en cours à l'échelle mondiale vont-elles modifier profondément les attentes des populations des pays industrialisés vis à vis de l'habitat ?

De prime abord on pourrait s'attendre à ce qu'elles aient des incidences sur la répartition de l'emploi sur chaque territoire national et sur les taux de chômage. Cela aurait pour conséquence, en matière de logement, d'obliger une partie de la population à la mobilité géographique en provoquant à terme un renouvellement du patrimoine bâti.

Nous voudrions montrer, à partir de l'examen de quelques recherches menées sur la situation française, que les choses sont moins simples et surtout qu'elles sont plus préoccupantes.

Ces réflexions ne sauraient être transposées même aux autres pays industrialisés en l'état de nos connaissances, et a fortiori elles ne doivent pas être entendues comme prémonitoires de la situation dans les pays en cours de développement.

I- Quelques conséquences prévisibles de la mobilité forcée

Pour examiner cette question on utilisera une recherche qui avait pour but de décrire statistiquement les(1) conditions du dernier déménagement d'un échantillon de personnes choisies pour la variété de leur situation sociale et de leurs conditions de vie.

De façon générale, il en ressort que plus les changements de logements sont rendus obligatoires ou inévitables par les conditions économiques, par la difficulté de trouver un travail qui permette de gagner sa vie, de faire vivre sa famille, plus il est difficilement accepté. Ceci s'aggrave encore quand le logement a été imposé.

A) Les déménagements réussis

Des cadres moyens, des artisans et des commerçants dont les revenus se situent dans le tiers supérieur de notre échantillon étaient réellement satisfaits du changement de logement même si celui-ci, mis à disposition par un employeur, n'a pas été véritablement choisi. Ils habitent, en général, de grandes maisons individuelles neuves avec jardin dont ils ne sont pas toujours propriétaires. Il est vrai que l'on a aussi trouvé des ouvriers non qualifiés et des femmes employées qui vivaient leur dernier changement de logement avec une réelle satisfaction teintée de regret. Ils habitent des maisons individuelles neuves ou anciennes, souvent avec jardin, dont ils sont propriétaires et qu'ils ont choisies parce qu'ils recherchaient un mode de vie.

A leurs yeux cette maison est leur dernière maison, celle qu'ils ne quitteront plus ; non qu'elle soit la meilleure qu'ils aient pu rêver mais parce qu'ils renoncent à tenter de s'approcher davantage de leurs rêves.

Mais tous ces ouvriers et ces employées ont choisi leur logement en dehors de toute contrainte venant du monde du travail.

B) Les perspectives de déménagement des ouvriers et employés

Des ouvriers et des employés qui seraient obligés de déménager pour aller dans une autre région ou une autre ville chercher un travail semblent n'avoir que peu de chances d'aboutir dans un logement qui leur donne une véritable satisfaction.

En effet les résultats de cette enquête mettent en évidence l'existence de trois autres populations aux caractéristiques nettement différenciées : celle des personnes qui voient le dernier déménagement comme un malheur ou au moins comme un échec dans leur vie, puis celles des personnes qui sont indifférentes à leur habitat, enfin celles des personnes pour qui le logement n'est qu'une "machine à habiter".

1/ Le malheur d'avoir déménagé

Ce n'est pas véritablement le privilège d'une catégorie sociale. D'ailleurs, nul ne sera surpris que tel soit le cas des femmes confinées dans les tâches ménagères ou souffrant de la solitude qui qui rêvent de renouer avec la société en travaillant. Mais on trouve aussi des femmes exerçant une activité professionnelle comme cadre supérieur ou dans des professions libérales, filles d'ouvriers qualifiés ou d'agriculteurs, qui vivent leur dernier emménagement comme un échec à l'égal de certains ouvriers qualifiés, eux-mêmes fils d'ouvriers qualifiés.

Cette population nous intéresse particulièrement dans la mesure où les gens qui la composent ont dû changer de logement pour se conformer aux exigences du marché de l'emploi et plus précisément pour s'adapter aux changements de localisation de l'offre d'emploi. On peut remarquer que le changement effectué à l'initiative du chef de famille entraîne une rupture avec la vie quotidienne antérieure. Le logement n'a pas été choisi mais attribué par l'employeur ou une administration ; très souvent un habitat collectif remplace l'habitat individuel ou le grand ensemble succède au petit collectif. On ne saurait s'étonner que cette attribution d'un logement soit vécue, par la personne concernée, comme un rejet ou un manque d'égard du système social dont elle dépend. Peut être ce qui étonne le plus quand on étudie cette population, c'est de découvrir avec quelle force elle rejette le milieu d'accueil et comment elle s'empêche d'établir des relations de voisinage alors même que cette absence de communication amicale et anodine lui pèse.

Mais tout ceci ne suffirait pas à justifier que l'on parle de déménagement malheureux si, à ce rejet du nouveau quartier d'habitation et de la population des alentours ne s'ajoutait une impossibilité à trouver dans le logement une protection satisfaisante, un refuge contre les difficultés de la vie en société. Cela se traduit par une aggravation de l'insécurité personnelle, du doute sur soi-même, et de l'incapacité de faire du nouveau logement un symbole de l'unité familiale ou de l'unité du couple. Ce qui a pour conséquence évidente que les difficultés propres au couple ou à la famille se trouvent aggravées par le déménagement. Pour cette population l'idée même de chercher à s'approprier le logement est repoussée explicitement.

Une telle situation est assurément difficile à vivre et l'on pourrait croire qu'elle touche des gens dont la situation professionnelle a été durement affectée par la nécessité de changer d'emploi. Or il n'en est rien. Au contraire, c'est une population qui éprouve un réel sentiment de sécurité quand à son avenir professionnel dans la mesure où ces personnes jugent en général de manière plutôt favorable l'évolution d'ensemble de l'économie.

Le rapport au travail n'est donc pas angoissant en lui-même, bien que ce ne soit guère plus qu'un moyen de subsistance dans la mesure où il n'est pas une manière de se réaliser dans la société, au moins pour ceux d'entre eux qui sont ouvriers.

Cette population se caractérise aussi toutefois par des traits de personnalité qui manifestent une pré-disposition à l'anxiété. Cela nous amène donc à penser que certains des ouvriers qualifiés, d'origine ouvrière, obligés de changer de lieu de travail pour travailler dans une entreprise qui est installée hors d'une zone de dépression économique vivraient comme un échec personnel leur changement et ne trouveraient aucune consolation dans leur logement bien que leur avenir économique leur paraisse assuré et qu'ils n'aient pas à sa plaindre des qualités fonctionnelles de leur logement.

2/ L'indifférence au logement

Il s'agit ici d'une population assez particulière, peu nombreuse dans notre enquête, composée de célibataires dont les revenus sont les plus faibles de ceux de l'échantillon et qui consacrent le moins d'agent au logement. Pour la plupart de sont des ouvrières non qualifiées, filles d'ouvriers non qualifiés.

C'est en général pour suivre un employeur dont l'établissement était déplacé qu'elles ont accepté de changer de logement et d'occuper celui qui leur était attribué. Il s'agit en général de logements très petits, une pièce le plus souvent, dans des immeubles anciens, qu'elles jugent inconfortables et petits mais sans se plaindre de cet inconfort ou du manque d'espace. Elles ne cherchent nullement à s'approprier leur logement et ne semble pas éprouver de besoin de s'attacher au logement ou au voisinage, ni de se retrouver elles-mêmes en jouant de leurs rapports avec l'un et l'autre. En réalité elles refusent d'entretenir un rapport émotionnel à l'espace qui les conforteraient dans leur identité afin d'être mobiles, disponibles au changement. En quelque sorte le changement lui-même répond au souci d'échapper aux contraintes aliénantes qu'impose l'univers du travail et de façon générale la société. C'est ainsi que les modèle généraux les plus répandus dans la société sont systématiquement refusés. Par exemple elles refusent d'accroître des dépenses vis à vis du logement considéré comme un bien ou un service consommable, ou encore de façon peut-être plus évidence elles se refusent à envisager d'être un jour propriétaires d'un logement bien qu'elles en éprouvent le besoin.

3/ Les utilisateurs de machines à habiter

Cette dernière population composée d'ouvriers non qualifiés et de femmes d'ouvriers, semble avoir trouvé un nouvel équilibre dans le rapport au logement.

Ces personnes sont soumises à une très grande mobilité résidentielle du fait de leurs situations dans le monde du travail et vivent les changements de la société comme lourds de menace pour leur vie et celle de leur famille. Mais ils ont complètement accepté les contraintes qui s'imposent à eux et la mobilité qui leur est imposée est considérée comme un fait qui ne suscite ni intérêt, ni passion, ni colère.

Chaque logement est apprécié selon les facilités matérielles qu'il offre et sans faire référence à un logement idéal auquel d'autres personnes le comparerait. Ces personnes n'attachent pas non plus de valeur au statut social conféré par le logement et elles ont plutôt tendance à refermer leur vie sur la famille.

Cette population très mobile, qui ne voit dans le logement qu'une sorte de machine et pour qui habiter se réduit à faire fonctionner cette machine, à en faire usage, est très marginale dans notre enquête mais elle est peut-être indicatrice d'un changement dans le rapport humain et social à l'habitat.

C) La mobilité forcée pour raisons économiques

Il convient d'être prudent dans l'utilisation de ces résultats. D'ailleurs toutes les personnes de notre échantillon n'entrent pas nécessairement dans l'un de ces groupes. Les attitudes des personnes sont loin d'être aussi fortement caractérisées et il en existe dont les attitudes et les comportements s'éloignent tout-à-fait des types que nous avons présentés. Ces derniers rassemblent seulement des traits communs à quelques sous-population dont l'analyse statistique montre qu'ils ne sont pas fortuits.

On peut avancer qu'un certain nombre d'ouvriers et d'employés qui sont obligés d'envisager un changement de région où habiter pour des raisons économiques risquent fort d'éprouver leur déménagement comme un malheur à moins qu'ils ne parviennent à devenir indifférents à leur logement voire à ne plus le considérer autrement qu'un objet utilitaire quelconque. Pour eux, donc, le logement ou le quartier en probabilité ne pourront pas leur fournir la compensation affective, la zone de sécurité, de soin et de protection individuelle et familiale qui atténueraient les effets inquiétants du changement économique.

D'autres ouvriers et d'autres employés éprouveront différemment ce changement de logement mais nous ne saurions rien avancer en probabilité quant à leurs comportements ou leurs attitudes.

II- Quelques effets des attitudes face au changement social

Il nous faut insister sur l'importance du rapport émotionnel à l'espace afin de montrer comment l'inquiétude très générale que provoque l'évocation du changement social a des conséquences importantes sur la façon dont des personnes vivent leur changement de logement.

A) Bons et mauvais logements

Il suffit d'un regard autour de soi pour constater qu'il y a des personnes dont le logement est l'objet de soins constants alors qu'elles se désintéressent tout à fait de leur voisinage, tandis que d'autres semblent tirer une grande satisfaction du voisinage et de désintéressent de leur logement.

Dans une recherche publiée en 1972, J.Palmade (2) avait montré que la réalité était sensiblement plus complexe et que pour un certain nombre de personnes le logement ne pouvait être apprécié que dans la mesure où il était situé dans un voisinage lui-même acceptable. Mais surtout elle a précisé quelques aspects du rapport émotionnel particulier qui peut s'établir avec les lieux que l'on habite. Non seulement ils peuvent fournir des satisfactions immédiates en répondant par exemple aux exigences fonctionnelles ou à d'autres nécessité également ressenties comme impératives mais il peut aussi, de ce fait, donner à son habitant le soutien nécessaire à la protection et au développement de sa personne ; en quelque sorte l'espace que l'on habite pourrait prendre le relais de la mère protectrice et nourricière qui assure au petit enfant les ressorts indispensables à la constitution de son identité. D'un tel lien nous écrirons qu'il est habitable alors qu'on écrira simplement d'un lieu qui ne satisfait qu'aux exigences fonctionnelles qu'il est logeable.

Cela revient à dire qu'habiter un lieu c'est disposer d'une relation à un espace parmi tous ceux qu'une person ne peut fréquenter dans sa vie aussi exceptionnelle que la relation d'un enfant à sa mère parmi toutes les relations sociales dont il peut disposer. Il ne s'agit pas d'une simple analogie. L'espace que l'on habite peut fournir un étayage à la construction toujours inachevée et souvent menacée de l'identité propre à chacun. Mais il convient de faire deux remarques : il n'est ni vraisemblable, ni nécessaire, que tous les hommes disposent d'un tel rapport à l'espace ; et quand il se réalise ce peut être dans un tout autre espace que celui du logement ou dans un ensemble de lieux formant système, au nombre desquels peut ou non se trouver le logement.

Une enquête achevée en 1977 a permis de préciser (3) ces résultats et de mettre en évidence trois grandes familles d'attitudes ; celles des personnes qui entretiennent un rapport affectif privilégié avec le logement seul, celles pour qui le logement et son voisinage sont inséparables, l'un évoquant l'autre et ne pouvant être apprécié qu'en relation avec cette évocation, enfin celles pour qui l'espace ne peut être le support d'un rapport émotionnel que si les significations liées au logement et celles qui sont liées à l'environnement peuvent être maintenues séparées.

Dans tous les cas il semble que le fait de rester dans un logement favorise la possibilité d'y trouver cet abri qui protège l'identité personnelle en établissant symboliquement la continuité de l'expérience présente et de l'histoire familiale, ce qui permet de maitriser l'angoisse ou l'inquiétude que provoque le changement social, voire d'en atténuer les effets dans sa vie. Certes ceci n'est pas vrai pour tout le monde mais sans doute pour le plus grand nombre le bon logement est un espace protecteur, porteur d'irrationnel.

B) La peur du changement

On pourrait imaginer qu'après deux décennies de prospérité économique les français pourraient accueillir avec calme et confiance les transformations actuelles de l'ordre économique mondial. Ce serait une erreur. En effet depuis quinze ans des recherches ont mis en (4) évidence une inquiétude largement répandue devant les effets du changement social.

Mais que désigne-t-on par changement social ? Pour un quart des populations enquêtées ce sont les transformations des valeurs sociales, des normes, de la morale ; pour les autres ce sont principalement la technique, les conflits du travail ou les modes de vie liés au logement qui rendent palpable le changement. A un niveau conscient la population se partage a peu près également entre les personnes qui le juge négatif et celles qui le juge plutôt positif mais les expressions d'un espoir tempéré de crainte laisse quelquefois filtrer dans les discours des personnes enquêtées une inquiétude beaucoup plus profonde. D'une analyse de ces représentations inconscientes, lors d'une recherche sur la mobilité résidentielle, on a été conduit à distinguer quatre familles de personnes.

Pour les premières le changement social est porteur de danger, de menace sur les conditions de vie, sur ce qui est le plus fondamental pour chacun et ceci d'une façon irrémédiable.

Pour les secondes la société tend à faire perdre toute personnalité aux individus, a en faire des instruments.

Pour les troisièmes, la société est tout aussi puissante mais elle incite à la lutte, au combat, à la ruse.

Pour les dernières la société devient la source de bien être de tous.

Les attitudes à l'égard de la mobilité résidentielle en sont fortement affectées. Les personnes appartenant aux deux premières familles éprouvent le besoin de trouver dans la permanence du logement une protection de leur idendité. Elles craignent toutes la mobilité, même celles qui acceptant les nécessités économiques se résignent à changer de région.

On sait qu'à l'exception des catégories favorisées les personnes qui habitent les quartiers d'urbanisation récente en périphérie des villes se sentent rejetées, exclues de la ville. Or ces quartiers neufs sont puis- (5) samment évocateur du changement social. Dans la mesure où celui-ci est inquiétant on a constaté que les personnes qui ne peuvent s'approprier leur logement qu'à travers une relation positive à la fois au logement et à son voisinage , celui-ci est alors rejeté, rendant du même coup impossible de s'attacher à son logement et d'y trouver un abri attentionné à soi, et à sa famille. Pour les plus chanceux parmi ces gens au besoin d'appropriation impossible à satisfaire, pourra se substituer la recherche du confort ou celle du prestige social, palliatif dont on peut craindre qu'il n'ait qu'une efficacité temporaire.

HYPOTHESE POUR UNE REFLEXION SUR L'ACTION COLLECTIVE

En conclusion de cet examen rapide de quelques résultats d'enquête il semble possible de faire plusieurs remarques :

1- Le logement n'est pas un outil

Tout d'abord l'appréciation du logement ne se réduit à une appréciation de ses qualités techniques et fonctionnelles que pour deux populations particulières.

L'une minoritaire se distingue par une grande mobilité résidentielle et attacherait plus d'importance à l'exploration de la ville à travers des déménagements successifs qu'à la qualité des logements. Préfiguration de l'implantation en France d'un modèle culturel américain?

L'autre, une population essentiellement ouvrière, n'adopte un discours fonctionnel sur le logement que parce qu'elle n'a pu obtenir ce qu'elle désirait profondément : un logement situé dans un environnement qui lui renverrait une image positive d'elle-même telle que le voisinage et l'habitation puissent être aimés comme un enfant aime sa mère.

Par contre l'espace et le confort qu'assure la qualité technique de la construction dans son ensemble sont fortement appréciés par les cadres et professions libérales qui sont satisfaits de leur nouvelle résidence. Mais cette satisfaction tient à la possibilité qui leur est ainsi offerte de trouver dans l'espace du logement un refuge contre les signes d'un changement social, vécu au fond avec inquiétude, et d'y loger des objets d'amour, plutôt qu'à l'addition des satisfactions que procureraient l'absence de bruits, de fuites, d'odeurs...

2) La mobilité forcée rend difficilement acceptable le logement ouvrier

Dans une zone géographique soumise à une profonde restructuration industrielle il est vain d'espérer que le changement de logement, même s'il s'accompagne d'un amélioration de la qualité des logements, fournirait une compensation aux inquiétudes nées de la situation de travail pour l'ensemble de la population ouvrière.

Il nous est impossible d'évaluer la part d'une telle population pour laquelle ce changement serait vécu comme un échec à partir des enquêtes dont on dispose aujourd'hui. Il semble qu'elle serait importante.

Pour les ouvriers ou les employés qui cherchent un confort affectif qui protège leur identité, celle du couple et celle de leur famille autant dans le voisinage que dans le logement, on peut penser que la situation de déracinement provoquée par un changement imposé aggraverait le sentiment d'impuissance qu'ils éprouvent devant le changement social. Or ce sentiment les paralyse en les rendant incapables de chercher à s'adapter. Ils risqueraient fort de ne pas pouvoir s'intégrer dans leur quartier ni dans leur nouvelle société d'accueil et de se replier sur un logement qu'il maudissent sans pouvoir en sortir.

3) Réponses envisageables

a/ vivre au pays

D'une part il semble certain que pour une bonne part de la population le maintien sur place, dans la mesure où il garantit la continuité de l'enracinement familial dans un lieu, est préférable à tout changement de résidence, même s'il doit s'accompagner d'une aggravation de la situation professionnelle (par exemple, des migrations alternantes très longues).

b/ Encourager les plus mobiles en agissant sur sur l'offre de logement

D'autre part il est vraisemblable qu'une fraction de la population est susceptible d'accepter la mobilité si celle-ci est offerte sans contrainte. Cela suppose que le choix ne se situe pas entre un travail ailleurs et le chômage sur place.

Un certain nombre d'ouvrières célibataires accepteraient volontiers des logements, même très petits, pourvu qu'ils soient très bon marché et à proximité d'un centre urbain.

Des ouvriers qualifiés, peu nombreux sans doute, seraient très mobiles et d'autant plus satisfaits que les logements seraient plus fonctionnels et les services utiles à leur vie familiale plus accessibles.

Par ailleurs, pour tenter d'offrir une satisfaction réelle à la population ouvrière qui cherche à étayer son identité sur un logement situé dans son environnement, il est peut-être possible de concevoir des ensembles de logements dont la réalisation effacerait les signes de la construction industrielle, visibles dans le quartier et l'environnement du logement. En effet il semblerait possible d'imaginer que l'image d'un quartier neuf soit elle-même fondée sur l'évocation de la continuité avec l'histoire et la nature, significations antinomiques du changement social.

Cette suggestion est avancée à titre de conjecture. Elle ne saurait être tranchée par la simple spéculation intellectuelle dans l'état de nos connaissances.

(1)La dynamique psychosociologique de la mobilité résidentielle.
J.Palmade,
Direction de la Construction - Paris 1978

(2)La dialectique du logement et de son environnement
J.Palmade, F.Lugassy, Françoise Couchard
D.G.R.S.T., Ministère de l'Environnement Paris 1970

(3)Système symbolique et idéologique de l'habiter
J.Palmade
D.G.R.S.T. Paris 1977

(4)Représentations et attitudes vis à vis du changement social
F.Lugassy INFA , Paris 1966

(5)Les nouveaux villages
J.L Siran
Direction de la construction Paris 1978

User Participation in the Planning of Residential Areas - an Evaluation of Four Experiments.

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Summary

The low-dense housing concept, as it was suggested by the Danish Building Research Institute in the early seventies, was not only a new way of building rental housing after the widespread multi-storey building form of the sixties, but it also introduced a new lifestyle into the social environment of these housing areas in admitting user participation in the planning process as one of the major components of this concept.

Four initial experiments have been carried out, and this article describes some of the main problems envisaged in the course of these projects, particularly the facts that such projects take more time than anticipated, and that public authorities and housing corporations tend to be somewhat reticent.

All four experiments were carried out as social housing projects, i.e. that they had to be produced within certain maximum price limits per square metre. This, of course, entailed certain restrictions for the implementation of the user requirements.

Such limitations have caused some of the initial users to withdraw from the projects.

Moreover a mild polarization occurred between inhabitants with educational professions and the other users.

The article recommends various considerations in practice - and perhaps even in legislation - which might result in a greater amount of influence on the part of the users.

The Low-dense Concept.

In 1971 the SBI invited to a public competition for ideas to develop low-dense housing systems. In the competition-programme it was stipulated that the proposals should not merely deal with housing forms or technological solutions, but that they should also provide new management-ideas, both for the organization and administration of the housing areas concerned and for the whole institutional and city structure so as to achieve more self-sufficient communities, comprising housing, common activities, working places, a.s.o. The users of these future areas were to participate in the planning process right from the start.

In 1972 a conference was held to discuss the ideas emerged from the competition and the actual possibilities of implementing them via Parliament, the central administration, public housing corporations, financial institutions, researchers and experts. The conference confirms the necessity to carry out coordinated experiments in accordance with the scope of the competition. Subsequently, four experiments were initiated. The planning process of two of these experiments has been closely monitored by the SBI, while the other two have had a minor support from the institute in negotiations with the Ministry of Housing in the form of supplementary advice and supporting documentation.

While it is still too early to evaluate the success of these experiments, as far as the social content of the areas is concerned, the success and failure of the user participation in the planning phase can certainly be assessed. Three of the neighbourhoods have been completed, and the inhabitants have moved in last year. The fourth area is still in the final design stage.

The Four Housing Areas

The four experimental projects have all been carried out as subsidized rental housing areas. One of the projects represents a combination of rental housing and home-ownership.

Tinggården

Figure 1. Situated in Herfølge, south of Copenhagen, this housing area includes 79 apartments and is sub-divided into six smaller groups, the socalled family-groups, forming the basic organizational units. Each unit has its own communal facilities. The average housing area is 87 square metres, of which 78 square metres are apportioned to the private housing space and the remaining 9 square metres to community facilities. In Denmark normally 3 pct. of the gross dwelling area is allocated to community facilities. In Tinggården, however, 13 pct. are apportioned for this purpose, and this new ratio points to the fact that greater importance is being attached to community facilities in this housing area. Each family group comprises a community facility of 100-200 square metres, to be used as desired by the members of the groups, e.g. for meals, gatherings, etc. Apart from this, there is a communal facility of 200 square metres for the whole community, normally used for large gatherings and decision-making of common concern.

Drejerbanken

This residential area is situated in the rural area of Skalbjerg in the southern part of Funen. The area comprises 200 housing units, a community facility, and a central boiler house. Ten of the housing units are rental units under the administration of a social housing corporation, the other ten are privately owned. These two types of units each form a sub-group in the area, and the communal facility is placed as a link between the two.

Figure 2. The community facility consists of a 240 square metres building with a cellar. The dwellings are 1-2 storey buildings around a common free area used a.o. as a close-by playground for small children. Due to the special combination of social housing and private home-ownership, the management of the project represents a combination of the model of Danish public housing corporations and traditional home-ownership.

Grønlandsparken

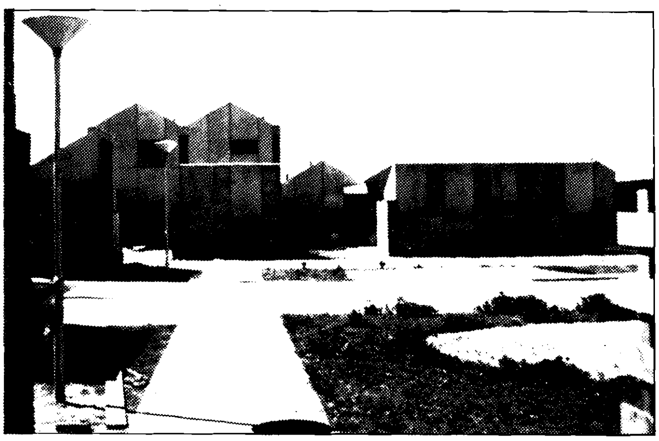

Figure 3. This low-dense area is situated north of Esbjerg in Jutland. The area comprises 190 housing units, of which the first phase includes 54 housing units and a community facility. The area is structured in rows of 8-22 housing units grouped around a market place with a playground and a community facility. The dwelling units are in one or two storeys, placed on a plot of 160 square metres. The average area is 76 square metres.
The community facility, in the first stage includes close to 3 pct. of the total floor space of the housing area, i.e. 120 square metres. While decisions about its use will be made later on, it will be equipped from the start with the necessary kitchen and toilet facilities, a meeting room, a laundry unit, some storage space, and a caretaker's office.

Klyngen

This housing area is planned to be placed in Hundige, south of Copenhagen. While the plans have been completed, the construction work has not yet been started. The area is planned to include 40 housing units, either in 2-storey row-houses or in 3-storey housing units.

The community facilities are planned to be placed centrally in the area, and they comprise 10 pct. of the total floor space. Plans have been made to include a daycare center for 20 children for a shorter period of time.

The Users

The major goal of all four experiments was to involve a broad section of the users in the experiments in Tinggården. In order to achieve this, all the experiments had an element of user participation. The methods for this participation have varied greatly. In the case of "Klyngen" it was a matter of advertising in the Copenhagen area newspapers that an introductory meeting was to take place. To this meeting 25-30 adults brought along 10 children. After the meeting a group was formed including 12 households, comprising one retired person, one student, four single mothers with children, and six couples with children. The group was rather differentiated, both with regard to income and type of occupation.

In the experiment of "Grønlandsparken" a thousand posters were distributed to the housing corporations, housing projects and local public institutions such as libraries and educational facilities. These posters explained what the experiment was about, the ideas and ideals behind it, the time it would take to carry it out, etc. At the two introductory meetings there were 45 households present. After the second meeting, the group was reduced to about 30, which formed the final user group participating in the project. This group represented a broad social scope of the population. The majority of the participants were workers, and only a few of them were university graduates.

In the experiment of "Tinggården" there was an imitative exhibition arranged in Køge by the Danish Building Research Institute. For the recruitment of the participants a certain background material was worked out, including slide shows, posters, and special newspapers and folders. The newspapers were sent to all residents in the multi-storey areas and to the large industrial working places.

Several introductory meetings were held for trade unions and schools. Later the material was displayed in a tent on the town square. It is estimated that about 3,000 people saw the display, and 150 households announced their interests.

In the "Skalbjerg" project, were the initiative was taken by the users themselves, the basic core was a group of friends. The group grew in size by the initiators asking other friends and advertizing in the newspapers. While the members of the home-owner group of this experiment were families with children and economically better off, the majority of the members in the rental units were one parent families. Most of the people participating in this group were ideologically motivated to move into a housing area with more social contact and new forms of housing.

In all the projects large changes have taken place in the user group during the planning process. While the general trend pointed towards a decrease in the number of participants from the very first introductory meeting until the meetings of the group finally participating, there were also reductions in the group size during the process later on.

One of the conclusions emerging from the experiments is that the recruitment phase is one of the most important phases in the process. It is here that some of the basic ideas are presented and a selection of the final group is made. The experiments showed that it is difficult to achie an allround composition of what was due to different background and different reasons, such as: An interest to buy a house of one's own, the planning phase taking too much time, decisions being made to quickly by experts, difficulties in participation in the group process, and differences of opinion, particularly with regard to the social content of the community and the equipment of the housing area. Also too high a rent as opposed to the prospects held out in the initial plans contributed to a reduction of the group size.

	Invitation		1. meeting	Start of programm.		End of programming			Designing	Moving in		Number of dwellings	Total number of families involved
TINGGÅRDEN	50	-	75	75	-	35	35	-	15	11	-	79	more than 300
DREJERBANKEN	35	-	35	35	-	20	20			20	-	20	" " 75
GRØNLANDSPARKEN			20			15	15	-	10	2	-	50	" " 35
KLYNGEN	65	-	25	25	-	3						40	" " 85

Figure 4. The number of participants varied to a great extent in the different phases in all four experiments.

The Planning Process

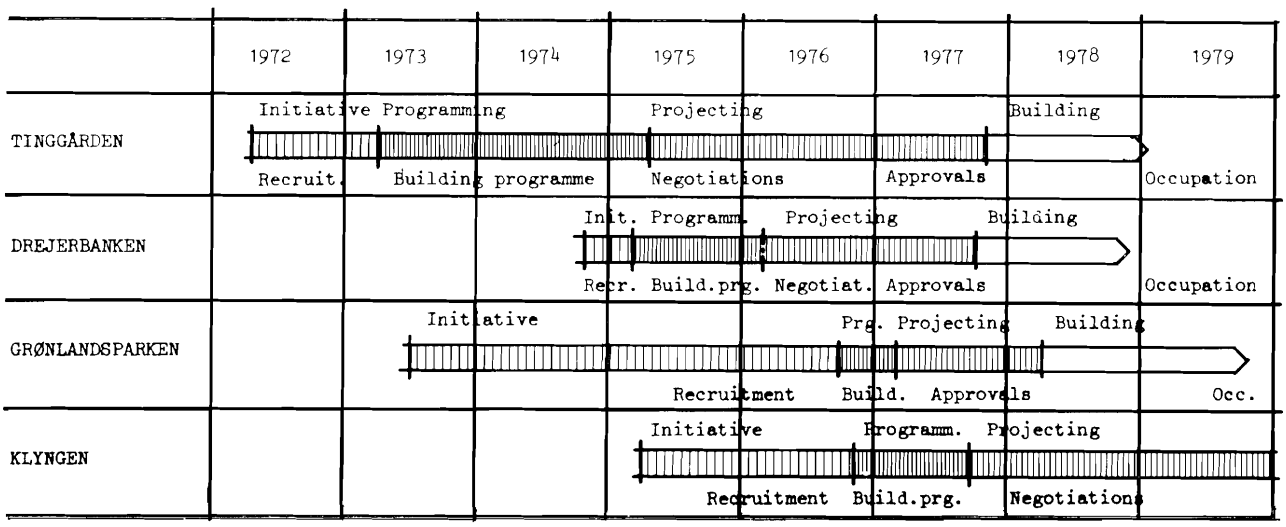

Figure 5. The time used in the different phases varied in the four experiments. Particularly the time used in the preparatory work, due to pre-negotiations with the housing corporations and with the authorities.

As it is obvious from the table, the organization of the planning process varies a great deal. In one of the experiments the users have been participating right from the start, being the initiative group, whereas in another project the users have come into the picture rather late in the process. In a third case a systematic start by a preparatory meeting and an organization of the planning process in different phases has been applied, as opposed to a process, where the users presented their ideas in a very short time and in an unstructured way.

First of all it seems that the users a more motivated for participation the earlier they come into the process. Secondly, the necessary time for the process should neither be too short, nor too long. Thirdly, the procedure of getting acceptance for site plans and other public approvals should be speeded up to prevent discouragement of the users. Fourthly, the planning process should be worked out in distinct phases, and this plan should be presented to the users to provide an overview of what is to come. This would undoubtedly diminish the turnover of the group during the planning process.

Forms of Cooperation

In all four experiments the client (the social housing corporation), the architects, and the authorities have been positive towards user participation in design. However, the forms of cooperation have not been decided upon beforehand, which resulted in a "trial-and error" procedure during the process.

Various methods of cooperation have been tried out in the four experiments. In "Klyngen" the users did not wish to constitute an independent group and to chair the meetings themselves. Everyone participated in all meetings, which were all conducted by the architects. The main idea was that, to begin with, the users were to have a talk about the overall goals and about details of particular interest. Thus the architects felt that everyone would come up with what seemed important to him or her without too much guidance. The ideas were not documented in a systematic way, and the minutes of the meetings are scarce.

The cooperation in the Esbjerg project was based on weekly meetings with the architects. The form of the meetings was improvised and informal and they started with an introduction from the architects, or from another member of the group, of a specific topic to be discussed, such as parking problems, special arrangements in the dwellings, etc. After the introduction, the group divided itself into sub-groups (during the same meeting), and each of these discussed the same problem. According to the architects, the largest problem in the process was the time. Another three months would have been needed for going into depth with all the problems. The users' non-committal attitude (not obliged to move in), was another problem observed by the architects. While the participation of the users was extensive in the programming phase, the subsequent design phase was largely dominated by the architects. In this phase of the project also the social housing corporation played a larger role and dominated some of the decisions, particularly as far as economics were concerned.

In "Tinggården" the forms of cooperation have been more complicated. The design group was composed of both researchers from the Danish Building Research Institute and architects with private practice. The Municipality has been actively involved, and the social housing corporation representing the client responsibility was not set up until later on. While at the beginning the Municipality had a positive attitude towards the experiment and made special allowances in the initial phases, there were later on some conflicts related to the marketability of the housing units. In general, the cooperation between the design team and the users was a positive one. However, there have been some conflicts on the role of the design group as opposed to that of the users. In the process there are examples, where the planners have retreated to the old role of telling the users what is best for them. During the process there was a conflict of attitudes between the group of teachers and the rest of the user group, with the result that the latter have to some extent left the enterprise.

In the "Skalbjerg" project the objective was that all users were to participate in all important decisions. Working groups were set up to work with various problems such as economics, the design of the project, negotiations etc. During the whole period there were weekly meetings for all users, supplemented sometimes by weekend-meetings. In spite of the democratic intentions, there was in the process a need to select a working committee to decide on questions requiring a fast decision. Such a committee was set up and it consisted of the chairman of the board for the social housing corporation, the legal adviser of the users and a member of the user group for both rental and ownership housing. Both the Municipality and the social housing corporation have been extremely cooperative. The conflicts in the process have mainly been due to overrun time schedules. Due to the lack of practical experience in the planning of housing areas with user participation, the architects were too optimistic about the time needed. Another problem was the introduction of new members into the group in consequence of the continuous turnover.

It is obvious from the experiments that in cases, where the cooperation with the Municipality and the housing corporation has been a smooth one, the users have been more motivated to participate.

The role of the architect is a sensitive one, and a new alternative planner role is required in the future. This implies a new type of expertise in being able to explain and define problems to the users as well as clarify the consequences of all alternative choices. It requires a sensitivity in cooperation, rather than knowing better what is best for the users.

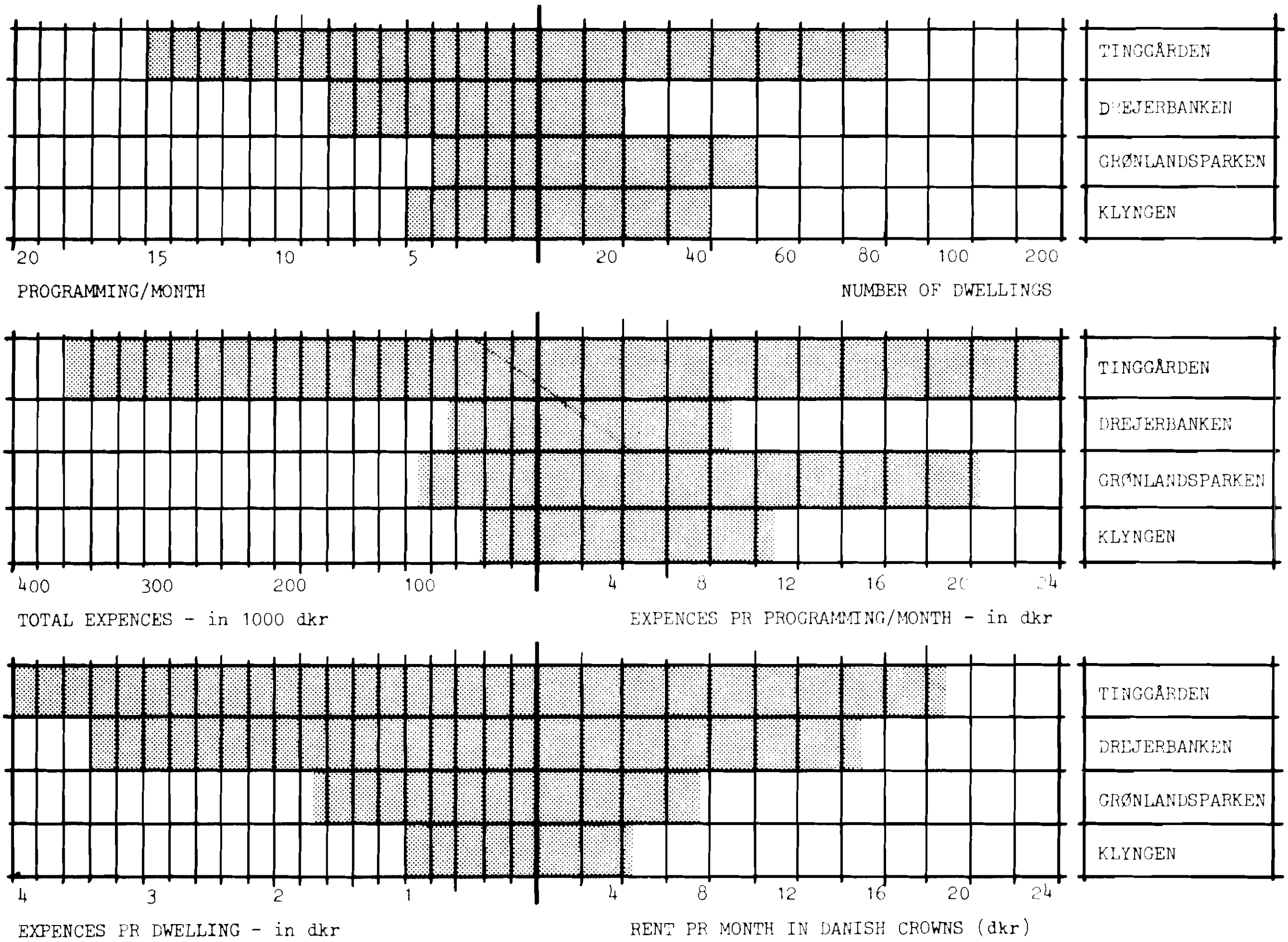

Figure 6. The expenses in connection with the user participation in the programming phase.

The general conflict of the users is that they need more time to go into depth with decisions to be made or previous decisions to be revised, whereas the architects feel obliged to take certain standpoints in order to proceed with their work. This problem could to a great extent be prevented by an agreed meeting schedule clarifying to the users what decisions it will be necessary to make and when. Another cause of frustration is that due to the economic limits the social housing corporations were later in the design phase compelled to cut on some of the qualities decided upon by the users.

The Social Environment

The objective in all the experiments was to achieve a new form of living based on a closer social contact among the users of the housing areas. One of the assumptions was that user participation in the planning process would imply a social process, where the users could get to know each other and, consequently, would be better equipped to create and maintain a social environment in the neighbourhood. An additional aspect was the question of community facilities, which in turn would allow for social activities among the users.

Thus, the community facility is one of the more interesting questions of the final physical design of the housing area. Planning of this facility is one point, which brought most of the conflicts among the users into daylight. One of the problems discussed in all the projects was that, even if the users participating in the process were interested in a certain community facility, the attitude of the rest of the users to be recruited after the completion of the area was still unknown. Another thing to be agreed upon was the use of the community facility, i.e. the activities to take place therein.

In "Klyngen" f. inst. the community facilities were planned to be 10 pct. of the gross floor space of the housing area, and it was assumed to be an open space, the functions of which were to be agreed upon after that the inhabitants had moved in.

In "Grønlandsparken" the architects were greatly interested in providing for good community facilities. The interest of the users, however, in the community facilities was rather limited. The questions of community activities and social contact were only superficially discussed in the project. The community facility built in this neighbourhood is now close to 3 pct. and does not include any supplementary areas to the dwellings.

In "Tinggården", on the other hand, the amount of space for community facilities was increased from 3 pct. to 13 pct.. Each family group, consisting of 12-15 households, has its own community facility, the activities of which the families can decide upon for themselves. Moreover, there is a 200 square metre community facility for the area as a whole. In this project, many of the participating users were interested in the social content aspect of the project, including that of the children. Even though some of the users were motivated by other reasons, the attitude towards social aspects has both been an advantage and has, at the same time, provoked feelings of insecurity with others.

In "Skalbjerg" the community facility, amounting to 3 pct. of the total floor space, was planned for the maximum size legislated for social housing. The building was to be flexible in use, and a list of functions was prepared by the users. Generally, they would have preferred a larger community facility, the limited size presenting difficulties in setting priorities for the areal requirements and functions. In this project the social content has had a high priority right from the start, and the users have been in ideological agreement about giving priority to the community facilities in preference to the private dwellings.

Conclusions

The wide spectrum of results received from the four experiments indicates strongly the initial difficulties, when starting with a new planning procedure for housing areas. In the experiments described, the users, the organization of the planning process, the form of cooperation, and the final results vary to a great extent.

A common problem is that of a high turnover of users during the planning process. This points to the fact that the users are not at any price interested in participating in the planning of their housing area. The recruitment, the time required for the planning, and the organization of the process, play an important role for the motivation of the users.

Another problem is the time aspect. In some of the projects the time has been too short, i.e. there has not been time enough to penetrate the problems in depth. The other extreme is, where the time necessary for the planning has been too long, which has strained the users' patience. To some extent, this has been due to time-consuming approval procedures. Therefore, it is important to consider the time aspect very thoroughly already at the beginning of the planning process.

The experiments vary to a great extent, as does the organization of the planning process. Some general conclusions, however, can be drawn:

- It is important from the very beginning of the process that the users have an overview of the topics to be discussed, decisions to be made, when to make them, and what the consequences of the decisions are for the further process.

- The organization of meetings has to be given great consideration. Regular meetings with discussions in smaller groups during the meetings chaired by the users seem to be a reasonable form.

- The critial point is how the decisions are made. The experiments include procedures, where the users have to be unanimous, the majority rules, or where the decisions are made by the architects or the social housing corporation. Whichever method of decision-making is chosen, it is important that an agreement to this effect is made with the users already in the initial phase.

Cooperation between the architects and the users is a matter of importance. The architects should not use their expertise to override the users, but rather to formulate the problems in the process, present alternative solutions, discuss such solutions with the users, and clarify the consequences of the decisions made. The users, on the other hand, have to gain an understanding of the course of the planning process, and the relationship between various design factors, as well as to express clearly their ideas of the housing they want.

When initiating the experiments, there seem to have been expectations on the part of the architects and the housing corporations that the users participating would always be unanimous and would all have the same needs and wishes. The users, even though in agreement on general objectives of the project, will always disagree to some extent. Therefore, it is important that the planning process is being organized in such a way that these disagreements can either be solved, or that a procedure can be etablished for restructuring the group.

It is important to work out planning tools to enable the users to better understand the planning process and make their decisions. Here there is a great need for further research.

The final results of the three housing areas already built in Denmark are interesting both in terms of architecture, planning and social content. This should be sufficient to ensure further interest in similar experiments. The Danish Building Research Institute is following the in-use phase of the projects in order to gain a better understanding of the connection between the social process during the planning phase and the social environment of the housing neighbourhood in use.

Le logement dans les villes du tiers monde. Les ressources et les besoins.

Bernard Delaval, Ingénieur Civil-Architecte-Urbaniste à l'Office de Promotion Industrielle, Belgique.

In the last 25 years, the third world's total population has doubled, but its urban population has tripled. According to estimations of the United Nations, the populations of third world cities will increase by 1 billion inhabitants by the year 2000. If drastic measures are not rapidly taken, the urban centers of these countries will become enormous slums. According to a World Bank study, 50 to 70% of the populations will not have access to government assistance; only the most privileged classes will benefit from such aid. It is useless to hope for any improvement.

What remains is the "squatter settlement sector" which requires all the attention and help of housing policies. It is of utmost importance to promote modulated formulas which favor the exploitation of available local ressources, and which truly meet the real needs of the populations by encouraging their active participation via the concept of self-help. To attempt to destroy the slums under present conditions is a Sisyphean task.

Durant les 25 dernières années, la population totale du tiers monde a doublé; la population urbaine a triplé. Selon les estimations des Nations-Unies, la population de ses villes augmentera d'un milliard d'habitants d'ici l'an 2000. Si des mesures drastiques ne sont pas rapidement prises, les centres urbains de ces pays seront d'immenses bidonvilles. Selon une étude de la Banque Mondiale, 50 à 70% de la population ne peut bénéficier de l'aide de l'Etat; seules en profitent les couches les plus favorisées. Il est vain d'espérer une amélioration.

Reste le "secteur spontané du logement". C'est lui qui mérite la vigilance et l'aide de la politique de l'habitat. Il importe de s'orienter vers des formules modulées qui tiennent compte des ressources disponibles et répondent aux besoins réels des populations en faisant appel à leur participation active par le biais de l'autoconstruction. Dans l'état actuel des choses, vouloir détruire les bidonvilles rappelle le mythe de Sisyphe.

1. Les bidonvilles de l'an 2000

Les politiques de l'habitat des pays du tiers monde sont généralement inspirées de celles des pays industrialisés. Si des modifications radicales n'interviennent pas rapidement, il apparaît inévitable que les centres urbains du tiers monde soient en l'an 2000 d'immenses bidonvilles.

L'explosion que connaissent les villes des pays en voie de développement depuis une vingtaine d'années est le mouvement de population le plus explosif de l'histoire de l'humanité.

Pour le maîtriser, il est indispensable de réorienter fondamentalement la politique de l'habitat et de satisfaire les besoins élémentaires des populations par une utilisation rationnelle des ressources disponibles.

2. Les approches classiques de la politique de l'habitat

Les approches classiques de la politique de l'habitat dans le tiers monde s'orientent autour de trois axes:
- une estimation normative des besoins en logement;
- des opérations de logement dit "économique";
- des opérations de destruction des bidonvilles.

2.1. Estimation normative des besoins en logement

Les méthodes d'estimation des besoins en logement dans les villes du tiers monde sont généralement inspirées de celles utilisées dans les pays industrialisés.

Ces estimations sont normatives. Elles définissent les volumes de construction à réaliser pour aboutir à l'issue d'une période déterminée à des conditions de logement jugées satisfaisantes (qualité minimale, taux d'occupation, âge,....).

Ces évaluations s'inscrivent dans la lignée de l'urbanisme "hygiénique". Elles ne tiennent pas compte des ressources disponibles et ne précisent pas le type de logement à construire.

Vu la croissance de la population et l'état du parc (renouvellement, desserrement), elles conduisent à des besoins théoriques de 7 à 10 logements par an et par 1000 habitants.

2.2. Les opérations de logement dit "économique"

Le secteur officiel du logement est celui qui respecte le cadre administratif de l'urbanisme réglementaire (enregistrement des titres de propriété, respect des normes de construction, octroi de permis de bâtir).

Il se compose, en proportions variables, d'une promotion privée et publique. La promotion privée répond aux besoins des couches les plus favorisées de la population (hauts fonctionnaires, cadres supérieurs, professions libérales, expatriés).

L'aide au logement s'effectue en général par le biais des programmes dits "économiques" des sociétés immobilières. Le coût de ces logements est de l'ordre de $200/m^2.

Le secteur officiel (privé et public) est le seul à bénéficier de l'aide de l'Etat en matière de logement:

- prise en charge des coûts d'aménagement et de viabilisation;
- bonification des taux d'intérêts des prêts hypothécaires;
- subventions directes et/ou indirectes dans le cas de la promotion publique.

Malgré ces diverses formes d'aide, les programmes les plus économiques des sociétés immobilières ne sont accessibles qu'à une clientèle du type "classe moyenne" (enseignants, commerçants, fonctionnaires).

Le secteur officiel est le seul à faire l'objet de statistiques dans la comptabilité nationale.

Dans le tiers monde, la FBCF dans la construction de logements représente en moyenne 4% du PNB [1], ce qui correspond à des taux de construction de l'ordre de 2.5 logements par an et par 1000 habitants [2].

La production de logements du secteur officiel (privé et public) ne représente donc qu'un tiers ou un quart des besoins théoriques définis par les estimations normatives.

Cet écart peut se vérifier en pratique dans diverses villes du tiers monde:

Villes	Logements/1000 habitants x an	
	Estimations normatives	Production "officielle"
Esfahan	6.5 à 9.3	3.1
Mosul	6.4 à 9.0	2.8
Ouagadougou	7.5 à 12.1	2.5
Tunis	7.5 à 9.3	3.9
Yaounde	9.0 à 11.3	3.3

Une étude menée par la Banque Mondiale [3] dans diverses villes du tiers monde conclut par ailleurs qu'en pratique de 50 à 70% de la population ne peut avoir accès aux logements les plus économiques produits par le secteur officiel.

La conséquence directe de cet état de fait est que l'aide de l'Etat dans le domaine du logement ne profite en fait qu'aux couches les plus favorisées de la population.

2.3. La destruction des bidonvilles

Il n'est pas étonnant dans ces conditions que les bidonvilles ou quartiers spontanés accueillent la majeure partie de la population urbaine du tiers monde.

De nombreux pays ont essayé de combattre ce qu'ils considéraient comme une forme de sous-habitat en détruisant les bidonvilles. La population délogée était soit renvoyée à la campagne, soit placée dans des programmes de recasement.

Dans tous les pays où elle a été pratiquée, cette politique se solde par un échec. Les familles renvoyées à la campagne regagnent tôt ou tard les centres urbains. Les programmes de recasement ne suivent jamais les rythmes nécessaires.

Vouloir détruire les bidonvilles rappelle le mythe de Sisyphe. Les abris détruits dans un quartier de la ville repoussent immanquablement en un autre endroit.

Cette politique conduit à un gaspillage cruel et inutile. Elle brise les efforts souvent énormes que les familles réalisent pour subvenir par elles-mêmes à leurs besoins en logement sans leur offrir d'alternative.

3. Réalité de l'explosion urbaine

Durant les 25 dernières années, la population totale des pays du tiers monde a doublé, la population urbaine a, quant à elle, triplé.

L'explosions des villes du tiers monde est le phénomène démographique le plus extraordinaire que notre planète ait jamais connu. Cette croissance exponentielle ne se modifiera pas de façon significative à moyen terme.

Elle repose en effet sur trois phénomènes qui se conjuguent pour rompre les équilibres démographiques séculaires:

A. Les progrès de l'hygiène et de la médecine qui réduisent les taux de mortalité. Dans la plupart des pays du tiers monde, ces derniers sont toujours à un niveau voisin de celui de l'Angleterre du 19^e siècle décrit par Engels. Il serait difficilement soutenable de ne pas espérer que l'état de santé des populations du tiers monde ne s'améliore dans les années à venir.

B. Les taux de fertilité se maintiennent à un niveau relativement constant. Les travaux récents des démographes démontrent que le choix du nombre d'enfants est le reflet d'un environnement social et économique. Celcui-ci n'évolue que lentement. Quelles que soient les politiques de limitation de naissance, les taux de fertilité résultent de choix personnels.

C. L'exode rural résulte également du contexte économique. Les migrations entre la campagne et la ville sont en effet la conséquence d'un choix rationnel dans un contexte où l'opportunité de trouver un emploi rémunérateur en milieu urbain est nettement plus élevée qu'en milieu rural. Peu de pays se sont engagés dans la voie d'un aménagement du territoire qui permettra à moyen terme de répartir de façon plus homogène les possibilitiés d'emploi.

Il est donc bien improbable que les tendance actuelles en matière de croissance urbaine se modifient de façon sensible durant les 20 prochaines années. De plus, quel que soit le résultat des politiques suivies, la population adulte de l'an 2000 est déjà née. Le problème de son logement est donc déjà posé.

Suivant les estimations des Nations Unies, la population des villes du tiers monde augmentera de plus d'un milliard d'habitants d'ici l'an 2000.

Pour abriter cette population, il faudra construire, en 20 ans, 120 villes de l'importance de Londres, New York ou Paris, ou aménager chaque jour une superficie urbanisée équivalente à Rennes, Southampton ou Aix-la-Chapelle.

4. Pour une estimation réaliste des besoins

L'explosion urbaine du tiers monde pose un défi extraordinaire. Il faudra aménager durant les 20 prochaines années une surface urbaine équivalente à celle qui existe aujourd'hui sur l'ensemble de la planète.

Seule une approche réaliste de la politique de l'habitat pourra permettre de maîtriser ce phénomène en utilissant de façon rationnelle les ressources disponibles pour satisfaire les besoins essentiels des populations.

4.1. Ressources mobilisables dans le secteur spontané du logement

On a vu que les bidonvilles ou quartiers spontanés accueillaient la majeure partie de la population urbaine du tiers monde.

Les structures souvent précaires sont réalisées par auto-construction ou par tacheronnat. Elles ne s'inscrivent pas dans le cadre de l'urbanisme réglementaire. Il n'en demeure pas moins qu'elles assurent la fonction d'abri pour les familles qui les occupent.

Le secteur spontané du logement, bien qu'il se situe pour l'essentiel en dehors des circuits monétaires présente de plus des potentialités économiques non négligeables:

- création d'emplois dans le secteur traditionnel de la construction et effet multiplicateur;
- utilisation préférentielle des matériaux disponibles localement.

La construction spontanée de logements constitue également la seule possibilité d'épargne et d'investissement pour les couches les plus défavorisées de la population.

La destruction des bidonvilles constitue un gaspillage intolérable. Elle représente la négation des efforts réalisés par les familles pour subvenir par elle-mêmes à leurs besoins en logement. La non prise en considération des ressources mobilisables du secteur spontané est d'autant plus regrettable qu'il n'existe pas de moyens d'offrir aux habitants "déguerpis" une solution alternative.

Les organismes internationaux, la Banque Mondiale en particulier, ont entrepris depuis quelques années des projets de restructuration des quartiers spontanés.

Ces projets ont pour objectif de remédier aux déficiences de ces quartiers (statut foncier, viabilité, services, accessibilité) tout en conservant un maximum du parc immobilier spontané.

4.2. Vers une approche positive des besoins en logement

La restructuration des quartiers spontanés constitue une amélioration de la situation existante. Le défi de l'explosion urbaine ne sera cependant relevé que si parallèlement, les politiques suivies en matière d'habitat permettent d'éviter la prolifération des bidonvilles.

Comme l'ont montré les travaux de Charles ABRAMS et de John TURNER, l'amélioration des conditions de vie des populations urbaines du tiers monde implique en plus de l'accès à un logement, l'accès à un emploi et l'accès à l'éducation des enfants.

Vu l'ampleur des problèmes auxquels sont confrontés les pays en développement, il n'apparaît pas réaliste d'espérer une augmentation de l'aide de l'Etat au logement urbain.

Il apparaît par contre indispensable que cette aide soit réorientée pour mobiliser les ressources disponibles des diverses couches de la population en leur offrant les structures administratives et physiques qui leur font défaut (sécurité foncière, assainissement, équipements collectifs).

Les ressources publiques doivent être utilisées en priorité pour la viabilisation des terrains et pour la construction des équipements de développement (écoles, dispensaires, ateliers artisanaux, marchés,....). L'expérience montre en effet que la construction des logements peut relever de l'initiative privée.

Une telle politique implique une approche positive de l'estimation des besoins en logement tant sur le plan quantitatif que sur le plan qualitatif:

- Sur le plan quantitatif, il importe de dimensionner des opérations d'une taille suffisante pour accueillir les nouvelles familles et éviter ainsi la prolifération des bidonvilles;

- Sur le plan qualitatif, il importe de choisir des niveaux d'aménagement qui pour les infrastructures et les équipements soient compatibles avec les ressources publiques et pour les logements avec les ressources privées.

Cette approche positive doit s'appuyer sur la demande effective ou solvable en matière de logement des différentes couches de la population.

Un exemple théorique de cette évaluation est doné en annexe.

Elle permet d'exprimer d'une façon globale la situation à laquelle les responsables de l'aménagement urbain sont effectivement confrontés. Cette image d'ensemble conduit à extérioriser les assistances directes ou indirectes que les pouvoirs publics accordent aux différentes couches de la population.

L'approche positive pourra ainsi permettre d'intégrer progressivement le secteur spontané du logement au secteur reconnu par une politique qui répond aux objectifs essentiels qui sont:

- la régularisation de la situation foncière;
- la réservation des terrains nécessaries à la croissance urbaine;
- la réalisation des infrastructures de viabilisation et des équipements collectifs;
- l'assistance technique et financière pour la construction des logements.

Annexe

Exemple d'estimation positive des besoins en logement

Les considérations précédentes peuvent être quantifiées par l'exemple théorique suivant.

Considérons un pays du tiers monde dont le revenu moyen est de l'ordre de $450 par an et par habitant.

La population totale est de 6 millions d'habitants, le PNB de $2700 millions.

La population urbaine représente un tiers de la population totale, soit 2 millions d'habitants.

Les revenus urbains sont deux fois supérieurs aux revenus ruraux. Le revenu moyen en milieu urbain est de $675 par personne et par an, ou $340 par ménage et par mois.

A. Approche normative

Vu l'état du parc immobilier et les taux de croissance urbaine, admettons que l'approche normative ait abouti à des besoins en logements urbains de 9 logements par an et par 1000 habitants, soit 18.000 logements par an en milieu urbain.

En considérant une FBCF pour la construction de logements de 4% du PNB, l'on obtient une valeur totale de $108 millions.

Si l'on admet que cette somme ne représente que le secteur moderne urbain, le coût théorique des logements à construire est de: $108.000.000/18.000 = $6000.

En pratique, l'on peut s'attendre à ce que le rythme de construction du secteur officiel ne soit que de 6000 logements par an et d'un coût moyen de $18.000.

B. Approche positive

L'approche positive implique que l'on prenne en considération les sommes que les familles sont disposées à payer pour leur logement.

L'on retiendra une distribution des revenus typiques pour le tiers monde.

Tranche de population (pourcentile)	Revenu moyen par ménage et par mois
95 - 100%	6.00 x Rm = $2040
80 - 95%	1.73 x Rm = $ 590
60 - 80%	0.90 x Rm = $ 310
40 - 60%	0.60 x Rm = $ 200
20 - 40%	0.42 x Rm = $ 140
0 - 20%	0.28 x Rm = $ 95

En admettant un taux d'effort constant de 17.5%, l'on obtient les revenus disponibles suivants pour le logement:

Tranche de population (pourcentile)	Revenu mensuel	Taux d'effort	Paiement mensuel
95 - 100%	$2040	17.5%	$357
80 - 95%	$ 590	17.5%	$103
60 - 80%	$ 310	17.5%	$ 54
40 - 60%	$ 200	17.5%	$ 35
20 - 40%	$ 140	17.5%	$ 25
0 - 20%	$ 95	17.5%	$ 17

Pour des conditions habituelles de financement (25 ans à 10%), le coût du logement est égal à 100 fois le paiement mensuel:

Tranche de population (pourcentile)	Coût logement	Nombre logements	Coût total
95 - 100%	$35.700	900	$32.130.000
80 - 95%	$10.300	2700	$27.810.000
60 - 40%	$ 5.400	3600	$19.440.000
40 - 60%	$ 3.500	3600	$12.600.000
20 - 40%	$ 2.500	3600	$ 9.000.000
0 - 20%	$ 1.700	3600	$ 6.120.000
Ensemble:		18.000	$107.100.000

C. Conclusions pratiques

En première approximation, on peut retenir les coûts suivants:

- viabilisation: \$500 à \$1000 par parcelle
- construction spontanée: \$50 à \$100/m^2
- construction économique: \$150 à \$250/m^2
- construction moderne: \$300 à \$500/m^2

Il apparaît donc que:

- La tranche A (les 5% les plus favorisés) peut avoit accès à un logement moderne de superficie normale (80 à 100 m^2) sans aide de l'Etat;

- La tranche B (les 15% suivants) a accès à des logements économiques non subsidiés de dimension moyenne (50 m^2). C'est en général cette tranche qui bénéficie de l'aide directe ou indirecte de l'Etat pour avoir accès à des logements plus grands et mieux équipés.

Les 80% restants de la population ne peuvent avoir accès, sans aide de l'Etat, aux programmes classiques de logements économiques.

Un calcul rapide montre que si l'on voulait permettre l'accès de cette population à des programmes ultra-économiques (40 m^2 à \$150/m^2 + \$500 de viabilisation = \$6500), le montant total des subventions nécessaires serait de l'ordre de \$50 millions, soit 2% du PNB, ce qui est clairement irréaliste.

Il apparaît donc indispensable de s'orienter vers des formules modulées, qui tiennent compte des ressources disponibles et répondent aux besoins réels des populations en faisant appel à leur participation active par le biais de l'autoconstruction.

Références

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A Method for Determining Spatial Requirements with Special Emphasis on User Comfort

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This paper presents a method developed for determining spatial requirements of users in artificial indoor environments from the viewpoint of comfort.
Models and field studies of spatial requirements, including variables on shape and dimensions of space, total activity, equipment and functional areas of space, number of users, psychological area coefficient, density of activity and density of user interaction are reviewed. A method for determining spatial requirements of users is developed through these models.

Ce texte présente un méthode développé pour déterminer les bésoins nécessaires des usagers sur les environments internes artificiels du point de la vue du confort. Les études des modéles et du domaine sur les bésoins nécessaires, y compris les variables sur la forme et les dimensions de l'éspace, l'activité totale, l'équipement et les surfaces spacieuses fonctionnells, le nombre des usagers, le coefficient des domaines psychologiques, d'ensité de l'activité et de l'action réciproque des usagers sont revisés. Un méthode pour déterminer les bésoins nécessaires spatiaux des usagers est développé par ces modéles.

Introduction

As a natural consequence of the present day of continuous technological developments, industrialisation of society, humans have begun to spend their time mostly in an indoor environment. With the rapid change of society the problem of indoor environment which should be aim at has called for more attention than heretofore.

One of the main purpose of the indoor environment is to provide adequate space for human beings. The space that human require depend upon the functional value needed for their physical activities and that for their psychological satisfaction. As Grandjean [1] pointed out the physical need space is determined by the personal charecteristics of human, the space needed to move round the equipment and the space necessary for passages to and fro. From the static and dynamic antropometrics point of view human space requirements are vell defined.

A problematic question in the field of assesment of total valume of a living space is that concerning the psychological needs for space. In spite of works of Jeanpierre [2] and Acking [3] there are still many open question to be answered in the field.

To the auther's knowledge there are no analytical and practical way for assessing the total volume of room, or its proportions but on the other hand minumum heights, areas are often valumes as well figure in the building regulations and codes of many countries. These minimum measurements are generally a comprimise between the economical viewpoint and a very vaque concept of what space human require. As a natural consequence of the comprimise living areas, houses and flats have been becoming progressively smaller in the last few decays. [4]

The present stúdy tries to introduce of a method that takes into considerations psychological responses and factors effect on the space requirements as well as physical factors which are measurable comparatively easier.

Theoritically, factors in space magnitude seem to be valid for all kinds of space units. But in such units as a classroom, a hospital ward, an hotel room, alongside with the psyhological and physical factors, there will be factors related to the order of activities, administrative systems, maintanence and educational systems. These factors are not included in the developed model and therefore applications in dwellings will give sounder results. And, in dwellings, only living rooms are selected as the area of application since there is more oppurtunity of working in these particular spaces during field studies.

Basicly, two-dimentional interaction models between defined factors which effect room size and human psyhological responses to those factors have been used in a suggested order in proposed analytical method.

Earlier Studies

Earlier studies which are related to the human response to the space could be reviewed in order to define the factors effect on subjective response. These studies mainly carried out by psychologists, may be grouped as below;

.Studies related to the feelings of spaciousness of exterior or interior space, such as studies done by Inui [5], Hasselgren [6], Garling [7], and Imamoğlu [8]

.Studies related to the measurements of subjective response of users to size of a given space done by Holmberg [9].

.Studies showed the effect of the dimensional characteristic of space on the subjective response done by Acking and Küller [10].

.Studies aimed to search of the effect of sex and body built on the perception of spaces carried out by Coblentz and Jeanpierre [11].

.Studies on the effect of users density on the space evaluation done by Stokols, Rall, Pinner and Schopler [12].

.Studies on the effect of age on the space preferances done by Argyle and Dean [13].

.Studies on the effect of cultural differancies on space preferences carried out by Rapoport and Watson [14].

.Study of the effect of furniture density on the subjective evaluation of spaciousness and estimation of size of room done by Imamoğlu [15].

.Studies on the effect of colours and lighting on the evaluation of the size of a living space, such as carried out by Acking and Küller [16].

.Study on the effect of total area of space, functional area of space, total activity area, total furniture area, number of users, psychological area coefficient, density of activity, density of furniture, density of the interaction of the users on the subjective judgement of comfort. The study carried out by Ertürk [17] is showed that there are significant effect of those variables on the spatial comfort judgement. Definition of those variables and bilateral relations between those variables and spatial comfort is shown on the Figure I.

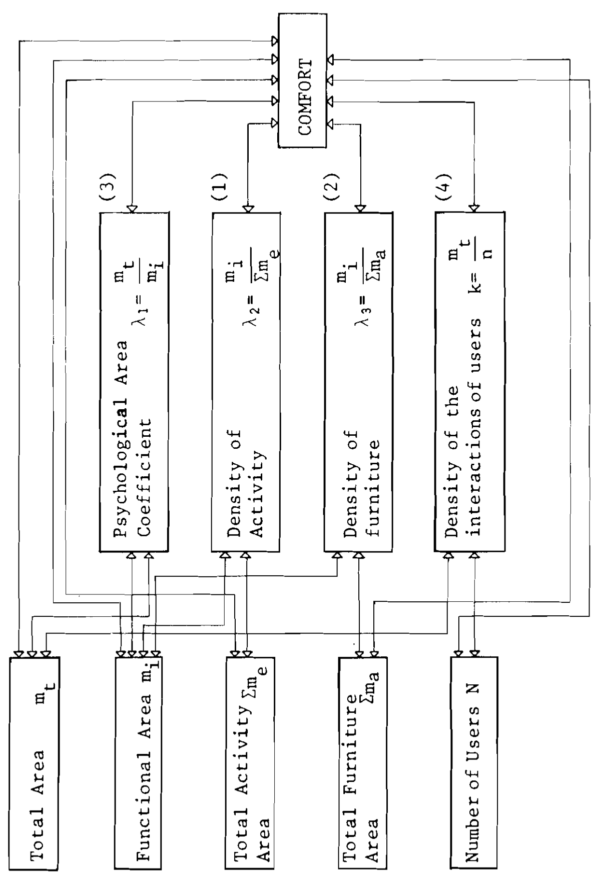

Figure I. Bilateral relations between variables taken into consideration in the research and spatial comfort.

Suggested analytic method

First step will be determination of the relation models between variables ($\lambda_1,\lambda_2,\lambda_3$,k) and users subjective response to those variables. The relations can be established by the means of basic regression analysis.

Basicly there are three types of two dimensional relationship between physical values of space and satisfaction. [18]

. Linear and curvilinear,
. Step function,
. Monotonic.

Above listed relationships all present mechanical models for human interactions with the environment, and its assume that a given level of environmental input will give rise to a given level of psychological response. [19]

The problematic point here is to measurement of the subjective response of users. As a measure for the subjective response of users to a given spatial characteristic of the space the commonly used seven point pscho-physical comfort scale is used:

Numerical value	Subjective response
+3	feeling very large
+2	feeling large
+1	feeling slightly large
0	feeling comfortable
-1	feeling slightly small
-2	feeling small
-3	feeling very small

A scale is thus obtained which is easier to remember, as it is symmetrical around the zero point, so that a positive value corresponds to the large side and a negative value to the small side of subjective feelings of comfort. It is aimed at first step to determine users preference patterns of the above defined variables of a given indoor environment.

On "K_m" axis values of ($\lambda_1,\lambda_2,\lambda_3$,k) corresponding to the point zero which determines subjective feeling of comfort is found. Neverthless in order to allow flexibility for the designer it is usefull to define comfort not as a single point but as a range, that is, to consider the values between "-1" and "+1"

In the second step by the means of relations models the functional area "m_i" can be calculated as follows.

Taking into consideration the equation $K_m = f(\lambda_2)$ the limits of "λ_2" value which defines the subjective feelings of comfort range is found. Total activity area is calculated in relation to the activities which will be performed in the space to be designed. And through the equation of

$$\lambda_2 = \frac{m_i}{\Sigma m_e} \qquad (1)$$

functional area "m_i" is calculated.

In this step the coefficient of equipment density can be used as a means of control. If in the equation

$$\lambda_3 = \frac{m_i}{\Sigma m_a} \quad (2)$$

the ratio of "m_i" to "Σm_a" which is the total area for equipment to be used falls into the subjective response of comfort determining range, it can be suggested that the calculated "m_i" value is acceptable for the space to be designed. But if the ratio does not fall into the comfort determining range of "λ_3", it means that either the equipment to be used were accessively loaded by different activities or on the contrary the sugges-ted equipment were not sufficiently made use of. Such being the case, some changes have to be made in the total area of activity in order to eliminate these drawbacks.

In the last step, the "m_i" value found in the previ-ous step and the value limits of psychological space coefficient corresponding to the comfort range on the scale will determine a range of value for total area requirement through the equation

$$\lambda_1 = \frac{m_t}{m_i} \quad (3)$$

And in this step density of users interactions can be used as a means of control. If the ratio of "m_t" to the number of interaction of users of the space falls in to comfort determining range of "k" value obtained from the scale it can be suggested that the "m_t" value is suitable for the space to be designed. But if the ratio of "k" valume does not fall into the comfort determining range changes on the value of "m_t" and "m_i" have to be made.

Applications of the suggested method

The data was collected by means of a field study at East Blacsea Region of Turkey, in order to apply deve-loped method.

Data collection process consists of two stages:

1. First is, in order to select sampling group to gather relevent information.
2. Second is, measurements of variables of living rooms of selected houses, and the measurements of the subjec-tive response of sampling groups using seven point comfort scale.

In the first stage using demografic data of the East Blacsea Region informations gathered on the listed points;

. Structures of the families, characteristic of users,
. Economic structures of families,
. Educational structures of families,
. Characteristics of houses.

In this stage approximately 200 houses taken into account using a random sampling. In the light of this pilot study 40 family were taken as sampling group. The data, subjective judgement of the father of the families selected among middle class and spent appro-ximately five years in urbanisation process and their living rooms relevant variables such as total area, functional area, total activity area and furniture area are given on the Table I. Culculations of the $\lambda_1, \lambda_2, \lambda_3$ and k are given on the Table II.

Some factors were taken as independent variables under control in order to show the effects of $\lambda_1, \lambda_2, \lambda_3$ and k on the subjective responses. In view of this statement, the following proporties of the space were seeked in the sampling;

. That the condition a=b (length, witdth) is roughly satisfied.
. That the value of height is in the range of 2.60-2.70 m.
. That the window openings are equal in area and look either Nort, Nort-West or Nort-East.
. That there is means of artifical lighting suspending from the ceiling.
. That the dominant colours are light i.e. white, light yellow and light grey.

	K_m	m_t	m_i	Σm_e	Σm_a
1	-3	12.00	9.6	18.40	7.90
2	-3	12.50	9.6	19.80	8.00
3	-3	12.25	9.35	19.50	7.80
4	-3	11.50	8.70	17.95	7.25
5	-3	13.00	9.80	19.70	8.00
6	-3	13.50	10.00	20.45	8.25
7	-2	14.00	9.30	18.65	7.40
8	-2	14.00	9.20	17.50	7.30
9	-2	14.25	9.50	17.15	7.60
10	-2	15.00	9.90	16.95	7.90
11	-2	15.25	9.80	17.95	7.75
12	-2	14.80	9.60	17.00	7.55
13	-2	15.00	10.10	18.30	8.10
14	-1	14.75	8.70	15.30	6.95
15	-1	15.20	8.95	15.35	6.90
16	-1	14.80	8.45	14.50	6.50
17	-1	15.15	8.60	14.50	6.60
18	-1	15.80	9.00	15.60	6.90
19	-1	15.75	9.10	15.00	6.70
20	-1	15.90	9.25	16.00	6.85
21	-1	15.60	9.20	16.40	6.75
22	-1	15.50	8.90	16.15	6.55
23	-1	15.25	8.60	15.55	6.35
24	0	16.00	8.65	14.55	6.25
25	0	16.50	9.00	14.30	6.60
26	0	16.75	8.70	15.20	6.35
27	0	15.80	8.15	13.85	6.00
28	0	16.80	8.80	14.50	6.40
29	0	15.90	8.40	14.00	6.20
30	0	16.10	8.70	14.50	6.50
31	0	15.80	8.65	13.50	6.30
32	+1	17.50	8.80	13.45	6.25
33	+1	17.00	8.50	13.60	6.00
34	+1	16.90	8.45	13.60	6.00
35	+1	17.75	8.50	13.65	5.95
36	+2	19.50	8.85	13.75	5.90
37	+2	18.75	8.70	13.00	5.80
38	+2	20.50	8.90	13.80	5.70
39	+3	20.00	8.35	12.20	4.75
40	+3	21.00	8.75	12.75	4.20

Table I. Subjective judgement of the father of the families selected among middle class and spent appoxi-mately five years in urbanisation process and their living rooms' relevant variables.

k	λ_1	λ_2	λ_3
1.2	1.25	0.52	1.21
1.25	1.30	0.48	1.20
2.04	1.31	0.47	1.19
1.91	1.32	0.48	1.20
2.16	1.32	0.49	1.22
1.35	1.35	0.48	1.21
2.33	1.50	0.49	1.25
2.33	1.52	0.52	1.26
2.37	1.50	0.55	1.25
2.50	1.51	0.58	1.25
2.54	1.55	0.54	1.26
2.46	1.54	0.56	1.27
2.50	1.48	0.55	1.24
2.45	1.69	0.56	1.25
2.53	1.69	0.58	1.29
4.93	1.75	0.58	1.30
2.52	1.76	0.59	1.30
2.63	1.75	0.57	1.30
0.62	1.73	0.60	1.35
2.65	1.71	0.57	1.35
2.60	1.69	0.56	1.36
2.58	1.74	0.55	1.35
2.54	1.77	0.55	1.35
2.66	1.84	0.59	1.38
2.75	1.83	0.62	1.36
2.79	1.92	0.57	1.37
2.63	1.93	0.58	1.35
2.8	1.90	0.60	1.37
2.65	1.89	0.60	1.35
2.68	1.85	0.60	1.33
2.63	1.82	0.64	1.37
2.91	1.98	0.65	1.40
2.83	2.00	0.62	1.41
2.81	2.00	0.62	1.40
2.95	2.08	0.62	1.42
3.25	2.20	0.64	1.48
3.12	2.15	0.66	1.50
3.41	2.30	0.64	1.56
3.3	2.39	0.68	1.75
3.50	2.40	0.68	2.08

Table II. Calculations of the $\lambda_1, \lambda_2, \lambda_3$ and k.

It cannot be said that all of these proporties are equal for all the space sampled; because sophisticated equipment were not used in measuring the physical quantities in the field study. For instance, no equipment were used to measure the level of illumination. But the differences were very little to effect the responses. As the third dimensions "h" of the space in the range of 2.60-2.70 m. does not influence the comfort feelings statistically meaningly, there is not any consequences in limiting these properties.

The interviewers were student of architecture, and they were told about the way to be followed, and in due course the techniques of data collections are discussed in hope of preventing failures.

The method which is based on bilateral relations will be illustrated in an example. The example will be one of the homes surveyed in the field study.

Data no: 26 (Table I and II)

Number of users, N = 4 (The parents and two childen in secondary education)

Number of relations between the users, n = 6

Total area of the equipment or furniture: $\Sigma m_a = 6.35 m^2$

Total area of activities: $\Sigma m_e = 15.20\ m^2$

The first step is to determine the range of values that the user prefer of

. the psychological area coefficient,

. the density of activities,

. the density of furniture,

. the density of the interactions of the users of the space in the form of two-dimensional systems from the graphs shown in Figure II.

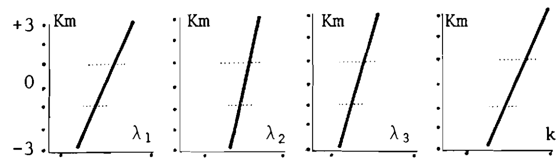

Figure II. Two-dimensional linear relations between subjective response and defined variables $\lambda_1, \lambda_2, \lambda_3$ and k.

As it is shown on the graphs the range of values prefered (as ±1 was taken in the scale of values) are:

for λ_1 the range is 1.63 - 2.00,

for λ_2 the range is 0.55 - 0.62,

for λ_3 the range is 1.25 - 1.48,

for k the range is 2.44 - 3.55.

The second step is to determine the functional area: $\Sigma m_e = 15.20\ m^2$.
as the range for "λ_2" is 0.55 - o.62 and from the equation (1) the range for "m_i" is 8.36 - 9.42 m^2. For the control of the step two, the range for "λ_3" related to the range of "m_i" is calculated by the equation (2), and hence 1.31 - 1.48. This calculated range is enclosed in the range of preference, i.e 1.25 - 1.48 and hence, making no change, all the values of functional area in the calculated range 8.36 - 9.42 m^2 are appropriate. Taking a value in this range, say 9.00 m^2, the calculation goes with step three.

In the step three the total area is to be calculated. For "λ_1" the range is 1.63 - 2.00 and by the equation (3) the range for "m_t" is calculated as 14.67 - 18.00m^2. In the control of step three, the range for "k" is calculated by the equation (4) and for the range of "m_t" calculated above, 2.44 - 3.00 is obtained. As this calculated range is contained in the range of preference, without making any changes, all the values in the range 14.67 - 18.00 m^2 calculated for the total area are appropriate to give comfort in the living rooms in respect of space requirements.

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Community involvement in the identification of housing requirements and community priorities

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English Summary

An appropriate development project within a low income housing research and development programme to effectively accommodate the views, aspirations, preferences and priorities of the community concerned through the direct involvement of its members in the formulation and implementation of the development strategies and projects is described. Salient findings are that a sufficiently wide range of house types and alternatives is necessary, that communities can identify problems, determine priorities and responsibly evolve, formulate and implement solutions which are positive and highly acceptable.

French Summary

On décrit un projet de développement approprié qui comprend une étude de logement à bas revenu et un programme de developpement tout en tenant compte avec efficacité des vues, aspirations, préférences et des priorités de la communauté intéressée par la participation directe de ses membres dans la formulation et l'exécution de stratégies du développement et de projects. Les traits dominants sont qu'une assez large sélection de types de maison et d'alternatives est nécessaire, que les communautés peuvent identifier leurs problèmes, déterminer les priorités et développer avec responsabilité, formuler et executer des solutions qui sont positives at parfaitement acceptables.

Introduction

Development agencies charged with the responsibility of planning and implementing development policies, programmes and projects must have a clear understanding of the meaning of development, specifically in the sense of its relevance and viability. Without such understanding and definition little opportunity exists for those agencies to monitor and evaluate the performance of their respective policies, programmes and projects at any particular point in time.

In the formulation of development goals, the following five considerations or responsibilities should apply to lend meaning and conviction to the fundamental base of the development process:

Legitimacy: Goals and objectives should reflect a legitimate political system endorsed by its elected leaders and representatives and sanctioned by Acts of parliamentary legislation.

Representation: The socio-political structure must be such that all community groups have access to top level decision-makers, through a democratic system.

Accountability: The system and structure of representation should be accountable to the various sectors and sub-groups within the community it represents.

Realism: Development goals and strategies should recognise and reflect the realities of the processes, conditions and characteristics of country, region, metropolitan or local area, as these factors are perceived by the various socio-political organizational structures within the country.

Viability: The development process together with its goals, objectives, policies, programmes and projects must become a reiterative cycle through repeated implementation.

Forms of government

The dominant form of government in Western Europe and America is representational democracy. This form of democracy is characterized by the way in which public authority is divided among legislative, executive and judicial bodies. The legislative body comprises representatives of the people and it is through these people that the wishes, requirements, problems and priorities of the electorate need to be recognized and rationalized within an acceptable development framework. Such a framework should create the appropriate economic climate necessary to sustain a desired level of economic growth together with an improvement in the general quality of life of its peoples. In a representative democracy, political decisions, including development decisions, are in practice not taken by the community but by one or more groups or bodies of elites, subject to periodic checks in the form of elections.

Lobbying

Since the only link between the community and government are the elected representatives of a geopolitical area, local interest groups have evolved within communities where either a threat to a continued way of life was perceived or where a group of local individuals came together to press for an improvement in their way of life. Generally these bodies comprised the more articulate and highly qualified members of a community who were able, by lobbying their local representative, to influence local development action in their favour.

Advocacy planning evolved as a response by committed professionals to the increasing exploitation of the poorer and less articulate urban majority. Lobbying can therefore be seen to constitute a fundamental part of the machinery of representational democracy.

South African context

South Africa is a country which comprises a wide range of different situations and conditions ranging from the highly industrialized urban concentrations to traditional rural communities. Furthermore, South Africa experiences the highest degree of urbanization of any major country in Africa. Currently some 48 per cent of all its peoples are urbanized, a figure likely to increase to 80 per cent by the year 2000. It has been estimated that the total population will increase from some 22 millions in 1970 to 50 millions by the year 2020.

Rapid urbanization inevitably gives rise to larger and more complex communities and their particular organizational structures which experience accelerated social and cultural changes. This is compounded by the fact that South Africa's population constitutes a plural society with different cultures, traditions and social characteristics. Individuals, families and groups of people who were born and reared in relatively small homogeneous and relatively stable communities, generally supporting the same overall goals, usually employing customary means of communication and decision-making, tend to experience varying degrees of alienation in the complex urban milieu. This can contribute towards an increasing feeling of powerlessness, disorientation and frustration leading to an escalation of the tendency to criticise the existing decision-making process, or lack of it, together with the parties and personalities involved. In short, due to the breakdown of conventional channels of communication between citizens and government, the need for a positive and meaningful form of contact becomes particularly urgent for those members of the community who need essential urban services.

Decentralization of decision-making

To facilitate a more equitable form of representative democracy, the NBRI in 1976 made recommendations regarding the devolution of decision-making powers to local communities. Subsequently in 1977 an Act of Parliament was passed to establish the legislative framework to facilitate the decentralization of executive powers previously controlled by Central Government, to local authority level.

A high correlation has been found to exist between the degree to which members of a community are actively involved in problem identification and decision-making and the stability and contentment of that community. In addition, the identification of community preferences and priorities can only be made with the direct involvement of those parties most affected by the decisions to be taken. Consequently all NBRI low income housing research and development projects are undertaken with the direct involvement of the various communities together with their elected representatives in the development process.

On account of the need to satisfy a diversity of individual and group aspirations and preferences, research and development activity has placed particular emphasis on the establishment of a range of opportunities at various scales of relevance to the community within development programmes and projects to encourage the active participation of the individual, family and group in shaping and personalizing their habitat.

Fig. 1 illustrates how an attempt has been made to involve the community more directly in the development process through the establishment of ward development committees and loca' residents' committees. This form of socio-political organizational structure has not been conceived of from a theoretical base, but rather it has evolved from grass roots experience gained by the NBRI in working with existing communities in both formal and informal housing areas in various parts of Southern Africa.

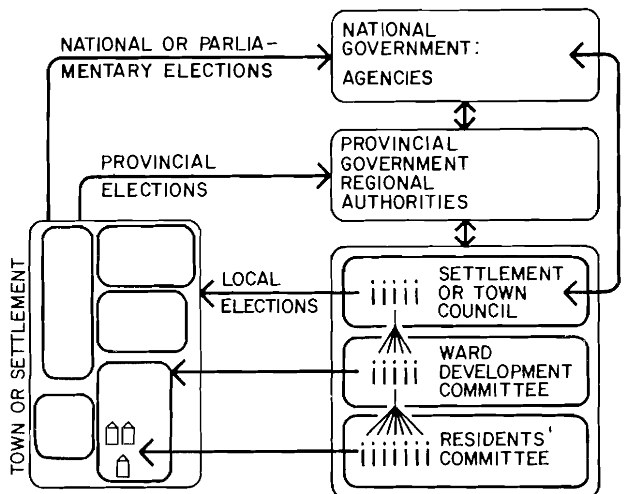

FIGURE I

The community has thus been able to become involved in the identification of problem areas - the quantification of these problems - the formulation of development strategies and the determination of locally perceived priorities. Recommendations have been made to Central Government resulting in both changes and revisions to development policy.

The realization that problems, policies and solutions must be examined through the eyes of those who are affected by them is fundamental to meaningful development activity. Any attempt, however, irrespective of the sincerity, honesty and motivation of those concerned with problem solving is destined to a measure of failure should the problem be poorly identified, understood and defined.

Since 1975 the NBRI has pursued a development with community involvement approach in all its low income housing research and development projects. The following descriptions briefly describe various aspects relating to community development through direct involvement in the development process.

Criteria for participation

Before any meaningful cooperation and collaboration can effectively take place in the field of community development and involvement certain basic criteria need to be satisfied. These are:

- o a socio-political organizational structure should exist within the community;
- o this socio-political organizational structure should be both representative and accountable to the community;
- o it should have a mandate from the community to represent it in the development process;
- o a perceived and felt need for joint effort and collaboration must be experienced by all parties involved;
- o the terms of reference regarding the roles and responsibilities of all parties must be acceptable and understood;
- o all community involvement activities should, wherever possible, be connected or associated with action, and mutual respect, confidence and trust must exist between all parties concerned; this is based upon, inter alia, the credibility of one party in the eyes of another;
- o community involvement must take place in a forum where all issues, concerns and problems relating to housing in urban development can be recognized, debated and resolved.

Contact and communication

The development process can only be successfully undertaken when effective communication and cooperation exists between the residents, their elected leaders, the informal community organizations and the promoters of development activity. It is not always necessary to establish new organizational structures and committees to achieve this cooperation since existing ones could and should become involved with the development process. It is, therefore, essential that a sensitive analysis is made of both the formal and informal networks and channels of communication, local representation and power from within the community together with its linkages to the external organizations, their members and responsibilities.

Problem identification

Each particular community experiences circumstances and difficulties different from the next community and accordingly a slightly different approach is adopted for each community. The NBRI was invited by a Central Government development agency to make recommendations regarding the upgrading and future development of Ngangelizwe, an existing suburb of Umtata. Here it was found that as a result of the high degree of local control exercised by the community, a more comprehensive perspective was held regarding problems in that community. Consequently the project team which included elected representatives from the community, decided to involve the following three main sectors of the community in the problem identification procedures:

- o existing socio-political organizational structure, together with its various ward development committees, sub-committees and interested individuals. This constituted the formal organizational network within the community;
- o informal network comprising community organisations and local interest groups;
- o a random sample of school children from a junior secondary and a senior secondary school in the neighbourhood together with their teachers and a selection of parents and guardians.

Problems, difficulties, frustrations and perceived needs were elicited from these three main groups of people over time. An adequate time scale is a necessary prerequisite if problem identification is to be effectively carried out. Very often however, development constraints tend to reduce this time scale. The need for a community, through its representatives, to contribute and participate in these exercises must be perceived by the community to be in their interests and leading towards action. The act of self-motivation by a particular body or sub-committee is a sensitive subject requiring considerable attention by both development agencies and key figures in the community. A forum for negotiation and collaborative action was established in which a range of different issues and problems were identified and their causal relationships were constructed, debated and refined.

Summary sheets were assembled during the course of these activities to inform the lay community, through the formal organizational structure of the concerns and their implications. This was found to contribute towards the establishment of credibility for the settlement council in the eyes of the community. Prominent citizens and interest groups who expressed a desire to present a particular case or argument in the abovementioned forum were invited to participate in these deliberations.

Student involvement

Further activities centred around the student community from the local higher primary school and the junior secondary school. All pupils together with their teachers participated in an exercise involving cognitive mapping techniques, written descriptions of how, if they were on the settlement council, they would go about improving conditions in the community, and in selected cases, personal discussions to solicit as wide a range of responses to locally perceived conditions. Arising from these activities, a junior settlement council was elected to represent the younger members of the community at settlement council meetings.

Local surveys

During discussions concerning the magnitude of the problems confronting the community, it was decided that more detailed information was required. Each councillor was made responsible for his or her own ward, each comprising approximately 200 sites. Each councillor called a meeting of his or her ward residents and formally elected a ward development committee to assist with the survey. A set of preliminary one-page questionnaires was drawn up, discussed, tested in the community, revised and finalized. Surveys were subsequently carried out with respect to characteristics including household and family size, age, sex, room occupancy, income and occupation, etc.

Simple cartoon-like graphics were prepared and translated into the languages spoken in the community to assist and explain to the people being interviewed the reason why the questions were being asked.

Select committees

Various select committees were appointed under the chairmanship of one or another council member to establish the nature and magnitude of a particular problem already registered in the forum. One such example concerned the local shopkeepers who, as a result of the activities of such a select committee, formed their own local chamber of commerce and conducted their own survey to identify where they could best be assisted.

Constrained by the realities of the existing development programme, the range of concerns and problems articulated by the settlement council were translated into a range of improvement options and classified in terms of what problems could be solved by means of actual physical development and those problems or causal relationships which required changes in policy, planning or legislation.

Priorities

Using these two basic lists of improvement options, the settlement council, acting as individuals, rated their considered priorities as they personally understood them. This exercise was repeated on several occasions over a period of time. During the intervals between each subsequent priority determination exercise, more detailed information relating to the problem statement, improvement options and their implementation was progressively introduced and discussed. Individual and group priorities tended to change as the individuals and parties concerned became more conversant with the various implications and consequences of competing improvement options. During the course of these exercises the lists of improvement options were expanded and reduced as a more refined and clearer perspective of the overall situation was formulated. In response to the priorities finally established by the settlement council in collaboration over time with their sub-committees, local groups and other community leaders, a motivation for development funds was drawn up and duly ratified at a local authority meeting.

Implications

Information relating to the source from which development funds come, the limitations regarding their use, cashflow and management was dealt with so that interested members of the lay community could better understand the problems and constraints within which their elected representatives were working. Each improvement option has a cost implication and this in turn must be related in a meaningful way to the budget available for that particular financial year. Meaning and value was established for the total budget by relating it to a purchasable item, universally available in the settlement, and of fixed and comprehendible value, like a standard basic house, built by the local authority. The selection of this standard house as the common denominator here enabled the community to see the total development budget in terms of housing; moreover it facilitated a comparison (trade-off) to be made between a créche or a school for example and basic houses.

Priority determination and decision-making

It was found that the development budget available was insufficient to purchase and secure all the improvement options ranked in order of preference in the overall upgrading strategy. This, therefore, necessitated a final priority determination exercise, based on the financial budget actually available.

Planning game

The project team, together with members of the settlement council, developed a framework within which contructive and well-informed decision-making could take place. Simply described, this comprised a chart on which all purchasable improvement options were described and illustrated, each with its own particular cost implications, graphically illustrated in terms of standard type houses. The basic mechanics of this approach were similar to those of a parlour game where chips representing money are provided in varying denominations amounting to the total budget available.

The chips prepared for these exercises were designed in such a way as to have their 'value' in terms of basic houses printed on the front face of each chip with the smallest denomination being equivalent to one half a house. The final selection of 'currency' denominations was based upon several trial runs of the planning game using various combinations of denominations. Members of the settlement council then assumed the role of various interest groups, and, according to the corporate list of priorities, together with the problem statement, they played the game through using simple gaming theory techniques. This was undertaken several times, over a period of some weeks with members adopting different roles when a particular interest group or issue was considered to be unrepresented. During the intervals between each session, the council was able to canvass local opinion, once again using their sub-committees and local groups. This procedure of report back is vitally important if selected choices, issues and concerns, and their implications, are to be effectively communicated to various interested sections of the local lay community. The framework provided by the planning game enabled the principle of trade-off to be understood and explored through the decision-making phases of these activities.

After considerable lively and responsibly conducted debate, consensus was reached with regard to a final improvement strategy, within the budget limitations and other recognized constraints. Many examples exist where local ingenuity and responsibility enabled a value engineering approach to be carried out, optimizing on available resources and local conditions. The final strategy, having received the blessing of the community, was duly ratified at a local authority meeting. The strategy was subsequently accepted in its entirety and finally presented to the Central Government development agency where the total strategy was accepted.

Non-physical policy decisions

Those improvement options requiring a change in policy, planning or legislation were subsequently incorporated within a report tabled at both local and central government level. The majority of the recommendations have subsequently been adopted for wider application.

Housing strategy

The need for housing was considered so critical that a sub-strategy was formulated at grass roots level to distribute the financial resources allocated by the council in the most effective manner. A range of housing alternatives was deemed necessary and consequently a balance between fully serviced and completed dwellings and serviced sites was established. The final distribution of serviced sites within the physical planning layout was made by council members.

Local residents' committees

The physical planning layout created the opportunity for groups of families, varying in number from 5 to 20, to take responsibility for the development and management of local pedestrianized forecourts. Groups of houses were planned around a series of communal spaces varying in size and configuration that are themselves connected to local distributor roads.

Local decision-making

Local residents were able, through a homeownership programme, involving both the local authority and a group of employers, to gain access to loans and other forms of assistance. This programme set out to involve the participants in decision-making with respect to choice of house, neighbours, and site, and subsequent improvements both in the house itself and in the communal forecourts over which the local residents, in the form of residents committees, exercised control.

Conclusions

The following benefits in the way of more effective participation in decision-making by elected leaders from local communities with regard to development strategies and action that benefit their respective communities, have emerged as a result of the research and development activities of the NBRI.

- A series of positive methods and development frameworks have been evolved and implemented to identify community needs and priorities more accurately.
- These frameworks have functioned, and continue to function, as an educational experience for both the community, its representatives and the planners who do not necessarily understand the priorities and preferences of the community for whom they are planning.
- Various groups of people in the community, including the elected representatives in the form of the settlement council, gained access to decision-making opportunities relating to matters affecting them. These opportunities coupled with their resultant action have been found to reinforce the credibility of the elected representatives and local leaders of the community, thus promoting stability, respect and contentment in the community.
- An understanding of the technical, organizational, financial and planning aspects relating to the field of development has been gained by the community, enabling more informed problem identification, quantification, solution formulation and decision-making to take place.
- Members of the various socio-political organizational structures have gained a clearer understanding of their own situation coupled with their ability to make constructive and informed decisions. This has led to the establishment of confidence and self realization.
- The administering authority concerned was able to devolve responsibility for decision-making to what is essentially the settlement council, their respective ward development committees and local residents' committees: this enabled the implementation of decisions and actual development to proceed with the backing and commitment of the local community ensuring a healthy 'working with' situation.
- A measure of representational democracy was created, along with an associated level of participatory democracy which encouraged the process of lobbying. This, in turn, established the dynamics of socio-political accountability within the various communities concerned.

Concerning aims and forms of tenant influence. Some preliminary considerations.

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Background

In Sweden tenants of rented dwellings are able to exert an influence on their living conditions at two levels. The individual tenant has obtained through legislation an increasing position of strength in relation to the landlord. This has been strengthened and extended as, by an Act of 1975, tenants have also been given the right to carry out, at their own expense, smaller improvements within the dwelling, without obtaining permission from the landlord.

Tenants also have the right to negotiate about the rent. This occurs by means of negotiations between the landlord and the local tenants' association.[1] In accordance with the rules for negotiations there is also the right, since 1971, of raising general questions about the residential environment.

In addition to these kinds of influence discussions have also been going on in Sweden since the beginning of the 1970's, also in a number of governmental reports, about some kind of collective influence on housing management. A certain amount of organized experimental activity with local tenants' influence has been carried out. Among these was the experiment in Gothenburg from which my examples are obtained. There are also examples of groups in single multi-family houses and in housing areas trying to influence their residential situation through spontaneous action.

In April 1979 the Tenants' National Association and SABO (Swedish Public Utility Housing Enterprises)[2] agreed on a "Recommendation on tenants' residential influence". With this, such an influence has also obtained a formal basis in the established negotiation system of the rented dwelling market. So far there is, however, no documented experience of influence within the framework of the recommendations.

Of latter years the debate has intensified and grown to apply to residential influence in general, in some cases linked to a discussion on decentralization of the municipal decision-making [1].

Other aims than actual management influence have been taken up in the debate as well as other forms of residential influence. The aims of tenant influence will be dealt with later. With regard to the forms tenants' influence should take, increased tenant activities in housing management have been discussed, as also influence on special maintenance funds and a transition to other forms of tenure than tenancy rights [2]. These forms are now in the process of being investigated by governmental committees, the Maintenance Fund Investigation and the Co-ownership Committee.

This paper is confined to the question of tenant influence. The purpose here, against the background of the experience gained from the experiment with tenant influence in Gothenburg, is to discuss the relation between the aims of influence and the organization and method of working with this influence.

The general thesis of the paper is that different types of organization and forms of work for influence can be considered to fulfil different kinds of aims for influence. This is something that, at least in the Swedish debate, has been treated very incompletely.

Concerning aims for tenant influence

The aims set up in different contexts for the introduction of a local collective influence for tenants are of various kinds. How the aims are formulated may be partly influenced by the motives of the initiators for starting an experiment, and partly by the reasons that provide legitimacy for the experiment in the general debate. Motives that lack legitimacy will problably be toned down or completely eliminated in the formulation of aims, whilst more pressure may be expected on aims considered to provide higher legitimacy. In some cases it may even be expected that aims will be advanced in order to provide higher legitimacy.

Furthermore, the paper is limited to experiences gained from tenant influence that have been initiated by others than the occupiers themselves, usually the managing company, as was the case in the experiment studied.

The reasons for initiating an experiment may by sought in the aims of a more general and principle character that the company is considered to have, and also in the problems arising in its own work, which are identified by the company, and to whose solution tenant influence may be expected to make a contribution.

[1] In Sweden about 1/3 of the tenants are organized in Tenant Associations (there are 21 dispered all over the country). They are organized into the Tenants' National Association. The tenant associations have through a special system for negotiations both with the public and private housing companies a strong position as a part in regular rent negotiations.

[2] SABO is a national organization to which most of the larger public housing companies in Sweden belongs. Its main tasks is to give information, to cooperate with other organizations at the national level and to help the member organizations at the rent negotiations.

With regard to the general aims for the type of company involved here, public utility, these can be summed up in the social aims formulated for Swedish housing policy: "the whole population shall be provided with healthy, spacious, well-planned and suitably equipped dwellings of good quality at reasonable costs" [3].

To this overall aim can be linked the following aims for tenants' influence:

- to realize in residence also, the democratic ideals that are sought in politics and working life. This is often expressed as, that democratization of residence is regarded as an aim in itself [4].
- to increase justice in tenure by giving tenants some of the influence that is considered to be present in other kinds of tenure, in co-ownership tenancies and in private home ownership [5].
- in residence to teach people a democratic way of thinking. Here the residential influence is seen as a means of realizing the overall aim of political democracy [6].

Problems identified by the company may be general problems of the residential environment as well as those that occur directly in its own organization. To the former category may be assigned the following [7]:

- segregation; the tendency that different socioeconomic population categories will settle in housing areas with varying degrees of "quality"
- isolation; lack of social contacts
- a lack of "home-feeling" that gives insecurity and anonymity
- a poor physical environment because of a building construction that is mainly too technical.

Among the company's problems the following are often mentioned [8].

- financial losses because of unrented flats, a high degree of wear and tear and even destruction, as the tenants do not "accept responsibility" for the company's property
- rapidly increasing management costs
- increasing conflicts between tenants and management personnel
- an increasing inefficiency in the big management companies
- an increasing criticisim of the public utility companies because of deficiencies in the housing areas, complaints about inefficiency and improper favouritism in the governmental housing policy
- difficulties in obtaining coverage of costs in rent negotiations.

The following aims for tenant influence can be linked to these:

- to reduce management costs. Directly, by the tenants themselves taking a more active part in the work of management, or the acceptance of a lower standard. Indirectly, as the tenants tend to move away (because of not feeling at home and the lack of possibilities of exerting influence) to a lesser degree, and as they decrease their wear and tear and destruction of the property - "take more responsibility".
- to increase the attractiveness of the housing areas by adding a function (a greater chance of influencing the management of the area) whose absence is considered to be a reason for many tenants moving to co-ownership dwellings or their own homes.
- to improve the physical environment by letting the tenants' priorities direct maintenance and possible new investments in the area
- to increase the social togetherness and feeling of home and decrease the social isolation in the area by providing the tenants with a common interest and, in some cases, a chance to work together with others on management tasks. Here also belongs the idea that if the tenants take part actively in decisions and/or the maintenance work itself, they will directly assume a greater responsibility for the environment. In such ways, for example, as through a keener informal social control of the youngsters in the district. Sometimes people even have the conception that in this way it is possible to prevent different types of "social problems", which cause increased wear and tear, less well-being and increased selected moves from the district.
- to create among the tenants a greater understanding of management costs and the organizational problems involved, which should bring about decreased resistance to rent increases and a better working climate for the employers of the company.
- to create conditions for a decentralization of the management organization.

As appears from the above examination, there are many and great expectations involved in tenants' influence. But it is rather seldom all of these aims are stated in one and the same presentation. However, the purpose of this monograph is not to examine the aims but to use them as the basis for a discussion about different forms for tenant influence.

Many of the aims are connected in what may be called "chains of positive expectations". That the tenants themselves may take part and reach decisions on various measures is expected to bring about greater respect for the housing area concerned and so result in less wear and tear and a keener social control, leading in turn to decreased destruction in the area. It is hoped this will bring about lower management costs, a greater understanding for the company's point of view, a better status for the area and other advantages.

In the further presentation attention will be concentrated on two main types of aims into which most of the above could be grouped; technoeconomic aims such as a better physical environment, lower costs and a smoother management, and also social aims such as increased contacts, greater community, less isolation, greater social control and responsibility and fewer social problems.

Initially a brief account is given of how the fulfilment of aims has been regarded in the evaluation of the experiment in Gothenburg.

Evaluation of the Gothenburg experiment

The experimental work started in the spring of 1975 in four physically and socially different housing areas in Gothenburg. The areas contained between 260 and 900 dwellings. The initiators were SABO, AB Göteborgshem (Gothenburg's Homes Ltd.) [x] and the Tenants Association for Western Sweden.

In the experiment it was desired to test a representative influence model. This meant that the managing director of the company concerned delegated the right of decision on a number of management questions to a neighbourhood committee. The neighbourhood committee is elected each year at a neighbourhood meeting to which all the tenants have been invited. The neighbourhood committee consists of 7 ordinary members and 3 deputies. In this committee there are also included, but without voting rights, one representative from the company (the local manager) and one from the tenants' association. The company's trade union organizations also have the right to have a joint observer present at meetings.

The questions over which the neighbourhood committees initially received the right of decision were cleaning, refuse collection and disposal, traffic and parking, playgrounds and external environment as well as leisure time. During the third year of the experiment questions dealing with maintenance were also included in the right of decision.

Few of the aims shown above were expressly set for the Gothenburg experiment. The only definite aim was that the tenants should receive a genuine influence. Therefore in the follow-up study care has been taken to follow the experimental activities and, from a report on these, assess the consequences of the influence on the housing management's results with regard to the social environment and the relations between the company and the tenants.

The conclusions formed on the basis of the evaluation are briefly as follows: "the formal right of decision assigned to the tenants in the experiment did not correspond to any genuine right of decision. Three important conditions are not fulfilled. First lacking is the insight into the company that is required in order to really be able to make decisions; secondly, the area of decision is often covered by agreements with other parties but, above all, by current praxis and routines of management having a continuity that is not easy to disturb; thirdly, the neighbourhood committees have little or no control over the execution of their decisions.

The good effects on management expected from the tenants' participation are greater practicality, as the tenants are "experts" in their own particular housing area; they can give priority to measures in a better way for their area and have greater control over the condition of the area. Certain results of this kind have been obtained in the experiment, usually of an uncontroversial nature.

Further, increased insight is expected to lead to an increased responsibility for dwellings and their environment with a resultant decrease in destruction. To a certain extent this has happened in the housing areas. Similarly the social environment, "well-being" and contacts between people are expected to improve through a greater influence for the tenants. In this respect the results are difficult to interpret. What is obvious is that the leisure time premises opened by the neighbourhood committees have filled a great need, especially for children and young people.

The tenants' influence in management can also be regarded as a means to better relations between the tenants and the company. Whether these are generally improved is difficult to decide. The neighbourhood committees and the local manager, however, obviously constitute a channel for better contacts in both directions. A risk exists, however, that this may be utilized mainly by the company, as the stronger party, to impose on the committee members its way of looking at things.

The conclusions arrived at from the problems and results presented, to put the matter very simply, are that the influence given to the tenants in this experiment has so far not fulfilled the aim of being genuine because it has been given on the company's and not on the tenants' conditions [9].

Some further observations from the Gothenburg experiment

Towards the end of the three-year follow-up and during the two years that have passed since then a development has taken place that was only mentioned in passing in the final report, mainly in some of the housing areas. But this development forms the basis of the ideas advanced in this paper.

The development, called "professionalization" in the report, of the neighbourhood councils finds its expression essentially in the fact that in the experimental areas where the possibilities exist, more people with economics or technology, especially building technology, as their professions are elected to the neighbourhood committees. One sign of this may be that the women tend to be underrepresented and receive a more subsidiary role in the internal work.

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x AB Göteborgshem is one of the largest public housing companies in Sweden and manages about 40 000 dwellings.

Professionalization also leads to increased differences between the neighbourhood committees in their ways of functioning in the four socioeconomically different, experimental areas. In one area especially where many live with occupations of the kind mentioned, there was an increased tendency to try to grasp the financial and technical conditions of housing management. This occurred - especially in this area - at the cost of contact activities directed at other tenants, with the result that a stratification took place in the neighbourhood committee. A few "experts" handled the contacts with the company in the area of finance and technical matters. To an increased degree there was a direct approach to the company's financial experts instead of using the channels, via the local official, etablished in the experimental activities. In the same area they have also succeeded in obtaining a special agreement with the company which, if the expectations are realized, will give the area, and in the end also the tenants, financial advantages.

Financially and perhaps also technically the change in direction may thus bring positive results for the tenants. Services may be both better and cheaper. *

But this development is accompanied by risks. Some of these will be given here hypothetically.

As the organizing of the tenants is initially weak and the tenants are socially and economically heterogeneous, the formation of a small "elite" stratum and its increasing cooperation with the company's officials, in a way that is impenetrable for other tenants, may cause the legitimacy of this "elite" group to act in the tenants' name to be questioned. Without a more intimate knowledge of the habits and preferences of the ordinary tenant the actions of the professionals may conflict with many of the other tenants' ideas and thus increase the conflict about legitimacy. The formal organization in the experiment hardly provided any guarantees that the tenants' representatives should be regarded as legitimate. It certainly provided the tenants' majority with a possibility of dismissing a committee that they considered was not serving their purpose. But at that stage, however, the whole experiment would have been in a bad way and its prestige difficult to repair.

The professional comradeship between the tenants' representatives and the company's officials may remove some of the innovative force that may lie in the situation that completely new categories get the chance of influencing management's terms and performance, for example women and manual workers.

A lesser concentration on measures that in the long-term may have a strengthening influence on the tenants' degree of organization and community, such as contact activities, leisuretime activities and own maintenance work, could reinforce the formation of an elite in the neighbourhood committees and also decrease the chances of achieving social aims through the activities. These aims are constructed on the idea that the influence is a means of obtaining more contacts, a greater community and, based on this, a positive informal social control.

An efficient job of decreasing costs for the tenants and improving the technical solutions in housing may certainly create faith in the neighbourhood committee that decreases the risks of a development such as is outlined above. Especially if the tenants are homogeneous and thus have similar interests in relation to the housing company. But on the other hand it must be remembered that the latitude for negotiation of the tenants' representatives, and even for the company, is so restricted that necessary compromise solutions may easily be regarded as disadvantageous by tenants who have no insight into the conditions of the decision-making. Compare for example the tenants' associations' constant acceptance of rent increases, which all the time undermines the tenants' faith in the associations.

The tenants' influence on housing management can hardly of itself create social contacts and community. Nor can the common work of a limited group in the neighbourhood committee influence processes in the whole district.

As an increased acceptance of responsibility and the associated decrease in wear and tear and in consumption of running water and energy is expected to arise from an increased sense of participation in decision-making and management work, these effects also run the risk of non-appearance if the tenants think that a small "elite" make the decisions in consultation with the company but without the insight and control of the tenants generally.

As to penetrate the technical and economic rules of the company's activities is a task requiring expert knowledge, those tenants who lack this knowledge easily fall outside the central work of the committee. There are tendencies, for example, for the active women to be assigned to occupying themselves with recreation questions, which at the same time are turned into secondary questions in the neighbourhood committee's work. The central knowledge for activities thus gravitates to a small number of committee members who will have difficulty in passing on the details of the technically advanced knowledge. If these people leave without being replaced by new "experts" there will be a break in the continuity of the committee's work. There is then a great possibility that activities will cease completely.

The risks that people of this kind leave are also quite large. The method of working is demanding, the alternative competing occupations - not least in their own jobs - are many: they are busy men. The rewards, both individually and collectively, are rather modest as the margins for changes at this level and within the framwork

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* As the follow-up was completed before these tenden cies made themselves felt, there is no detailed information about the continued course of events.

of the experiment are small. Nor does the method of working provide the social rewards that contact work, leisure-time activities and such things can give. They also, in the areas of tenant housing, represent an economically comparatively prosperous category who are very likely to move to their own homes.

If in an area with favourable potentials success is obtained in making the local management more efficient without breaking up the social community or creating conflicts between different tenant categories, risks arise at another level. Problems of fairness arise in relation to other housing areas with lesser potential among the inhabitants for such a method of working. Are the company's officials able to deal with, or even interested in, providing the distributive balance of resources required for different areas, with varying degrees of efficiency, at the same time as they give the local influence a reasonable amount of latitude? Will not the housing areas where there are experts who negotiate for the tenants be able to obtain advantages from the management organizations? If this is the case, housing areas that are already favoured in many ways will, by means of tenants' influence, obtain further advantages at the cost of those less favoured.

How has this development come about?

Many investigations on joint-influence experiments in Sweden show that right from the start the active people, in the equivalent of neighbourhood committees, represent an elite stratum in the society; young, well-educated, and often men with middle-class backgrounds. This tendency was not so marked in the experiment discussed earlier. The bias in recruitment discovered in the neighbourhood committees applied mostly to age; most were between 25 and 44 years old, and family types; most represented families with children. The development towards fewer women and more people with higher technical or economic education in the committees first occurred after some years of activities and was more noticeable in the areas where there were more inhabitants with such occupations. The impression was also obtained that the development was spontaneous in the sense that the tenants themselves, through the actions of the neighbourhood committees, the election committees and those attending the annual general meetings, forced this development.

Nevertheless, it is regarded as a result of the relationship to the company that such a development took place. To a certain extent this may have been due to the fact that, on the part of those responsible for the experiment, no attempt was made to formulate any social aims for the activities. Although a majority of the originally active tenants themselves expressed such ambitions, there were no experimental conditions that provided any motive force in this direction. The activities themselves in the experiment, to absorb technical and finansial information, to discuss problems and make decisions, are probably only attractive for people with experience of and interest for desk activities or intellectual work and without a demand for direct concrete results. It is also possible that non-professionals have difficulties, to interpret and act on the basis of technical information of the kind that was usual during the experiment. Very few people however, refused the task of working in the neighbourhood committees on such grounds.

An even greater effect may have been caused by the successive expansion of the areas of decision; from influence over certain simpler operational problems to problems of maintenance of greater technical complexity and greater financial consequences. It was during the fourth year of the experiment when maintenance questions seriously dominated the committees' work that the changes in recruitment to the committees became obvious.

The main hypothesis suggested here, however, is that the difficulties in obtaining insight into the company's actions and influencing them compelled the tenants to utilize the professional knowledge that was available in their own ranks. There has been an attempt to face the company's experts with equivalent expertize from the committees. This may be interpreted to mean that the tenants in their neigbourhood-council work were unsuccessful in formulating general principles and directives for the work of management. It may also be thought that the directives formulated by the committee have been unable to penetrate throughout the management apparatus. There is no doubt a great deal to be said for the validity of both interpretations.

Basic for the tenants' actions in this question has been their old established mistrust of the company's officials. The problem is whether this mistrust will be transferred to their own representatives. Whether this happens or not depends of course on how the committees in their continnued work succeed in influencing the management and how they succeed in establishing themselves among the tenants in the respective areas. These questions can only be answered by a renewed follow-up study after a further period of activities in the areas.

Consequences for a continued development towards tenant influence

Greater importance must be given to discussions on aims when experiments on tenants' influence are initiated. Also, the aims must be better clarified to the tenants and brought home to the company's employees. In conjunction with this conflicts about aims must also be observed and handled with.

The risks of conflict between technoeconimic efficiency aims and social aims must also be observed and dealt with. Perhaps one or the other must be given priority.

The primary condition must of course be that there is considerable scope for influence on management descisions. In some areas, as for exampletaxation, service fees of different kinds from this local authorities and working conditions (including saleries) there are very few possibilities of a local group of tenants influencing the outcome at the company level.

In the beginning of an experiment the tenants also must be given a better explanation of what chances they will have of exerting influence and within which frames they will have to work. The same information must also be given to the company's employees, who must be ready to accept changes; otherwise the possibilities of exerting an influence will be limited, consciously or unconsciously.

Risks of conflict between different housing areas must be dealt with and organizational procedures for dealing with them must be created.

The organizational arrangements must be adapted to the aims. The suitability of various organizational forms must be investigated. The kind of representation selected in Gothenburg is problably better when the aim of efficiency is high. A more decentralized and direct democratic form is problably better for promoting the social aims. But it must also be noted that it is hardly possible to realize the social aims without also providing at least some measurement of efficiency with regard to the effects of the influence on the management. If the social effects are the sole or completely dominating aim then the probability is that other and more directly social kinds of activities are more likely to produce the desired result than influence on management. But then we leave the area of tenant influence.

If the efficiency goal is given high priority the tenants must have a greater insight into the company's day-to-day running and long-term activities, better information and grounds for decision that are suited to their competence.

Greater attention should also be devoted to other things than direct budgetary work and reaching decisions about management problems. Activities to bring contacts between people into being as well as the common use of recreation time may be types of activities that will strengthen the social organization and increase commity in the area. Personal engagement in the housing management may also be valuable. This provides knowledge about such management, greater possibilities of bringing influence to bear and also social contacts. Conditional for this is that the personal contribution is designed according to the tenants' conditions and not those of the housing company.

But the main thing of course is to initiate tenants' influence in more housing areas.

What is essential for the research is to utilize the experiences gained in the experimental work still being carried on. It is also necessary by means of analysis and discussion to penetrate more deeply into problems of the kind touched on here. This should also include a more critical analysis of the aims of, and the forms for, tenants' influence from the tenants' perspective.

Notes

1. See for example Hallberg-Högberg, Anna-Lena: Områdesförvaltning för de boendes skull (Area-maintenance for the sake of the residents) Statens råd för byggnadsforskning, Rapport T19:1978 and Ricknell, Lars: Boendeorganisation och boendeförvaltning (Resident organization and area-maintenance) Mimeographed, Umeå 1979.
2. In Janson, Patrik et al: Ägarlägenheter i flerbostadshus (Owned flats in multi-family houses) Bulletin from the National Swedish Institute for Building Research M79:15, arguments for and against making rented flats into owned flats are examined.
3. Parliamentary bill 1974:150, p 343.
4. See for example SOU 1975:51 (Swedish official investigations) p 261, Hallberg-Högberg, Anna-Lena op cit, p 43, and Hjärne, Lars et al, Hyresgästinflytande - på vems villkor? (Tenant influence - on whose conditions?) Byggforskningen, Rapport R115:1979, p 191.
5. Parliamentary bill 1975:150, pp 351 - 52 and Hallberg-Högberg, Anna-Lena, op cit, p 43.
6. SOU 1975:51, p 262.
7. Hallberg-Högberg, Anna-Lena, op cit, p 12.
8. See for example Hallberg-Högberg, Anna-Lena, op cit, Juvén, Kent: Kostnadsutveckling och behovet av rationella metoder (The evolution of costs and the need for rational methods) in Förvaltning i focus (Maintenance in the focus), Statens råd för byggnadsforskning T32:1976 and Gärdborg, Ingemar et al: Bostadsförvaltningens utvecklingsproblem (Developmental problems of housing administration) Mimeographed Stockholm 1976.
9. Hjärne, Lars et al, pp 12 - 13.
10. Hjärne, Lars et al, - 158.

Summary

A discussion has been in progress in Sweden for many years about increasing tenants' influence to include the possibilities of influencing the local housing management.

A number of experiments have been carried out. Some conclusions are drawn from one experiemnt concerning the relation between the aims of activities and the forms these activities shall take.

Among the aims expressed in various contexts for tenants' influence two main types can be discussed. One that holds with a technoeconomic improvement of the housing management, and the other that expresses social ambitions - to improve personal contacts, to break down isolation and to create community. These two kinds of aims, that in themselves do not exclude each other, can best be satisfied it seems through different forms of infulence.

The monograph shows how in the actual experimental activities, under certain conditions, there is a move towards an increased technoeconomic bias. Even though this may carry with it advantages for the tenants the development implies certain risks, and these are discussed. Activities become vulnerable. A gap is easily created between the active groups and the other tenants. It is difficult to interest many of the tenants in more profound technical and economical discussions.

The conclusions with regard to the continued development of tenants' influence is that both aims and forms of this influence must be discussed more closely by the parties concerned. Differences of opinion and interest must be observed at an earlier stage. Activities must alos include elements to create better personal contacts between the tenants. Finally, the influence must be genuine and proceed from the tenants' conditions.

Resumé

Il se poursuit en Suède, depuis quelques années, un débat portant sur l'extension de l'influence des locataires au niveau même de l'administration locale du logement.

On a pu tirer de l'un des travaux d'essai réalisés, des conclusions concernant les rapports entre les buts de cette influence et sa forme.

Parmi les buts exprimés à plusieurs occasions, on peut distinguer 2 grands types.

Le premiier visant l'amélioration technique et économique de l'administration du logement.

Le second portant des aspirations sociales; amélioration des contacts entre locataires, rupture de l'isolement et création d'une vie commune.

Ces 2 types d'objectifs qui, au fond ne s'excluent pas, sont jugés réalisables à travers l'élaboration de différentes formes séparées d'influence.

Dans cette feuille est montré comment le travail d'essai en réalité sous certaines conditions, est canalisé sur une voie de plus en plus économique et technique. Bien que cela entraîne des avantages pour les habitants, une telle évolution comporte des risques développés dans cet essai. Une influence pareille devient vulnérable.

Il se peut qu'un écart se creuse entre le groupe actif et les autres locataires. En outre, il est difficile d'engager dans une telle activité tous les gens concernes.

La conclusion à tirer de l'évolution continue de l'influence des locataires est qu'il faut que les moyens, aussi bien que les buts de cette influence, soient plus profondément discutés par les parties intéressées. Les conflits doivent être decelés tôt. On doit insérer dans le programme des activités créatrices de contacts. Bref, l'influence doit être concrète. Elle doit naître des conditions dans lesquelles vivent les locataires eux-mêmes.

Social and Economic significance of Housing in Developing Countries

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Summary

The concept of housing in developing countries from one of the providing shelter to extended concept of covering housing services and improved environmental facilities is gaining ground. In the background of the vicious circle of massive poverty, high population density accompanied by high rate of increase, rapid urbanisation and scarcity of resources, the deteriorating housing and environmental conditions in developing countries have been briefly described in the paper.

The need to improve housing and environmental conditions is increasingly being realised in developing countries in recent years. The new awareness which is also growing as regards the role of housing in terms of its contribution to economic growth, income and employment generation, increased capital formation, has been emphasised.

Besides fulfilling one of the primary needs of shelter for the families, the social impact of housing and its contribution to social justice, motivation for social integration and improvement of living conditions for the coming generations have been brought out in the paper.

The vital role of housing in socio-economic progress in developing countries and the need for a multi-disciplinary approach have been stressed. The work done by National Buildings Organisation (which is also functioning as U.N. Regional Housing Centre for ESCAP) in the field of economic and social aspects of housing for evolving more purposive housing policies and programmes and for highlighting the contribution of housing to the national economies and social welfare, has been briefly mentioned. Some basic socio-economic issues pertaining to housing have been discussed in the paper.

Housing - A matter of national concern

Housing has emerged as one of the complex problems of public concern in recent years in developing countries. Caught in the vicious circle of (a) rapid growth of population increase (b) rapid growth of urbanization (c) comparative low rate of development in rural areas (d) low income and consquently low savings and capital formation resulting in low rate of housing construction etc. the housing conditions in majority of the developing countries are deteriorating. The resultant outcome of these forces is the massive housing shortage in the developing countries both in rural and urban areas. Only in Asia, the developing countries are expected to experience housing shortage of the order of 30.34 million dwelling units, 14.06 million units in urban areas and 16.28 million units in rural areas during 1980 -85 (1). It is not only the housing shortage which is a matter of public concern in developing countries but the more significant and different from the western World is the appalling conditions of the weaker sections of community in the developing countries than the overall all problem of housing shortages.

1.1 Rapid Growth of Population

The developing countries account for more than 2/3rd of the world population. The growth of population in developing countries is of higher magnitude, ranging between 2.2 to 3.5 per cent per year as against below 1.0 per cent in majority of the developed countries (U.S.A., U.K., France, Denmark, Sweden, Poland etc). The annual rate of increase based on 1970 - 76 population was more than 3.0 per cent per year in developing countries like Algeria (3.2), Ghana (3.0), Kenya (3.6), Uganda (3.3), Jordan (3.2), Libanon (3.1), Saudi Arabia (3.0), Syria (3.3), Pakistan (3.0), India (2.21) etc. In aggregate terms the high instance in population could be gauged by the fact that in India the population has increased from 460 million in 1961 to 540 million in 1971 which is expected to go up to 700 million by 1981.

1.2 Faster rate of Urbanisation

The pace of urbanisation in developing countries during the last two decades has been faster due to the process of industrialisation and the movement of a large number of rural migrants to urban areas in search of employment. The proportion of urban population to total population in less developed regions was 8 per cent in 1920, it rose to 10 per cent in 1930, 12 per cent in 1940, 16 per cent in 1950, 21 per cent in 1960 and 25 per cent in 1970. It is expected that this percentage will go up to 42 per cent in 2000 A.D.

1.3 Creation of Slums

The rapid growth of urbanisation has resulted in haphazard, unplanned an uncordinated development of urban centres resulting in creation of slums in course of time. The influx from villages to the cities is so enormous that any amount of new housing would be inadequate to meet the ever-increasing demand for more accommodation in most of the industrial cities. The situation has led to sub-letting and over-crowding of houses. Through the four-fold process of natural growth (birth and death), in-migration, disrepair of old structures, and disintegration of joint families,

(1) Survey of Rural Housing & Related Community Facilities in Developing Countries of the ESCAP Region - 1976.

the slums are coming up in urban centres and multiplying every year at a very fast rate. 20 to 30 per cent of the population in urban centres reside either in slums or sub-standard houses. In the year 1970, the population in slums and squatter settlements as percentage of total urban population in the country was 30 per cent in Ghana, 57 per cent in Morocco, 35 per cent in Afghanistan, 42 per cent in Bangladesh, 43 per cent in Sri Lanka and 20 - 25 per cent in India.

1.4 Deterioration Living Conditions

Housing and environmental conditions are also inadequate and inhygienic in developing countries. Overcrowding is found in almost all the big cities. Basic amenities like drinking water, drainage, paved road, lavatories, electricity and community facilities are not adequately available. The condition of a considerable proportion of structures in old cities are not congenial to health. In rural areas also, the provision of essential services and community facilities are lagging far behind the requirements.

1.5 Low rate of Dwelling Construction

The rates of dwelling construction vary from approximately two to five dwellings per 1000 inhabitants in less developed regions to approximately eight dwellings per 1000 inhabitants in European Countries (2). A housing programme producing 8 - 10 dwellings per 1000 inhabitants per annum is required for Africa, Asia and Latin America on the basis of United nations estimate in view of the data available for the period 1960 - 75 (3). None of the developing countries in Africa, Latin America and Asia (except Kuwait, Mongolia and Singapore) succeeded in building more than eight dwellings per 1000 population per annum. Dwellings completed per 1000 population in the year 1970 in some of the developing countries in the table-1 indicate that the production of dwellings is very much inadequate in relation to the growth of population.

2. Need of a suitable Housing Policy

Developing countries are becoming increasingly aware of the need to improve housing and environmental conditions. Social housing programmes for the low income groups, schemes for slum improvement and clearance, and projects for improvement in rural housing have been taken-up in many developing countries. The institutional base is being provided for promoting house building activities by creating institutions for mobilizing finances and providing loans at reasonable rates, Housing Boards & Developmental Authorities, Co-operating Housing Societies, and Building Materials' Corporations etc. Infrastructure facilities for housing development are being augmented and environmental improvement programmes are being undertaken both in urban and rural areas. In order to tackle the multifacet aspects involved in improvement of housing condition more purposive housing policies are being evolved on the basis of technological as well as social & economic considerations.

3. Significance of Housing in National Economy

The significance of housing in developing economies is being appreciated to a greater extent. Some of the basic macro-economic or performance variables in judging the significancs of housing in general are:

(I) Share of housing in the national income;
(II) Share of housing in Gross Fixed Capital formation;
(III) Employment potential;
(IV) Input-output ratios and inter-industry linkages.

Status and the role of the housing sector in the context of the developing countries, may by discussed in relation to these performance variables.

3.1 Share of housing in national income

The National Accounts Statistics of the developing countries reveal that the share of housing in national income varies between 2 to 10 per cent. The contribution of housing to the national income in the seventies of the century was between 6 to 8 percent in Puerto-Rico, Cypros, Greece, Japan, Italy, Switzerland, Malta, Finland etc., whereas in W. Germany, Netherlands, Sweeden, India etc., it was below 6 percent (table-2). It may however, be mentioned here that the share of housing in national income in some of the developing countries, having high population density is still below 2 per cent; such countries in Asia are Bangladesh and Pakistan.

3.2 Share of Housing in Gross Fixed Capital Formation

The U.N. Year Book of National Accounts does not provide data on the contribution of housing to the gross fixed capital formation. However, it provides data on the share of construction to the gross fixed capital formation. An idea about the housing contribution to the fixed capital formation can however, be had from the fact that the construction sector which generally envelops about 1/2 to 2/3rd of the total fixed capital stock or investment (as per table-3) in developing countries, buildings-residential and non residential would account for nearly two or three parts of the investment. Even out of this, a sizeable portion, it will be noticed, is comprised of residential buildings.

The National Accounts Statistics of India for the period 1960 - 61 to 1976 - 77 (4) however, reveal that

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(2) World Housing Survey, 1974, United Nations

(3) World Housing Conditions and Estimate Housing Requirements, United Nations.

(4) Handbook of Housing Statistics (India) - 1979 Table 1.4, P.7.

the share of housing in the gross capital formation ranges between 10.3 per cent to 14 per cent. Similar situation may also be assumed for many other developing countries having economic base identical to India.

3.3 Employment Potential

In terms of employment the construction/housing sector accounts for a good proportion of working force. In advanced countries, such as U.S.A., U.K., W. Germany, France, Canada, Italy and Japan, the proportion of workers engaged in construction industry to the total workers employed is relatively higher (around 6 to 12 per cent) as compared with the developing countries like Nepal, India, Pakistan, Ceylon, Indonesia, U.A.R. etc., where it is very low (around 2 per cent or less) (5).

Housing industry is particularly important in the contect of employment generation mainly because it tends to be a labour intensive activity and can provide larger employment per unit of expenditure as compared with many other sectors of the economy of the developing countries, where there is abundance of unemployed unskilled workers. As per the estimates prepared by NBO a building project of value Rs. 10 million provides employment of the order of 1432 man-years. The housing industry can thus serve as an interim solution for the problem of unemployment in the developing countries.

3.4 Input-Output ratios and Inter-industry Linkages

The N.B.O. study on "Economics of Housing" (6) has revealed that among the twenty sectors of the indian economy, construction ranks third in terms of the sectoral contribution to the gross output as well as final demand in the economy as a whole, agriculture and other services being the only two sectors ranking higher than construction.

The construction sector has fairly strong direct backward linkages in the developing countries. In India this sector ranks 4th as to backward linkages, it ranks 10th with regard to forward linkages with other sectors of the economy. This clearly indicates that the total requirement and housing/construction sector's output for supporting an overall expansion of the economy is significantly high especially in terms of its inter-industry use. The study also points out that the sectors which receive higher degree of growth stimulus on account of increased investment in housing are mining, wood and wood products, non-metallic minerals, basic metals and metal products, electrical machinery, chemicals, electricity, other transport, and other services.

This position clearly suggests that housing should receive a high priority in the allocation of scarce material resources in developing countries because, through its backward and forward linkages with the rest of the economy, it would be instrumental in stimulating and accelerating the pace of economic growth.

4. Social-Welfare Approach to Housing

4.1 Welfare aspect of housing

Improvement in housing conditions in developing contries is a matter of abiding value for raising the standard of living of masses. In slum and squatter settlements the living conditions are apalling which are responsible for many social evils. A home however, modest it may be is the primary need of the family for leading a social life. Improved housing and environmental conditions contribute to human dignity and civilised way of life. Over-crowding and lack of privacy, not only greatly hinder personal development but also create social maladjustments. Public housing is therefore, guided by a scale of social priorities, the policies being to provide houses to those groups of the population which are unable to own even rent housing of a minimum acceptable standard. The rationale of public housing is, thus, to direct and regulate resource allocation to housing in such a manner that economic criteria are tempered by social criteria in the matter of investment, production and distribution of houses. In other words, a welfare approach to housing would bring to bear greater consideration to the demands of social justice in the operation of public housing schemes whose social benefits far outweigh the conomic returns on housing investment.

4.2 Social benefits from Public Housing

The private value of housing services to individuals may be less than their value to society. The exact nature of this confliction relationship between private and social value takes a number of forms. It is the traded off inherent in such relationship that has promoted public intervention in housing to the economically weaker sections and other low-income groups in many developing countries such as Tanzania, Indonesia, Phillippines, Kenya, India, Sri Lanka, etc.

Research studies into the socio-economic impact of subsidised housing in India and abroad have brought out that improved subsidised housing generates a stream of social and personal benefits which are far in excess of those resulting from the kind of housing provided by the uncontrolled operation of market forces. The stream of benefits from better housing are:

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(5) Year Book Labour Statistics 1977 I.L.O. Geneva.

(6) Economics of Housing: A study conducted by NBO-1979.

(I) improvement in the standards of living and health of the individuals.

(II) upgradation of the environment and reduction of blight, making for improved social cohesion,

(III) increased capacity or desire to work resulting in higher productivity in the form of increased output per person per annum and lower absenteeism and

(IV) stronger incentive to save more and an increase in household savings.

4.3 Improvement of Social and Economic Status of Rural and Urban poors through Public Housing

Housing policies of the developing countries have been specifically oriented to meet the housing needs of the rural as well as the urban poor as a matter of primary social justice. In countries like India, Pakistan and Kenya etc. the rural housing needs are being taken care of under comprehensively planned programme of minimum needs in terms of which the poorer sections of the rural population are being given housesites either free of cost or at very nominal cost, besides being financially assisted by loans and/or subsidies to put up dwellings of minimum acceptable standards. In addition to taking care of the shelter needs of the population, programmes also emphasised provision of essential community facilities to improve the housing environment in rural areas.

In the field of urban housing, the developing countries, particularly countries like India, Tanzania, Phillipines, Kenya, Pakistan etc. have undertaken a number of social housing schemes to provide houses to the economically weaker sections and to upgrade the quality of housing in the slums and squatter colonies in the metropolitan and industrial towns. To encourage mass construction of low cost dwellings for the benefit of the urban poor and other low income categories. State policy is being directed to the socialization of the land in cities and towns which have come under acute housing stress, by legislating for a ceiling on urban land holdings. The policy is also being directed to encourage private developers to undertake housing construction for the economically weaker sections through the incentive of land being assigned to them for the purpose and other appropriate fiscal and monetary incentives being given to them. In regard to the slum housing, there has been a conscious shift in policy from eradicating slums to the aggregation of slums under a programme of providing suitable construction subsidies to enable slum dwellers to have a house within their paying capacity. Metropolitan housing authorities in most countries like the Municipal Corporations, Housing Boards, Housing Authorities etc. have also undertaken large scale rental housing schemes for the benefit of low paid industrial workers and slum dwellers in employment under subsidized rentals. Some of the local housing authorities are also building low cost tenements for being allotted to low income households through a scheme of hire-purchase under which the cost of the house is recovered in reasonably small monthly instalments spread over a long period of 18 to 20 years. Given the fact that bulk of the urban as well as rural poor have very low incomes from out of which they are unable to save and pay for a house, liberal public subsidies are a characteristic feature of social housing schemes in all the developing countries. Public housing specifically directed to the needs of the poor has been instrumental in all these countries inducing the low income households to own a house which left to themselves could not have afforded cost of the high initial capital cost involved in housing construction. Investment in public housing has, therefore, been able to generate a stream of social benefits which while helping the society at large has helped individual households in improving their economic and social status.

5. Work done by the National Building Organisation & the U.N. Regional Centre for ESCAP, New Delhi in the socio-economic field of housing.

5.1 Research in Socio-Economic Aspects

Considering the significance of social and economic aspects of housing, in some developing countries research studies, surveys and assessment of prevailing conditions in this regard are being taken up as a new field of activity. The National Building Organisation which is also functioning as the U.N. Regional Housing Centre of ESCAP has started giving attention to social and economic aspects of housing and building from its inception in 1954. Based on the data obtained it aims to promote appropriate housing policies and programmes as well as appropriate technologies in the context of socio-economic conditons prevailing in developing countries.

5.2 Studies/Surveys

Some 40 socio-economic research studies and surveys have been completed by N.B.O. to bring out (I) economic significance of housing; (II) level of investment in housing; (III) administrative and legal measures required to promote housing, (IV) consumer preferences and reactions; (V) shelter needs of slums and squatter settlements; (VI) role of public housing; (VII) employment potential of housing industry etc. These studies have been found to be of great value in formulating more purposive housing policies and programmes, particularly those relating to (I) deciding priority for housing; (II) giving tax reliefs to low cost housing; (III) subsidy for different income groups; (IV) mobilisation of resources for housing; (V) re-orientation of land policy in urban areas, and (VI) planning and designing of residential flats.

5.3 Data Bank on Housing

Recognising the need for a multi-disciplinary approach, the N.B.O. has evolved broad schemes for developing housing and building statistics at the national level, to fulfil the requirements of researchers, planners, policy makers etc. These statistical schemes, implemented throughout the country involve a wide net work of central, state and public sector agencies and provide valuable data on (I) housing conditions; (II) additions to the housing stock; (IV) housing construction by public & private sectors; (V) prices of building materials, wages of building labour; (VI) employment, (VII) investment and financing patterns etc.

Important statistical in the field of housing are included in the publications, brought out regularly by the U.N.R.H.C. New Delhi. These are (I) Handbook on Housing Statistics; (II) Prominant Facts on Housing in India; (III) Bulletin on Prices of Building materials, wages of Building Labour; and (IV) Current Housing and Building Statistics (for public and private sectors).

5.4 Seminars/Symposia and Training courses

The N.B.O., in its capacity as the national coordinating agency and also as an U.N. Regional Housing Centre of ESCAP has developed expertise and consultancy service, in the socio-economic fields of housing, which has been made use of many developing countries in Asia and Africa. This is evident from the contributions made by N.B.O. Officers, either as Experts/Consultants, or participants in international meetings, seminars and conferences besides their work in the U.N. and related agencies.

6. Basic issues for consideration

Some of the basic issues related to social and economic aspects of housing in developing countries, which need to be tackled by national and international agencies are the following:

6.1 Housing for the masses

The need and requirement of undertaking massive programmes of housing are to be identified in rural and urban areas of the developing countries keeping in view the scarcity of buidling resources, huge backlog of house shortages and the growing population. It needs to be stressed here that what is actually required is not the mass housnig but houses for the masses - the urban and rural poor, whose paying capacities are limited owing to the inequitable distribution of income, in the developing countries.

6.2 Housing standards

Evolving appropriate standars for human settlements has been dictated by the exigency of situation related to physical needs for space and amenities based on climatic conditions, health requirements, size of family and way of living on the one hand, and constraints due to economic, demographic and planning considerations, on the other. The standards to be realistic have to be related to the general level of development in the country and have to be progressively improved specially in terms of having healthful homes, essential services for improving sanitation and hygienic living, community facilities for social development and public utilities for economic betterment.

6.3 Mobilization of Resources

It is evident that the key to the problem of housing finance is to mobilise, to the maximum extent possible, the resources of masses, so that the investible surpluses or savings may be diverted to housing. This can be achieved by creating a suitable "environment" in the developing countries. The environment may be created by providing a net work of housing finance institutions, such as Housing Finance corporations, Housing Co-operatives, Industrial Labour Housing, Saving Banks, Mortgage Banks etc. In other words, the Govts. cannot hope to solve this ecomplex problem by its own effort but has to set in motion a system of multiple - incentives both in public and private sectores, conducive to the growth of housing finance.

6.4. High priority to housing in developmental plans

In the developing countries there is a chronic shortage of capital or investible resources. In addition, investment in housing has to compete with other fields in investment which are more renumerative and hence more attractive. In this competition housing gets low priority. Considering therefore, the socio-economic significance of housing, while formulationg a national resource allocation policy, based on the objective of maximising the growth impulses of investment expenditure and thereby inducing a higher growth rate, a high priority should be accorded to investment in housing in both public and private sectors.

6.5 Priority to Rural Housing and role of the Co-Operatives

The Govts. of developing countries have so far laid more emphasis to the problem of urban housing than the rural housing. The task of improvement of rural housing and environmental conditions require enormous financial resources. However, motivation self help, community participation and public cooperation can ease a problem to certain extent. Rural housing co-operatives if formed in the developing countries can play a role in the integrated rural development by mobilising savings and channelising community action not only for the construction of houses but also for the provision and management of community facilities. This is being undertaken advantage of income of the developing countries like India, Pakistan, Malaysia, Thailand, Sri Lanka etc.

6.6 Reduction in cost through Appropriate technology

Steep rise in construction costs linked with the general inflationary tendencies in the developing countries has become one of the vital issues in the field of housing. This induces research in the field of planning, design and construction of buildings and houses, production of building materials, management and execution of construction projects etc. As a result of research work done in some developing countries and transfer of technology to practice, substantial reduction in cost of construction has been achieved. Still there is a greater need of transfering low cost appropriate technology to practice, so as to boost the house buidling programmes at a lower costs in the developing countries. The C.I.B. which is actively associated with building and research activities can do a great job in promoting research and application of results in practice.

6.7 Realistic approach to village end town planning
Realistic approach to regulate the growth of cities and villages is of prime importance in order not only to adequately cater to the low income groups but also to account for social, economic and cultural needs of the populous countries. As for instance, conservation of energy by avoiding long distance transportation within urban settlements, the density of residential neighbourhoods which are conducive to social living and the peculiarities pertaining to life styles and cultural values of the people leading the life below subsistence level, can only be checked by regulated planned growth of cities and villages.

7. Recommendations

The following broad recommendations may be considered:

7.1 Formulation of housing policy
More purposive housing policies, clearly indicating rural and urban priorities be evolved and implemented.

7.2 Priority to housing and urban development
Recognising the need and importance of housing priority should be accorded in the developmental plans of the developing countries. The international agencies like, I.L.O., W.H.O., I.B.R.D., UNCHS., and other agencies are required to provide active assistance for housing through their action programmes.

7.3 Priority to socio-economic studies and surveys
For the formulation of purposive and priority oriented housing policies, information and in the relationships of socio-economic factors affecting housing are of primary importance. Such information is not only inadequate but absent in many developing countries. It is, therefore, recommended that comprehensive socio-economic studies and surveys may be undertaken not only at the local levels, but at regional, national and international levels.

7.4 Need for inter-disciplinary approach to housing
Integrated and inter-disciplinary approach to housing incorporating the bottlenecks of scare resources, development of science and technology, building practices etc. is the need of the hour in the developing countries which would provide more viable and compromising solution for the problem of housing the millions.

7.5 Exchange of Technical know-how/experiences
exchange of technical know-how/experiences, at local, national, regional and international levels through workshops, seminars, symposia, training courses etc. may be initiated at greater length. This would greatly facilitate the understanding of vast and diverse problems of housing and environmental conditions of the developing countries. The C.I.B. being an international agency can play a vital role in this direction.

Table 1: Growth of population and dwellings completed in 1970

Country	Annual rate of population increase (1970-76)	Annual rate of urban population increase (1965-70)	Dwellings completed per 1000 population in 1970
(1)	(2)	(3)	(4)
1. Algeria	3.2	6.8	1.0
2. Egypt	2.2	4.2	1.5
3. Colombia	2.9	5.2	1.2
4. Ecuador	3.4	4.6	0.8
5. Venezuela	3.1	4.7	1.9
6. Iraq	3.4	5.7	1.8
7. Mongolia	3.0	4.2	3.9
8. Syria	3.3	4.8	2.6
9. Thailand	2.8	4.7	0,2

Table 2: Share of Housing and Construction in the Gross National Product of Selected Countries

Country	Share in G.N.P. Housing	Construction	Person employed in construction as % to total employment
France	8.7	14.7	10.4
Puerto-Rico	7.9	20.5	10.8
Cyprus	7.4	13.2	10.2
Creece	7.0	16.8	8.8 (1971)
Japan	6.8	-	7.6 (1970)
Italy	6.6	12.8	10.4
Switzerland	6.3	17.2	-
Malta	6.0	12.8	11.8
Finland	6.0	16.0	8.8
W. Germany	5.6	14.2	8.0
Netherlands	5.5	14.6	10.9
Sweeden	5.0	14.3	9.2
India	3.59 (1976-77)	12.7	1.23 (1971)

Source: (1) Statistical Background Paper - UNEC for Europe, Committee on Housing, Building and planning HBPIR 5.12. July, 1973.
(2) World Employment Programme I.L.O. Geneva (1975)

Table 3: Share of Gross Fixed Capital Formation in Total Gross Capital formation in selected countries

Country	Year	Share in %	Country	Year	Share in %
Burma	1962	69	Canada	1968	65
Ceylone	1968	63	Denmark	1968	56
China(Taiwan)	1978	46	France	1968	59
Malaya	1966	67	Greece	1968	59
India	1976-77	50	Italy	1968	64
Phillippines	1968	38	Netherlands	1968	58
Argentina	1968	55	Norway	1968	53
Chile	1968	54	Sweeden	1968	68
Honduras	1964	60	Switzerland	1968	65
Panama	1968	52	U.S.A.	1968	60
Tobago	1962	58	U.K.	1968	51
Austria	1967	61			

Source: (1) U.N. Year Book National Accounts Statistics 1970.

(2) National Accounts Statistics of India - 1979.

BASIC CONCEPTS FOR HOUSING THE POOR IN DEVELOPING COUNTRIES

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SUMMARY

A modest home is amongst the primary necessities of human beings for leading a healthy life with social dignity. For a vast majority of population especially those in the low income groups both in urban and rural areas in developing countries fulfilment of this basic human requirement has been greatly lacking.

The need for improving the housing and environmental conditions has become an urgent matter. However, to tackle this colossal problem in the face of paucity of resources it is necessary to realistically assess the basic requirements of living and also to evolve appropriate conceptual approach keeping in view the social and economic conditions prevailing in the developing countries. Some outlines in this regard have been suggested which deal with (a) Space requirements and built-up accommodation; (b) High density living; (c) Low rise development; (d) Self-help and community participation; (e) Technical assistance and financial subsidy (f) Ownership, motivation and community management; and (g) Urban - rural balance.

The attempts which are being made in some developing countries for housing the poor and the work done by the National Buildings Organisation which is also U.N. Regional Housing Centre for ESCAP in this regard have been indicated.

HOUSING NEEDS

There is considerable housing shortage in many of the developing countries. According to a study made by ESCAP*, the backlog of housing in Asia in 1970 was of the order of 8.10 million units in urban areas and 28.15 million units in rural areas. On the assumption that 40 per cent of the 1970 urban population and 50 per cent of the rural population will need to be re-housed in 30 years, the magnitude of housing needs during the period 1975-80 would be 25.56 million units - 9.14 million units in urban areas and 16.42 million units in rural areas and 30.34 million houses (14.06 million units in urban areas and 16.28 million units in rural areas) during the period 1980-85. The estimated housing needs of Asia during 1970 - 1985 is given in the Table below:

Table Estimated Housing Needs, Asia 1970-1985 (million)

Need arising from	1970-1975 Urban	1970-1975 Rural	1975-1980 Urban	1975-1980 Rural	1980-1985 Urban	1980-1985 Rural
New households[a]	4.88	4.71	5.76	4.69	10.68	4.55
Replacement[b]	2.03	7.04	2.03	7.04	2.03	7.04
1970 backlog[c]	1.35	4.09	1.35	4.69	1.35	4.69
Total	8.26	16.44	9.14	16.42	14.06	16.28
Percentage of total	67		64		54	

a Number of dwellings is calculated by dividing the average annual population increase by an assumed average household size of 5 persons for urban areas and 5.5 persons for rural areas.

b Calculated on the assumption that 60 per cent of the 1970 urban population will need to be rehoused in 30 years, while 50 per cent of the rural population will require rehousing within 20 years.

c Calculated on the assumption that 40 per cent of the 1970 urban population and 50 per cent of the rural population will need to be rehoused in 30 years.

HOUSING FOR THE POOR

The magnitude of the problem of urban housing for the economically weaker sections of the society can be gauged from the fact that as per 1971 Census over 109 million people, out of 548 million population, lived in urban areas of India.

It has been estimated that, generally, about 40.71 per cent of urban population in India live below the poverty line which means that the monthly earnings of urban families are below 44 Dollars (Rs.350/-) and as such they have meagre economic capacity to afford to pay even the rental for the sub-standard housing they are forced to have. Generally, one fifth of the population of metropolitan centres in India is estimated to be living in slums and squatter colonies.

It has become necessary to give urgent attention to the solution of the problem of urban housing consistent with the economic resources of the people, specially those who are economically weaker. To avoid heavy burden on the national exchequer, we have to evolve concepts of housing that ensure basic requirements of living a healthy and better

* Survey of Rural Housing and Related Community Facilities in Developing Countries of the ESCAP Region - ESCAP.

life, at the same time the cost of urban development is largely within the economic resources of the people and the Governments.

COMPREHENSIVE APPROACH

A comprehensive solution to the problem of providing houses within the economic reach of the people is a complex matter, national policies and resources. An attempt is, however, made to suggest an approach, keeping in view the housing and liveability requirements of the people and for meeting the same largely within their economic resources. Technical assistance and financial subsidy by the Government to some extent are unavoidable in the interest of the people and the community as a whole.

The basic concepts of the approach which are briefly explained below concern the following:

(a) Space requirements and built-up accommodation.
(b) High-density living.
(c) Low-rise development.
(d) Self-help and community participation.
(e) Technical assistance and financial subsidy.
(f) Ownership motivation and community management.
(g) Urban-rural balance.

(a) SPACE REQUIREMENTS AND BUILT UP ACCOMMODATION

For economically weaker sections of the people, we can ill afford to adopt the concept of providing more shelters based on only economic considerations. What people need for survival is no doubt shelter but people have also to perform daily chores of life, raise a family and live a healthy life. In this context, we have to ascertain minimum requirements of space and built-up accommodation which must be provided.

Five types of spaces are considered essential, the minimum standard of which, however, may vary from one region to another depending on the pattern of living, climatic and local conditions.

(i) A built up space for complete protection and privacy:

Protection for inclemency of weather, cold, rain, storm, flooding, etc. would have to be provided by building a room having four walls and a roof. This should be made of durable materials, which are fire resistant to some extent. This space is completely sheltered and provides complete security and privacy as well. Suggestive minimum size of room can be 10 sq.m. to 12 sq.m. (100 - 120 sq.ft.).

(ii) A built up space having a roof with one or two walls:

This provides a built-up space which is partially protected and can be used for living as additional accommodation, specially for families. It is a multi-purpose space for sleeping, working, cooking, etc. Depending upon needs and resources, such a space can also be converted into a fully sheltered space to provide an additional room.

A verandah which is 2 metre wide and 3 metre long (6' wide and upto 10' long) may be good enough. The area may be about 6 sq.m. (60 sq.ft.).

(iii) A space which has four walls but no roof:

Adjoining to the partially sheltered space an enclosed area bounded by walls of height equal to 2 metres (6ft.) and of area of about 15 to 20 sq.m.(150 to 200 sq.ft.) is necessary for out-door living specially in hot and arid climates. The courtyard is of great utility to the family and is used for multi-purpose. In it should be located service units such as bath room and W.C.

(iv) An open space which is a frontage to the house:

In the front of the house a small open space as a buffer between the street and the house is essential for safety from street traffic and for incoming people and for family use. An open space of 10 sq.metre (100 sq.ft.) may be adequate.

(v) A community open space:

For a cluster of houses for community needs, a completely open space is necessary. It serves multi-purpose. Generally, at least 50 per cent of the total space available should be left as community space in a suitable manner.

(b) HIGH DENSITY LIVING

There is a great need to adopt optimum densities consistant with land use economy as well as ensuring health and well being of the people. It is believed that such optimum net densities can be as high as 600 to 800 persons per hectare and even more for transitory types of settlements. In such developments, apart from space occupied by houses, it is possible to leave required open spaces. Moreover, in the houses itself, the front open space and courtyard helps to relieve over-crowding and congestion.

High densities, enable economy in several ways - by saving in land, cost of development and services. People in urban areas have been accustomed to very high density living of 1500 to 2000 persons per hectare and reducing these to optimum high density of 600 to 800 persons per hectare seems feasible without adversely affecting the health and well-being of the people. But this aspect must be carefully considered as the increase in population of a habitation is itself one of the main consequential factors which contributes to slum conditions.

(c) LOW-RISE DEVELOPEMENT

It is often assumed that to achieve high density housing it is necessary to resort to high-rise development. This is not only much costlier but also brings in its wake a variety of human and social problems associated with living away from the ground. Technological expertise and specialised knowledge, costly and scarce materials and investments of high order are required for undertaking high-rise development, the advantages of which are not commensurate with the cost and resources required. More-over, the self-help and community participation in such development are also precluded.

In the case of low-rise development - mostly single or at the most two storeyed development, the technological problems of planning, design, construction and use of materials as well as construction methods are greatly simplified and cost of development is low. The indigenously available materials particularly the local resources can be profitably utilised for development. Low-rise development is also suitable from the prevailing level of living standards, climatic conditions and safety from various hazards, like earthquakes, fire, etc.

In urban areas, low-rise development may result in unwiedly sprawl of the city. However, if self-contained developments with necessary community facilities and their proper integration with the city as a whole is ensured by communication system of roads and transportation, the handicaps of urban sprawl get limited and are compensated by the facilities which it provides for living in fulfilment of the basic needs of the family.

(d) SELF-HELP AND COMMUNITY PARTICIPATION

The size of urban housing problem is so enormous and complex that with meagre resources, the local/state or national Governments are unable to meet the expenditure of that magnitude. It is, therefore, necessary to take advantage of self-help of the people and of community participation in undertaking such programmes. Low-rise development affords the possibility of greater participation of self-help and the community, thereby contributing to the cost of development in kind and lessening the burden on exchequer. The programme of development can be so designed and undertaken in order to maximise taking advantage of self-help effort and community participation.

Self-help and community participation brings in a sense of involvement and satisfaction which contributes greatly to success of any venture. The technology of construction and the scheme of development should, therefore, be so evolved and designed so that maximum advantage is taken from self-help and community participation.

In self-help programme, it is essential to provide an organisation to motivate, organise and channelise self-help. Also adequate level of aid both in cash and kind and control on development should be provided.

(e) GOVERNMENTAL ASSISTANCE AND SUBSIDY

The Governmental assistance is necessary to the entire scheme at every stage of development. It should be in the nature of supplementing or initiating the community/individual to action.

Subsidy is also essential to a limited extent in order to enable the people to accomplish desirable standards, particularly for the creation and maintenance of healthy living environments. In this regard provision of essential services like potable water supply, sanitary system of collection and disposal of wastes, provision of streets and supply of electricity, etc. and provision of community facilities and social amenities are alrgely to be developed on the basis of Governmental subsidy.

(f) OWNERSHIP MUTIVATION AND MANAGEMENT

Although in a development scheme, based on self-help and community participation, it is necessary to instil motivation and promote it. This can be done in several ways. One of the important factors of great consequence is the right to ownership of houses and privilege to use essential services, community facilities and social amenities. The ownership could be provided in many ways - free hold basis, lease-hold basis, live-licence basis, living tenure basis, etc.

Similarly management aspect of development and specially of maintenance by the individuals and community must also be developed in order that the scheme as designed continues to be used as such. Housing management and community welfare are important subjects which must be given due attention.

(g) URBAN - RURAL BALANCE

The programme of urban development cannot continue to cope up with the rapid increase in urban population, specially due to influx of people from small towns and rural areas in search of employment opportunities and better prospects of life. It is essential to reduce the trend of immigration into urban centres by undertaking development of small towns and villages. For this improvement of housing conditions in small towns and villages is an important component. Therefore, it is essential to take an overall view of development, including urban and rural areas. How the urban-rural balance is to be achieved is a larger issue, which should also concern urban administration.

HOUSE FOR THE URBAN POOR

The house for the urban poor evolved by the National Buildings Organisation provides a plinth area of 17.15 sq.m.(Figure 1). The appropriate technology proposed comprises of adoption of 115 mm. thick 'Z' shape burnt brick walls and precast R.C.Channel roofs. The cost of the house is Rs.4,260/-. A set of 12 proto-type houses have been put up by National Buildings Organisation in a squatter resettlement colony in Sultanpuri in Delhi for Delhi Development Authority.

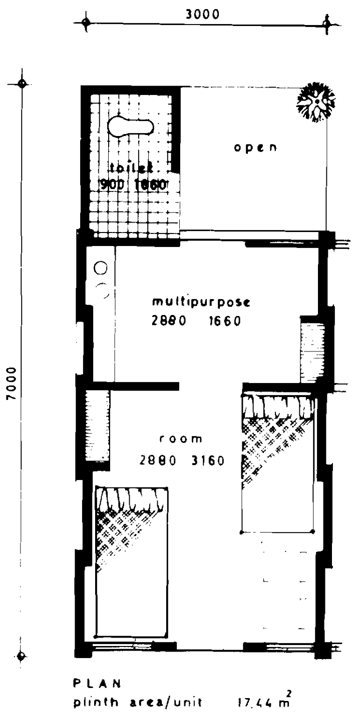
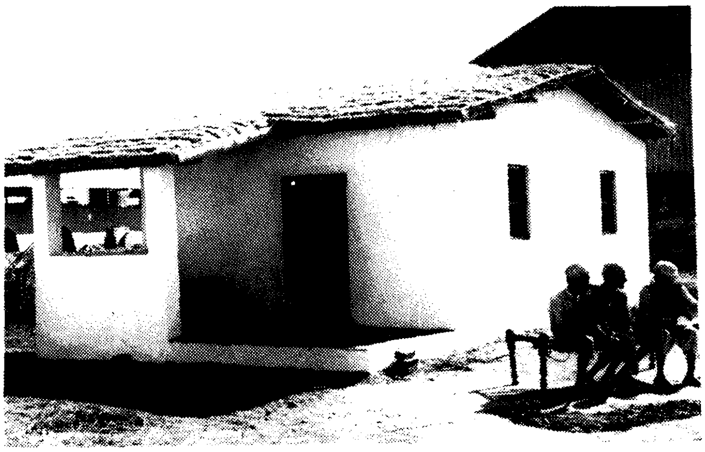


Fig. I. HOUSE FOR THE URBAN POOR

HOUSE FOR THE RURAL POOR

For over 11.3 million landless agricultural families in India, who are being provided house sites free of cost by the Government, the National Buildings Organisation has evolved a typical design of house(Figure 2) which can be built at low cost employing local materials and self-help. The plinth area of the dwelling unit is 24.4 sq.m. By adopting sun-dried brick walls with water proof mud plaster and thatch roof with fire retardent treatment, the cost of house comes to less than Rs.1,800/- when built through self-help.

A number of houses based on N.B.O. design have been constructed in different States in India.



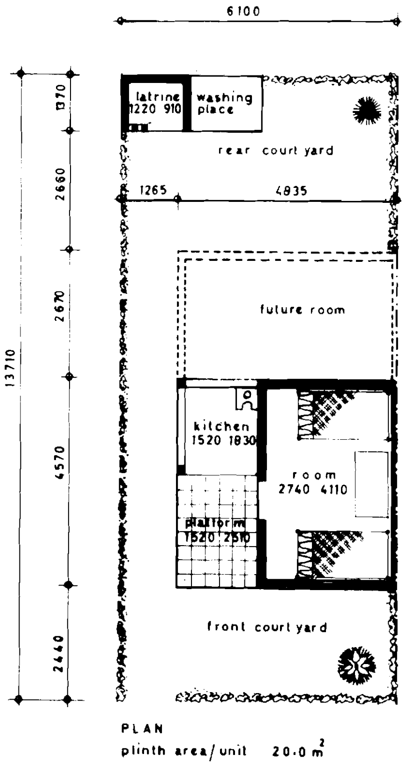


Fig. 2. HOUSE FOR RURAL LANDLESS

Inhabitants' Appreciation of the Environmental Quality in Public Housing Projects

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Synopsis

The study, which deals with inhabitants' needs with regard to public housing ("shikunim") in Israel, was carried out at five projects in Jerusalem, Beer-sheva, Kiryat Ono (one each), and Yavne (two). Within its framework, 115 inhabitants were interviewed by means of a questionnaire which included questions on the flat (quality of design and construction; other deficiencies) and the neighbourhood (sanitation, air pollution, noise, public parks, children's playgrounds, road safety etc.). In the second part, carried out in Jerusalem, Beer-sheva and Kiryat Ono and involving 64 inhabitants, interviewees were questioned on their reasons for choosing the neighbourhood, on the quality of provided services (public transporation, health and education), on the efficiency of the local authority in carrying out its responsibilities, etc.

The principal object of the study was to ascertain, at first hand, the most important needs in the environment of an Israeli "shikun", and the extent to which these needs are satisfied.

Findings indicate a number of deficiencies in the design and functionality of both the flat and the neighbourhood. The most frequent objects of complaint regarding the flat were inadequate storage space and poor construction quality; those regarding the neighbourhood - poor sanitation, lack of children's playgrounds and lawns, road safety, noise, air pollution, etc.

The findings, summarised in tables for each of the "shikunim", are expected to prove useful to architects, urban planners and policymakers in the construction-and housing sectors in Israel in their short- and long-term decision-making processes.

Sommaire

L'étude qui enquête sur les besoins humains dans le domaine de l'habitat public ("shikunim") en Israël, a été executé en 5 complexes: 1 à Jerusalem, 1 à Beer-Sheva, 1 à Kiryat Ono et 2 à Yavné.

Dans le cadre de cette enquête, 115 locataires ont été interrogés par questionnaires, dont les questions inclues: l'évaluation de leur appartement (qualité de l'aménagement (design), standard de construction, articles qui à l'opinion des locataires manquent dans l'appartement, et leur quartier (degré de properté, pollution de l'air, problème acoustique, parc public, parc de jeux pour enfants, condition de la sécurité des routes etc.).

Dans la seconde partie de notre etude (seulement à Jérusalem, Beer-Sheva et Kiryat Ono, avec la participation de 64 locataires). Les personnes interrogées ont eu a répondre à d'autres questions comme pour quelles raisons ont-ils choisis le quartier, quelle est la qualité des services (transport public, santé et éducation) à propos de l'efficacité de la mairie et des autorités locales dans leur charges respectives, etc.

Le principal but de cette enquête a été d'apprendre par les locataires eux mêmes, qualles sont les principales demandes (besoins) dans le milieu ambiant (dans le domaine de l'habitation) et dans quelles mesuresces demandes ont eu réponse satisfaisante.

Les résultats montrent de nombreuses lacunes concernant l'aménagement et le fonctionnement de l'appartement et du quartier des locataires. La source la plus fréquente de leurs plaintes est au sujet de l'aménagement de l'appartement, sa grandeur, le manque de placards et la mauvaise qualité de la construction.

Pour le quartier, les locataires se plaigment surtout du manque de propreté, l'absence de parc de jeux pour les enfants, l'absence de pelouse, le bas niveau de la securité de la circulation, le bruit, l'air pollué etc.

Les résultats de cette recherche sont réunis dans des tables pour chaque "shikun". Ces résultats peuvent être d'une aide valable pour les architectes, les entrepreneurs urbains et les autorités compétantes dans le domaine de la construction et de l'habitat en Israël dans leurs decisions dans le présent et dans le futur.

Introduction

Sociological research in Israel has to date largely centred on differences between individuals, groups, classes and cultures - to the actual detriment of the aspect of human needs in general and in the housing context in particular. Earlier work on construction quality and flat functionality, carried out by the author at public housing projects throughout the country between 1961 and 1977, constantly brought out problems which, although not directly related to the theme of the study, were regarded by the interviewees as extremely important. It transpired that flats were poorly designed from the functional and social points of view, and that the needs of the individual occupant (for whom the housing was, in fact, intended) were frequently overlooked in the design process. In these circumstances purely technological considerations no longer suffice, but must be supplemented by qualitative ones based on sociological research in the construction- and housing sectors.

The question posed in the present study was: "What are human needs in the environment of an Israeli housing project, and to what degree are they satisfied?".

The study was carried out at five projects ("shikunim") constructed by the Israel Ministry of Construction and Housing at Yavneh, Jerusalem, Kiryat Ono and Beer-sheva in the late 60's and early 70's. Within its framework, a questionnaire was administered to 115 inhabitants, who were requested to evaluate their flats in general terms and to point out the relevant advantages, limitations and drawbacks, as well as such items as should have been - but were not - provided by the contractor (albeit at increased initial cost). Further questions concerned the neighbourhood, including the aspects of sanitation, air pollution, noise, children's playgrounds, public parks, road safety in the neighbourhood and near it, public transporation, health-, education- and cultural facilities, social contacts, efficiency of the services provided by the local authority, etc.

The point of departure in constructing the questionnaire was a comprehensive literature survey which covered British, German, American, Danish, Swedish and Norwegian sources. In it, housing-relevant needs were classified under three categories: physiology, safety, and psychology, and the opinions of well-known specialists in housing sociology were compiled on the following subjects:

- The impact of the "living environment" on social contacts.
- Factors promoting friendships within the neighbourhood.
- The impact of physical and functional distance on social contacts.
- The impact of the "living environment" on privacy, and causes for lack of privacy (e.g. noise, etc.).
- Services and social functions which a neighbourhood should provide, etc.

Milieu of study. The Hebrew term "shikun" (pl. "shikunim") refers to a neighbourhood comprising from 100 to 2000 dwelling units of standard size, plan and quality - with communal, service and business facilities grouped together to form a local centre.

The "shikunim" of the present study were built by prefabricated methods. Statistical data on their populations are listed in Table 1. Of the differences highlighted by the table, none is more dramatic than that in density, between the smallest and poorest "shikun" and the largest and richest one.

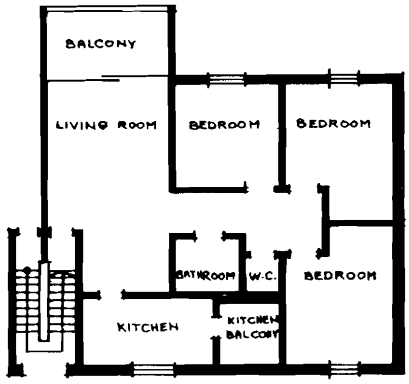

FIG. 1 SCHMATIC PLAN OF THE FLATS AT KIRJAT ONO (85 sq. m.).

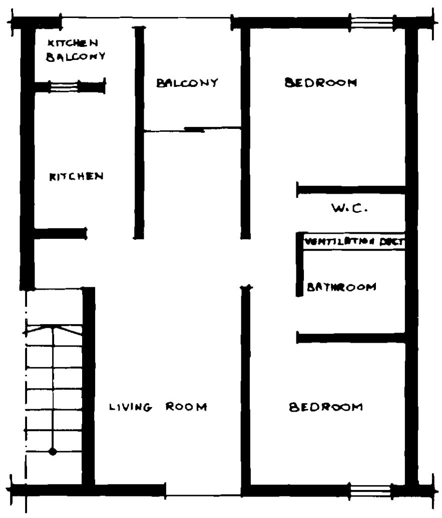

FIG. 2 SCHMATIC PLAN OF THE FLATS AT JAVNE (65 sq. m.).

Results and Conclusion

The findings of the study indicate as follows:

Layout

The interior layout of the flat is a matter of importance to the occupants, most of whom referred to it even when not explicitly asked to. The majority were satisfied with the existing layout, except for such aspects as difficulties in arranging the furniture in the smallest flats (65 sq.m.), inadequate storage space, and unsatisfactory provision for garbage disposal.

Table 1: Statistical data on the populations of the "Shikunim" (per cent)

Locality	Floor Area in sq.m.	Density (persons per flat)			Duration of occupancy Years in flat			Sojourn in Israel			Age group		
		1-4	5-6	7-9	1-2	3-5	6+	≤5	≥6	Native born	≤30	31-50	51+
Yavneh	65	40	32	28	--	24	76	--	100	--	4	64	32
Yavneh	75	88	12	--	12	50	39	8	98	--	54	27	19
Beer Sheva	79	80	20	--	19	82	--	76	6	19	44	51	5
Jerusalem	82	70	20	--	39	61	--	43	18	39	39	31	30
Kiryat Ono	85	94	6	--	41	23	37	--	64	36	10	41	49

Items listed as lacking were a bathtub, a window in the bathroom, laundry installations (incl. drying) carpet-cleaning facilities, cupboard niches, interior communicating doors, lofts, etc.

Physical environment

Among the important needs related to the physical environment, the following were most often mentioned: sanitation, respite from noise, road safety (especially for the children), and finally fresh air, attractive scenery, lawns, trees and plants.

Sanitation

The poor level of sanitation was the most urgent problem: in some of the localities 80% - 94% of the interviewees referred to it as "poor" or "very poor". This state of affairs is due to three principal factors: the inhabitants themselves; malfunctioning of the sanitary services; and faulty design. The first factor was actually admitted by about one-half of the interviewees, and the author concludes that at present the neighbourhood communities are unable to cope with the problem. A positive example has, however, been provided at one locality, where the inhabitants set up a voluntary maintenance assocation with encouraging results; similar organisations could also be set up by an external authority.

Noise

Noise was not a dominant problem* in the "shikunim" in question, but where it was mentioned, its sources were:

- Children playing in the street (in the absence of suitable playgrounds).
- Road traffic.
- In one of the localities, situated close to Lod Airport, there was also noise from aircraft.

Road safety

At some of the localities, parents refused to allow their children to attend a school on the other side of a main highway because of fear of accidents which, according to them, occurred almost every week; even adults wishing to cross the highway had sometimes to wait 10 to 20 minutes at the pedestrian crossing. (Traffic lights were only installed four years after the occupants had moved in.) Complaints about the low degree of safety were voiced at all localities, and interviewees pointed out that for them satisfactory solution of the safety problem took precedence over all others.

Social environment

Needs related to the social environment were found to be better satisfied at localities with larger flats and lower density, than in those with smaller flats occupied by families with many children. The needs listed as unsatisfied were, in order of priority: playgrounds and day-nurseries, community centres, parks, etc. The lack of playgrounds and outdoor recreation facilities was the most frequent complaint in four of the localities. (The fifth, at which there was no reference to it, is surrounded by spacious lawn areas, but there are very few children.)

Social contacts/friction

The findings lead to the conclusion that social contacts within the "shikun" were generally satisfactory. Typical quotations on this subject are:

- "Normal social intercourse between neighbours...."
- "No feeling of social isolation...."
- "No friction worth mentioning...."

What sources of friction there are, fall under four categories: noise made by children; noise made by neighbours; problems of maintenance and central heating; cleaning of carpets on upper floors.

Services

Local authority

The principal services expected by the shikun inhabitant from the local authority are:

- Improved sanitation.
- Improved maintenance of roads, playgrounds and parks.
- Provision of community centres and other leisure facilities.
- Provision of sidewalks.
- Effective snow-clearance measures (specific to Jerusalem).

Public transportation

The efficiency of public transportation from and to the city centre was usually in accordance with expectations. Only in one locality were there complaints of low frequency and slowness of the bus service - apparently due to the constant traffic jams characteristic of the Tel-Aviv area.

Urge to move

A family's degree of satisfaction with their present housing conditions can be measured by their urge to move elsewhere. Only 5% of the interviewees admitted such an urge due to dissatisfaction with the locality. At the same time, only 80% of those who were staying on replied an unqualified "yes" to the question. The others added reservations:

- "So long as my job is here...."
- "Provided I am allowed to add a room to the flat...."
- "Having no other option....", etc.

The above findings may prove useful to architects, town-planners and policymakers in the construction- and housing sectors in their short- and long-term decision-making processes.

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*The factor determining whether noise is or is not a nuisance, are: the type and intensity of the noise, the personality of the subject and the activity he (or she) is engaged in at the relevant moment.

Improvement of architectural and technical solutions of dwellings in the U.S.S.R.

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Summary. The concern of the report is the main trends in housing construction development in the U.S.S.R.; social, economic and technical prerequisites for a higher qualitative level of mass housing improving periodically every 10-15 years; the problems related to the improvement of principles of norms establishing and residential buildings designing, the development of methods of standard designing based on the differentiation of residential buildings according to their purposes, types of dwellings and the character of services with due regard for demographic, natural-climatic, social-economic and other peculiarities of a construction region.

The report deals with problems connected with the development of housing industrial methods, the improvement in heights of residential developments and in the structure of construction according to types of buildings and dwellings meeting the requirements of families of different demographic types.

The tendency is shown aimed at improving spatial-planning and technical solutions of mass housing for the perspective period (up to 1990).

Sommaire. Dans ce rapport sont exposées les tendances du développement de la construction de logements en URSS; les conditions sociales, économiques et techniques de l'élévation du niveau de la qualité de la construction en masse améliorée périodiquement au cours de 10-15 ans; les problèmes de la standardisation et de la conception des immeubles d'habitation, le développement des méthodes du projet-type basées sur la différentiation des bâtiments selon leur destination, les types d'appartements, le caractère de service en considération des particularités démographiques, climatiques, socio-économiques de la région de construction.

Dans le présent exposé sont examinés les problèmes du développement des méthodes industrialisées de la construction des logements, du perfectionnement de l'hauteur des immeubles d'habitation et de la structure de la construction selon les types des maisons et des appartements conformément des besoins des familles de différente composition démographique.

Outre cela dans ce rapport sont exposées les tendances d'amélioration de la conception spatiale et de plan et des solutions techniques du logement social sur la perspective (jusqu'a 1990).

In the forties and fifties the housing problem in the U.S.S.R. became most acute -- both socially and economically — as a consequence of the destruction brought about by the Second World War[x] as well as shortages engendered by the rapid growth of the urban population in connection with the extremely high rates of industrialization.

In the U.S.S.R. much consideration is given to the consistent improvement of the housing conditions of the urban and rural population. The main principles of the state policy in the development of the housing stock and construction stem from general aims and tasks involved in solving the housing problem in the U.S.S.R. The general social objectives of the housing policy aimed at improving the housing situation for the whole population and at creating more convenient hygienic and living conditions remained unchanged during the whole post-war period. The growth of the Soviet economy and relevant social and cultural transformations have been changing only the methods involved and the scope of their implementation.

In the last twenty years, the major instrument to improve housing conditions has been new residential construction. During this period in the U.S.S.R. there were built about 47 million flats and one-family houses with the total area exceeding 2 billion sq.m.including 1.3 billion sq.m. in towns and urban settlements. Annually in the U.S.S.R. 2.1-2.3 million dwellings with the total area of

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[x] 1,710 towns ans settlements and 70,000 villages were destroyed in the U.S.S.R. during the Second World War. As a result, some 25 mill. people were rendered homeless.

103-110 million sq.m. are commissioned, in other words, 8-9 dwellings per 1,000 inhabitants.

Valueless residential buildings are being demolished on a large scale. In recent years in towns and urban settlements residential buildings with the total area of 10-13 million sq.m. have been demolished. Annually, in the countryside the demolished housing has averaged 15-17 million sq.m.

The urban housing stock has increased fivefold since the pre-war period; during the years of Soviet power it has grown 11.6 times (total area). At the beginning of 1980 there were 44 million flats and about 10 million beds in hostels for students of higher education and secondary schools, young workers and other categories of people.

In the rural areas of the U.S.S.R. the housing stock is estimated at 23 million flats and one-family houses and 2 million beds in hostels of various types.

As a result of the great achievements in the development of housing construction and the housing stock, the basic principles of the housing policy have been formalized in the new Constitution of the U.S.S.R., in its Article 44 which reads that the citizens of the U.S.S.R. have the right to dwelling. This right is ensured by the development and protection of the state and public housing stock; by assistance for cooperative and individual housing construction; by fair distribution, under public control, of the living area that becomes available through fulfilment of the programme of housing construction, and by low rents.

The specific features of solving the housing problem in the U.S.S.R. consist in the prevalence of state-run forms of construction, distribution and operation of dwellings in towns and urban settlements. In recent years the state has financed more than 80 per cent of urban housing construction; housing cooperatives have provided the funds for eight or nine per cent of the housing built, with the share of individual customers also amounting to eight or nine per cent. At present 73 per cent of the total urban housing stock of the country fall on the state sector. Capital residential buildings with all modern conveniences are prevailent in it, with an average physical wear of the housing stock being 17 per cent.

The State assumes a considerable share of the expenses of the operation, maintenance and modernization of public-owned housing stock. State allocations for these purposes exceed 5 billion roubles per year. It is predetermined by low dwelling rent, which has remained unchanged since 1928. In the U.S.S.R. the average cost of rent and public utilities (cold and hot running water, central heating, gas, telephone, etc.) averages less than 3 per cent of the budget of an industrial worker's family.

The State encourages cooperative and privately-owned housing at the expense of the population. To this end, credits and loans on favourable terms are granted with long-term repayment (from 10 to 15 years or more). The cost of improvement and public infrastructure in areas earmarked for cooperative and individual housing is paid by the State. Cooperative residential buildings are constructed by state-run contract building organizations.

The achieved level of the Soviet economic development has made it possible to ensure an all-round and comprehensive approach to the solution of the housing problem, which is recognized as the major principle of the state housing policy:

- the consistent improvement of the architectural and technical solutions of residential buildings and dwellings;
- a correct balance between residential, cultural and communal construction;
- the development of the manufacture of furniture, household appliances and equipment on the appropriate scale;
- the improved maintenance and increased modernization of residential buildings;
- protection, improvement and sanation of the environment.

In order to accomplish these tasks some 100 billion roubles were allocated for residential and communal construction in 1976-1980.

The prevalence of state-run forms in construction and operation of urban housing stock in the U.S.S.R. predetermines great national economic importance of the efficient use of material, monetary and labour resources. This is why the State regulates the standard of mass housing, establishes obligatory norms of design and construction of residential buildings and community facilities as well as the norms and regulations of the planning and development of settlements, taking into consideration the economic possibilities of the society at every stage of its development.

In the U.S.S.R. the qualitative level of mass housing is raised radically every 10-15 years. This can be seen in the improvement of the building norms and regulations of design (SNiP), on the basis of which new standard and individual designs of residential buildings are worked out. Thus, the designs of 1958 (the designs of the first generation) were replaced by new, improved designs in 1963 (the second generation).

In the past twenty years 90 to 95 per cent of the state-run residential construction have been carried out to standard designs. The wide use of standard designs has greatly contributed to developing industrial and, first and foremost, full-prefabrication methods of residential construction, to increased housing scales and to improved quality and lower costs.

In the near future series of standard designs (the third generation) will be introduced into practice of the housing construction, according to which in 1980 about 60 per cent of state and cooperative residential construction volume will be built. The specific feature of this new series is characterized by the further improvement of operating and architectural and technical qualities of buildings and dwellings, as well as by the development of nomenclature of designs for buildings and "block-sections", ensuring different heights, configuration and spatial solutions for residential developments.

More than 10 types of flats with the number of rooms varying from one to five are practicable in the existing series of standard designs. A flat with the same number of rooms is designed in different sizes: big or small. It allows to take into consideration not only the number of inhabitants but their sex and age. Functional "zoning" and the necessary built-in equipment and furniture are provided in the lay-outs of these flats.

The urban development in the U.S.S.R. features the principle of differentiating residential buildings by their function, by types of flats and services, taking into account not only demographic but natural, climatic, social, economic and other specific features of the region. The designs have been worked out for 26 building-design and climatic regions as well as for major cities of the country - Moscow, Leningrad and others.

The prevailing type of dwelling is a flat (more than 90%), designed for families of different types.

In connection with the growth in the number of people of pension age and the improvement in their well-being, special types of residential buildings for this category of the population are being built as well as houses for old aged and disabled persons. 7-8 per cent of the total state residential construction fall on hostels for the temporary accomodation of students of higher and secondary schools and other categories of youth.

Hostels and boarding schools of different types ensure a fairly high level of comfort and community services.

The last decade is characterized by an intensive development of socialized residential construction in rural areas of the U.S.S.R. Levelling living conditions and services in rural and urban areas is one of the U.S.S.R. Government's basic objectives as it is a matter of fundamental political and socio-economic importance.

In 1978-1980 the allocations for state residential and community facilities in rural areas were considerably raised. As a result, great advances have been made under long-term programme to transform rural areas into well-organized settlements with up-to-date residential and community buildings.

The solution of the housing problem in the U.S.S.R. is carried out on the basis of long-term governmental programmes. In recent years the part played by long-term plans and forecasts (over a period of 15-25 years) within the framework of the U.S.S.R. planning national economy has been enhanced. In the U.S.S.R. the forecasts in the field of town planning and residential construction are nearing completion as part of the long-term draft for the economic and social development of the U.S.S.R. for 1976-1980 and for the more remote future up to 2000.

The ultimate purpose of the long-term governmental programmes in solving the housing problem in the U.S.S.R. is that of providing every urban and rural family with a up-to-date flat or a house, thus,creating the most convenient hygienic and everyday life conditions.

The state policy in the field of housing is aimed at reaching this goal, mapping out the residential development in the current five-year and long-term plans.

The present level of social and economic development and the rapid scientific and technological progress are creating real prerequisites for the further improvement of housing construction and for raising the quality of large-scale housing at future stages.

In general the social characteristic of a dwelling for the future can be outlined by the following principles:

- an organic combination of a family's personal life with social life;
- the creation of conditions for social communication and the development of collective interests;
- a free choice of the way of life: the upbringing of children at home or in children's institutions, taking meals at home or in public dining-halls, etc.

For the future construction in towns, it is planned to include additional premises for services in residential buildings or estates (premises for temporary shopping, reception centres of domestic services, children's rooms, clubs, libraries, etc.).

The introduction of these community services into residential buildings or their groups entails the enlargement of buildings and the increase in their height.

In 1980 9-storey residential buildings will make up about 40 per cent of all urban residential construction (32% in 1975) and in the big cities up to 65-70 per cent. Architectural requirements and town planning considerations will raise the percentage of 12-16 and more storey buildings, which will amount to 14-15 per cent; in the largest cities it will constitute up to 25-30 per cent.

In the terms of industrialization development, contemporary residential construction is running ahead of the other sectors of civil and industrial construction. In 1980 the share of fully prefabricated residential buildings (large-panel, box unit buildings, etc.) will make up approximately 60 per cent of the total state-run and cooperative residential construction as against 51 per cent in 1975.

The forthcoming stages connected with the ultimate solution of the housing problem in the U.S.S.R. will see a steady growth in housing construction volumes and in reconstruction and modernization of the town housing stock. This will require the further introduction of full-prefabrication and other industrial methods of house building, an essential rise in the degree of prefabrication in building structures and units, a wider application of effective materials and products, the completion of full mechanization and gradual transition to automated plant-and-building-site production.

One of the most important requirements is the ensurance of outstripping tempoe for the development of material-technical base of full-prefabrication and other industrial methods of housing construction. The practice of construction during the past twenty years proves this theoretical provision.

At present more than 450 enterprises manufacturing large-panels and boxes with total capacity about 58 million sq.m are operating in the USSR.

The housing prognoses up to 1990 and for the far future proceed from the necessity of maximum increase in the share of completely prefabricated housing so that the figure is to reach 80-85 per cent. Different modifications of large-panel housing will be prevailing and make up 70-75 per cent.

Table

Areas (sq.m)	3-room apartments		4-room apartments	
	1971-80 4 - 5 persons	1981-90 3 - 4 persons	1971-80 5 - 6 persons	1981-90 4 - 5 persons
Living area	36-38	42	46-48	50
Total area	58-63	68	70-74	81
Living room	16	18	18	20
Master bedroom	12	14	12	14
Bedroom	8-10	10	8-10	10
Kitchen	7	8	7	8
Sanitary units	3.5	4.8	3.5	4.8-5.3
Storage and built-in cupboards	1.5	2	1.5	2

Changes in apartment areas and premises

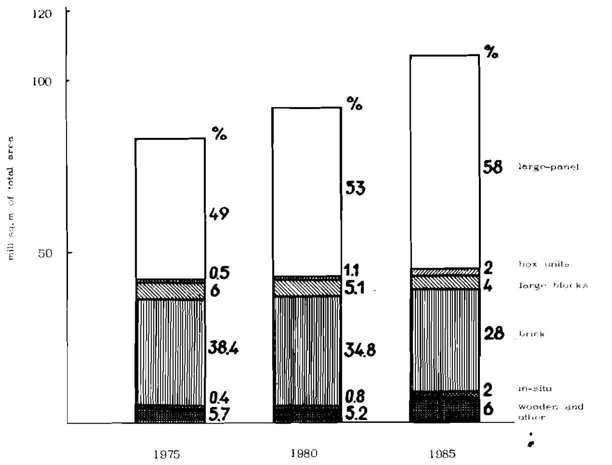


Figure I. Structure of state and cooperative housing construction according to structural types of buildings

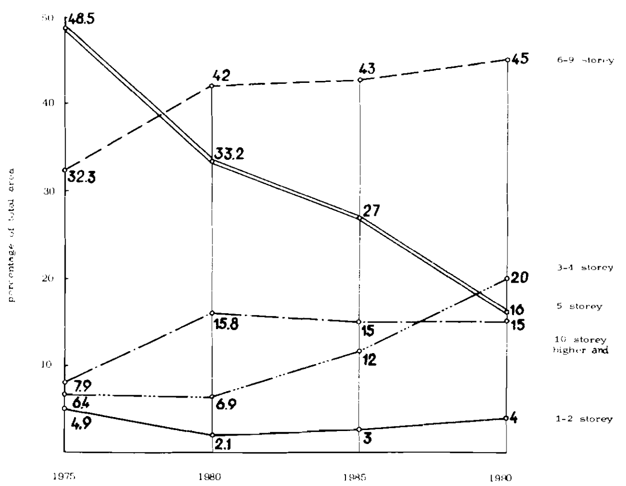


Figure II. Structure of state and cooperative housing construction according to height of buildings. 1975-1990.

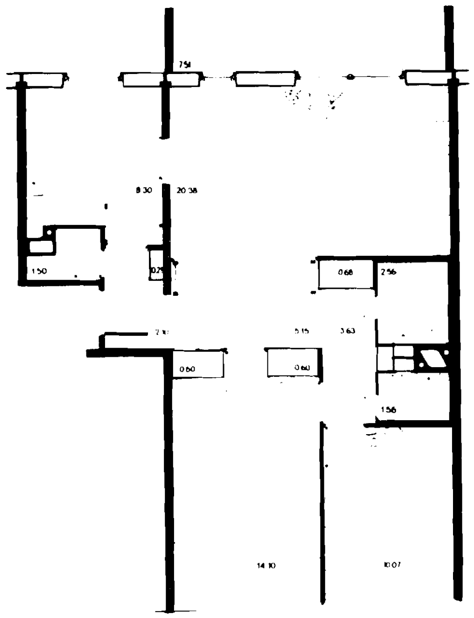
Figure III. Moscow. 22-storey large-panel buildings in Troparevo neighbourhood.

Figure IV. Moscow. 16-storey large-panel block of flats in Yasenevo neighbourhood.

Figure V. Togliatti. 16-storey large-panel blocks of flats in Sverdlov Street.

Figure VI. Minsk. Complex of 16-20-storey r.c. in-situ blocks of flats.

three-room flats



four-room flats

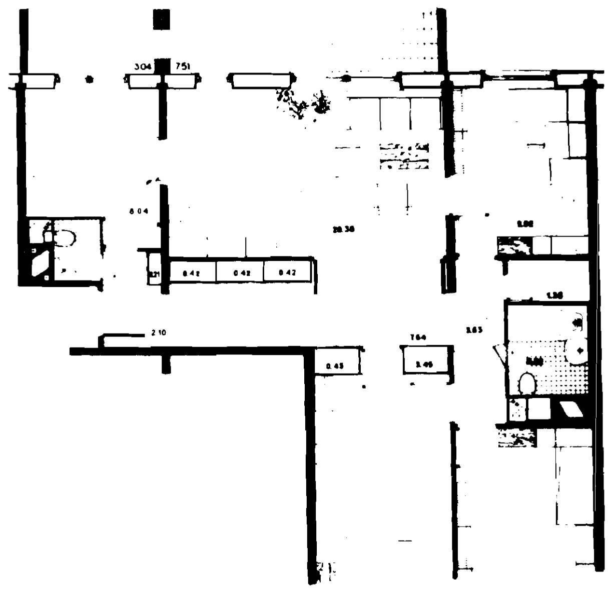


Figure VII. Lay-outs of apartment in projects for the experimental residential complex in Gorky.

MODULAR CO-ORDINATION IN ENERGY CONSERVING DESIGN FOR LIVING SPACE

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Summary:

The time has come for every designer, builder and the user to break loose from the depende-ncy on energy consuming devices which, in the recent past, had been considered the only solution to most problems encountered ay the design stages of the living space of man. newer problems warranted the sophistication of the appliances and not the design of the space itself.
The aim of this paper is not to come up with an absolutely foof-proof answer to any problem but, to make worthy contribution towards the studies on this subject that are being carried out in different part of the world. This paper concentrates on the design considerations for living spaces which, while minimizing the dependency on mechanical and electrical appliance, should endure to maintain an optimum level of comfort. For this purpose, various studies already done on 'human requirements' with respect to temperature, humidity, light, ventilaion, noise, etc., have been taken into serious consideration. The paper formulates and utilises a system of Modular Co-ordination with respect to all sizes pertaining to the living space and as a conclusion a comparison is made between the space so obtained with that which is dependent upon energy consuming devices.

Le temps est ici pour chaque dessinateur, constructeur et usager de se dégager des appareils qui consomment l'énergie et qui étaient, jusqu'à présent, considérés d'être la seule solution pour la plupart des problèmes rencontrés dans les phases des plans sur l'espace vitale de l'homme.
Nouveaux problèmes demandaient la sophistication des appareils et non le dessein de l'espace même.
L'intention de cette étude n'est pas d'atteindre une solution indétraquable pour aucun problème, mais seulement de faire une contribution digne aux études sur ce sujet étant éffectuées dans differentes parts du monde.
L'étude se concentre sur les considérations de dessein pour espace vitale, réduisant la dependence sur appareil mécanique et électrique, tout le temps soutenant un niveau optimum de confort. Pour ce dessein, des études variées déjà finies sur les conditions requises humaines comme température, humidité, lumière, ventilation, bruit, etc. ont sérieusement étés prises en considération.
Cette étude formule et utilise un système de coordination de module avec égard à toutes les dimensions ayant rapport à l'espace vitale et, en conclusion, une comparaison est faite entre l'espace ainsi obtenue et celle dépendente sur les appareils qui consomment l'énergie.

This report is the result of reserch on the room size for living room, bedroom, dining room, kitchen, bathroom, etc. with these room sizes reflecting module, modular co-ordination and performance of space with furniture, tools and appliances. Generally, room space is already built in contemporary housing, including prefabricated dwellings during industrization, and all furniture, tools and appliances should satisfy user requirements. There are, namely, three elements to space: space for human behavior, space for furniture and tools (plane) and cubic space where size of furniture and tools is relevant. When these elements are satisfactory, it can be said that optimum space for each room or similar area has been achieved under modular dimensional co-ordination.

This space co-ordination in housing must now be complemented with the manufacture of goods and the size of products should take an importance in mass-production equal to that of quality control and guarantee of durability. When room sizes differ, goods of different sizes should be available to permit co-ordination between man, furniture, tools, and space with building structure, keeping the size relation always constant.

1) Module and dimentional co-ordination,

Module and modular co-ordination are already set in good part by ISO, international standars, IMG, CIB, WG 24, with modular co-ordination basic module (ISO-1006) and modular co-ordination principles and rules (ISO-2848), etc. giving preferred and component sizes for a building. Every country wants to use international standards but, unfortunately, all

countries use different construction methods with, for example, different calculations for strength to determine size of a column or thickness of a wall, etc.
In Japan, for instance, part of it is in a seismic zone, with a soft foundation and for that reason building is using mainly frame construction rather than a panel system.

Dimensional co-ordination can be achieved in two different ways, as contained in ISO-2848 (modular co-ordination principles and rules) using either an axis based dimension or a boundary based one. (See fig. 1)

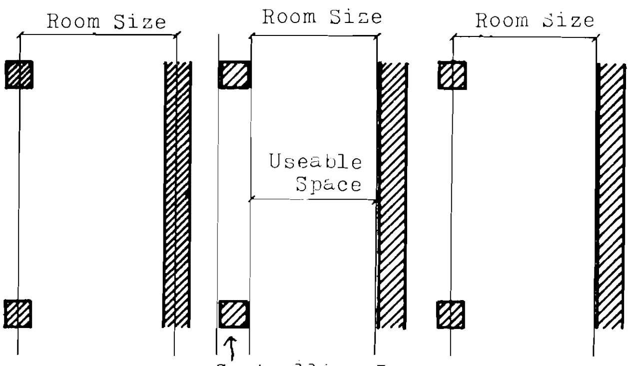


Fig. 1

Dimentional co-ordination by axis is rather easy to use between actual building sizes of an area but room sizes always end in different actual sizes depending on choice of materials used and the method of construction even when starting with similar nominal sizes. Now, dimensional co-ordination by boundary is the most advanced co-ordination between room size and all items to be put into the room, such as furniture, appliances, etc.
Above and beyond these dimensions which we have just discussed, we have, in Japan, another two aspects of dimensional co-ordination based on different measuring units. Local standards are particularly traditional and strongly imbedded in local custom. Japan is divided into two distinct areas called KANTOMA (eastern part of Japan around KANTO District--Tokyo) and KANSAIMA (western part of Japan around KANSAI District--Kyoto).
Both areas use a measuring unit called KEN. This unit is equal to 6-SHAKU, one KEN about 18 M* in KANTOMA (about 1818 mm) and is used to measure axis dimensions while the same one KEN is about 1909 mm long in KANSAIMA and is used to measure boundary dimensions, thus making a similar sized room in KANSAIMA larger than one in KANTOMA. This can also be said about what is commonly called a 6-TATAMI (grass mat) room and so on, with many other district differences in dimensional co-ordination..(See fog. 2)

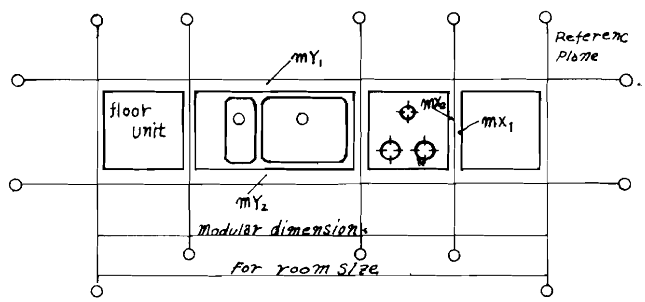
(Fig. 2)

Dimensions	AXIS		BOUNDARY	
Area	Shaku	mm	Shaku	mm
KANTOMA	6	1818	—	—
KANSAIMA	—	—	6.3	1909
KYUSHUMA	6.3	1909	—	—
ECHIZENMA	—	—	5.3	1707
BIZENMA	6.2	1879	—	—
KISEMMA	—	—	6.3	1912

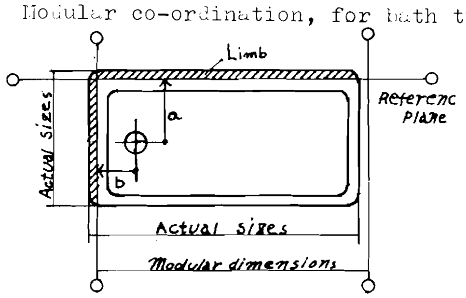
example for Japanese traditional module

The most important thing is dimensional co-ordination between room size and appliances e.g. kitchen equipment with floor unit, work-top, wall unit, tall unit, etc. Room sizes are especially important when fitting something to a wall, wall to wall, to the floor like bath room fittings such as vanities, ch chamber pots and so on. A bathroom may also have the limb of a bath tub fitted to the wall. (See fig. 3 -- 5)

(fig. 3)
Modular co-ordination Kitchen equipment for flooer units.



(fig. 4)
Modular co-ordination, for bath tub.



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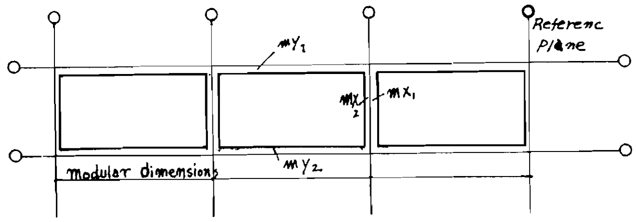
*See ISO 1oo6 modular co-ordination-Basic module

(fig. 5)
Moduiar co-oruination for storage furniture



However, it must given to the refference plan for the component.

It must not confusion the room sizes for between axis and boundary, which all, furniture, tool, and appliance, which raionalization of industry for that come up with an idea it should have priority demensional co-ordination with boundary system, because this system has measurement between wall to wall is easy to guarantee of room size for fitting.

2) <u>Dimensional co-ordination for the fitting of appliance</u>

Probably including furniture and tools and appliance, it neccesary to give to the reference plan for the component and room has reference plan for the assemble, it will be co-ordinate between those dual plan, for the integration, for that, even in Japan very much activity to prepared such a component of co-ordinating industrial standard,e.g. systematic storage furniture and systematic kitchen equipment and bath tub and light weight partition, and bath room unit etc.

Definition of such a component are probaly have two method, one of the method is able to give the module for the component, and another method is able to designate of position in building structure.
This is different meaning between material and component, because material are not expecting where fitting against wall, or ceiling before component.
Probably not able to give any reference plan to the material itself, However, material produced component and component produced space for the building element.

About furniture, sofa and chair and table probably could be said component an element of room space, such a case are not able to say the component, because furniture are much more free to use in the room, but if as same as component which designate of position of furniture in the room. e.g. lecture room in school it could handling to component them same component have especialy designation for corresponding to the installation, for jointing of pipe.

3) <u>Room size for the optimum conditioning in energy conserving</u>

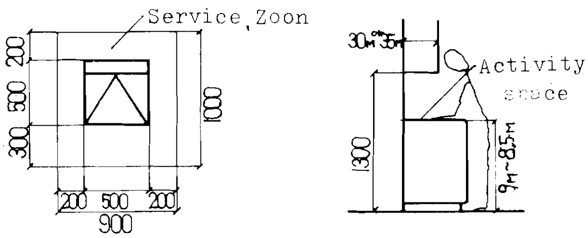
Ordinary people living in the house who is with family and goods, keeping healthy life and social activity, but some place people living quite different situation, all over the countries, which concerning climatologycal condition or some other reason, and some time people living in too small or too large space depend area and notionalty but views of energy conserving we must find minimum envelope for optimumzation way of reserch in this envelope sizes for living that is investigation for the human behaivior and requirement of people, activity space and service zone, also storage of goods children play in the room etc. and with environment of envelope, it must be co-ordination between man, tools, and spaces, for that, to investigation of human behaivor, for reading, writing, looking, eating etc., and it has function and performance even small room should be same, in Japan, particulary living room rather confusing way of use, because room sizes still decided from traditional way of room size, like a 8 TATAMI (grass mat) room 10 TATAMI room so on, (one TATAMI approximately 900 mm x 1800 mm) floor material only changed to rigid material, for chair and table insted of TATAMI.

Now, we using some furniture such a narrow living room, that is only about 13 m^2 -- 16 m^2 only if put in large sofa, number of chair may be full up on the space, but we find way of use in such a small living room for optimum, connected between dining room and living room, using compact bath room unit with vanities, and still using some TATAMI room with a few of furniture.

These our experiences, are one of the interest for the energy conserving with optimumzation.
Ordinary living space were more than 20 m^2, this is reasonable comfort, sence before, and also we expecting such a living room from economical and rational aspect with other ploblem.
Minimum envelope are also controlling with heat loss and opening space for windows and doors, when people use the space with furniture and some of the tools it must be co-ordination with furniture and activity space and service zone, for intigration of suitable comfort, for

instance, 50 cm x 50 cm (plane) sheet chair are oqupaied about 1 m^2 with service zone,(fig 6) including human behaivior, and some ranking, if could evaluate, can choice depend user requirement.

(fig 6)



Reference.

ISO 1006 Modular co-ordination - Basic module

ISO 2848 Modular co-ordination - Principles and rules

ISO 3055 Kitchen eqipment - Co-ordinating sizes

JIS A0061 Standard sizes for bathtubs

JIS A0017 Modular co-ordination sizes of modular components for system kitchen

JIS A4414 Inter unit for dwellings

The Basic Need of Space. An Example from a Squatter Settlement.

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This paper is a contribution on the theme "Basic Needs Related to Family and National Resources". The growth of shanty towns and squatter areas is a process occuring in most African, Latin American and Asian cities. The basic need of housing has not been supplied by planned use of national resources, but the individual families have provided themselves with shelter, investing family resources in material and building activities.

In this paper, the focus is put on one particular aspect of housing - the need of space. The analysis is based on the results from a recently published study of a squatter area, George, in Lusaka, Zambia.* Three field studies, including observations and interviews, were carried out in 1969, 1973 and 1977. This was the period just before the implementation of an extensive upgrading project. The area was legalised and supplied with water and roads. During the period under study, George was outside the control of the planning authorities, but it would be wrong to call it unplanned or spontaneous. The physical development was controlled by the local party organization and the location of each house was carefully chosen by the house-builder and accepted by the neighbours.

The people living in George are not only the users of the living area, they have, at the same time, to a great extent been the creators of their environment. An analysis of the use of space in George is, therefore, of special interest assuming that they have built their houses to satisfy their needs as well as possible under the circumstances of very limited resources. Two resources were free of charge - land and mud. The house-builders had to invest their work in making mud bricks, and their money was spent on doors, purlins and roof-sheets. If they could afford it, they paid a bricklayer to build the house.

Scarcity of land, real or created by private owners, is a problem in many cities. The land in George was partly owned by absentee European landlords, but the land was not protected and many of the squatters did not even know about this ownership. Traditionally, land is not privately owned. Unused land is free to be used by anyone in the village. If conflicts occur, the headmen have to judge. The local party leaders have been regarded as kinds of urban headmen, having a similar role to play in an urban setting. It would have been politically very difficult to evict the squatters and they had a feeling of security. This feature of George is basic for the subject of this paper.

Density and Urban Pattern

In 1977, George covered an area of more than one square kilometre. In 1960, farming in the area was given up. Scattered cultivation covered the land and a network of paths connected small groups of houses. Each house-group was probably the home of one nuclear or extended family. Small one-room huts, each for different functions (parent's room, children's room, kitchen, etc.) were clustered on a swept area. There were about 25 small housegroups like this and it seems as if a distance of about 50 to 100 metres between them was considered as deliberate. This was a kind of rural pattern used in an urban context. At the same time, a very dense concentration of houses was built up close to a shop in the area with 50 houses clustered on less than 0.7 hectares. The settlement was so dense that only a few more houses could be infilled during the following years. This was a kind of "workers' compound". The supply of houses for workers was never adequate and employers used to arrange for a site where the workers were allowed to provide themselves with shelter as best they could. Such compounds have been the nuclei of many squatter settlements.

In the years after Independence in 1964, a stream of impoverished rural population ended up in Lusaka. George and other squatter settlements expanded enormously. The new constitution ensured that everyone could settle where they wanted - a reaction to the colonial pass laws. The urban economy was expanding and building activity was high. There were lots of jobs in construction even for unskilled workers and the rate of unemployment was kept fairly constant - about 10%, depending on definition - in spite of an annual growth of Lusaka of up to 17%.

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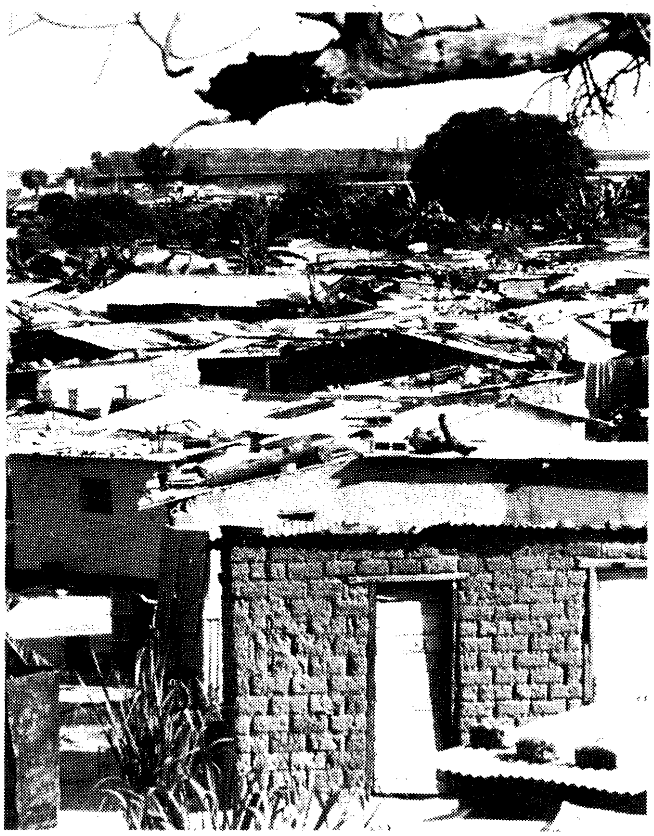
* Schlyter. Ann & Thomas. George - the Development of a Squatter Settlement in Lusaka, Zambia, Stockholm, 1980.

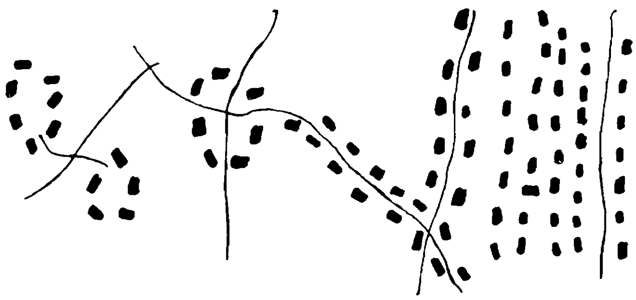


George was one of the largest squatter areas and it was situated close to the heavy industrial area. The settlement soon covered all available good land. The only open spaces which were left were swampy areas and plots around former farmhouses as long as they were protected by their owners. The density was fairly even, between 40 to 60 houses per hectare, which meant an average percentage of land occupied by houses of 20%. Newcomers built houses with a density of about 40 houses per hectare, but already after a year the density was about 50 houses per hectare, due to infilling.

The individual settler proposed the site for his house but it had to be accepted by neighbours and party leaders. A kind of concensus developed about what was a desirable density. If an individual settler wanted a greater distance from the neighbours, he could choose such a site, but he could hardly protect a large area from infilling.

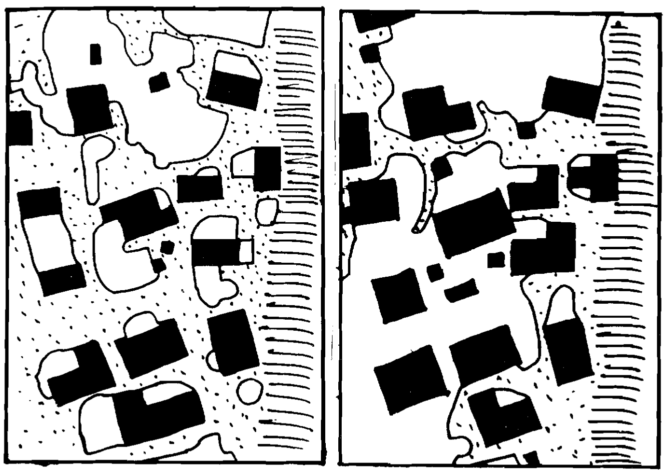
The most significant feature of the urban pattern of George was the absence of demarcation of plot limits. The houses were surrounded by scattered cultivation and in front of each house an area of about 20 square metres was swept. The swept area was regarded as an outdoor living room and people spent a great part of their time there, but no arrangements were made to ensure visual privacy from neighbours or others passing by. On the contrary, the women frequently talked to each other during their domestic work and the children played there together. Nevertheless, the swept area was regarded as private or semi-private land; an adult visitor hesitated before setting foot upon it. No fences were needed.

The location of the houses, doors and swept areas was very carefully considered when the house was built. Different principles of urban pattern coexisted and overlapped. One pattern was a free grouping around a common area. This area was not always left as open space but could be cultivated in small plots between a network of paths. It was public in the sense that it was overlooked by many. Another pattern was to build along existing paths and roads. During the last years of expansion, the principle of building houses in straight lines predominated. The grouping around a common area indicates an urban pattern which was also maintained when building according to the two other patterns. The houses along the roads faced each other and the road could be regarded as just a long, narrow variation of the common open space. Even when the houses were in line, the location of doors and swept areas and the arrangements of open spaces were such that common areas were created for groups of houses.



The pattern was also influenced by climatic and geographical preconditions, such as prevailing wind direction and slopes. About half the doors were installed in the western wall of the houses, while the eastern and southern walls tended to be avoided. The walls facing towards uphill slopes were not used as front walls due to risk of flooding during heavy rains. In spite of these restrictions, the pattern of grouping houses around a common area was maintained.

The urban pattern was continuously changing even within the existing structures. Traffic of heavy vehicles increased as the number of shops grew. Many houses facing the roads were changed so that the front door was blocked up and a new door opened facing a new swept area on the other side of the house. Other houseowners put up fences to protect their swept areas from motor vehicles. Many smaller roads were blocked to traffic, thus creating a protected space, used as a common play area or for cultivation. Vehicles always find new routes. There was a shrinkage of the common space. The predominating process causing this was the increasing density due to infilling with new houses and extensions of existing ones, making the use of remaining land more intensive. The need of space for children's play can be taken as an example. In 1969, the children could play around houses and gardens. In 1977, the land which was accessible for playing had shrunk so that only roads and narrow strips of land were left, apart from the swept areas which were of a semi-private nature. The figure shows an example. The white area is land which is not accessible, mostly swept areas and cultivation. The striped area is a road and the dotted area could be called "children's open space".



1969 1977

Another threat to the tradition of having common space might be an emerging market where title to land is bought and sold as a commodity. The legalisation of squatter areas to "improvement areas" was made together with the formal acquisition of land from absentee landlords. The houseowners were licensed to live in George through a kind of title to the land on which their houses were situated, but exact plot limits were never defined. In a market economy with shortage of houses, political control to avoid speculation will probably not be enough to prevent the titles to land from acquiring a certain monetary value. If this value can be realized by a sale, the exact limits of the commodity - the plot - will probably have to be defined. Such a definition will certainly strengthen the image of the plot as a private property, but will not necessarily imply a more private utilisation, though with the increasing shortage of land it is probable.

With the expansion of the settlement followed a shortage of space for cultivation. About 10% of the land within the settlement was used for small gardens. In addition to this, about half of the households also had cultivated land outside the settlement. The low level of wages and the rate of unemployment made this contribution to family subsistence necessary. The gardens were also a security for the women who had few possibilities of getting incomes if they were widowed, divorced or just left without support. Large tracts of land became cultivated as the number of inhabitants increased. An estimation is that an area about twice the size of the settlement was cultivated outside George. One third of the distant gardens were situated at more than one hour's walking distance.

The great expansion of George also affected the way density was experienced. One might tolerate living close together in a small settlement but feel captive in the middle of George. When asked about the greatest problems in George, every sixth person complained about things connected with the density. They said that there was no room for extensions of the house, for a garden, for a new pit latrine or for the children to play.

Need of Indoor Space

Residential density, measured in terms of the number of persons per spatial unit, is an often used aspect in the evaluation of a housing situation. Overcrowding is defined at a certain level of residential density. A definition of overcrowding can be used normatively as a goal for housing policy. Zambian authorities have avoided defining a specific level as standard. A political goal of such a concrete character must not be set too far from what is possible to reach. At the same time, the politicians do not want to set a goal lower than what they consider to be a decent standard.

The UN once defined overcrowding as the situation in which more than two persons are living in one room. This standard applied to the Zambian situation would mean that three-quarters of all dwellings were unsuitable for accommodating the average household of 4.6 persons. To what use is such a definition? It can be seen as a description of the poverty of Zambia, but if the purpose was only to describe and make comparisons it would be better to talk about residential density.

The living space in rural Zambia is not restricted to one or two rooms. A large swept area is used for outdoor living, a separate kitchen and special structures for storage also added. It is obvious that no standard can be generally applied regardless of organisation and use of space. Taking these things into account, the concept of overcrowding should be used only if the space is not adequate for the activities performed. Such a functional definition of overcrowding is better than a static definition, but still problematic, because it takes neither the dialectics between activities and physical structure, nor the subjective feelings, into account. According to domestic habits and climatic factors, a large part of Zambian rural housing might be regarded as adequate, but we do not know how domestic habits would develop if people had resources to build better houses, and we do not know how people experience their residential standard.

Many investigations have proved that it is difficult to grasp the individual experience of overcrowding by putting attitude questions. Another approach is to look at how people actually behave. In a situation of housing shortage and no choice this approach is difficult to apply. In a squatter area, it was assumed the house-owners have some possibilities of allocating their very limited resources to extensions of their houses if they regard overcrowding as a very serious problem. One could thus expect to find in George an evenly distributed residential density at a standard which is accepted under the specific conditions.

The assumption was supported by statistics which showed a higher residential density in rented houses owned by city councils or mining companies than in the squatter areas. It was likewise supported by an analysis of residential density and the use of space in 60 houses in George during the period 1969 to 1977.

In 1969, the average size of the sixty houses was 15 m^2. There was a great variation from small to large houses and the variation was, from the beginning, correlated to family size. Many young families moved into George and the number of children increased. The average amount of space per person, however, remained constant at 6.5 m^2 over the years. It is reasonable to assume that if residential density was experienced as a great problem, people who could afford it would extend their houses. However, extensions were fairly evenly distributed over the different income levels and so was the residential density.

The houses in George presented a great variety in form and layout. The size and location of rooms seemed to be adapted to individual needs; many rooms were built just to fit a bed, for example. Furthermore, there was a continuous adaption of the houses to the changes in the household. For example, a door between two rooms was closed and a second entrance door was opened to get a separate room for grown-ups or for tenants.

During the last few years, more and more houseowners let a room in their house to tenants. In spite of this, the residential density did not increase among the houseowners. A tenant household usually had only one room. Most tenants were single men but those who had children were the most crowded category, with three persons per room.

A subjective feeling of overcrowding is connected to the need of space for privacy. A large part of the domestic work took place outside. The indoor space was used as shelter against rain, for eating and sleeping, and for storing things. No-one seemed to care about visual privacy in the swept area. The front door was often left open, but the contrast between the dark room and the light outside made it difficult to see anything from outside. The semi-private character of the swept area made a buffer zone, so that visitors stopped some steps from the door, calling "hello!" As soon as a house had more than one room there was a functional division between the rooms and the inner room became the most private. Here was the parent's bed and here valuable things were stored, but there was seldom a proper door between the rooms.

Another aspect of privacy is noise disturbance from neighbours. The gap left between roof and walls makes it easy to hear the tenants conversation. One-family houses undoubtedly have advantages in this respect.

The organisation of dwelling space has developed from "one household in a couple of houses with one room" to "one household in one house with a couple of rooms" and further to "a couple of households in one house with a couple of rooms". The organisation of dwelling space has changed, reflecting changes in domestic habits, economic positions and possibly also by idealogical influence.

Two persons per room has been accepted residential density in George. This must be seen in relation to the organisation of space and the use of indoor and outdoor space, and also in relation to the quality of the houses. The most important quality of the houses was that they were cheap so that people could afford to build them. If there is a change, so that people can afford better houses which makes indoor life more pleasant, the demand for space can increase very rapidly.

Conclusions

To sum up some experiences from the study of George, it is obvious that George is in many respects a poor housing area. Concerning the need of space, however, some features can be seen as qualities:

- An adequate use of space in as far as the urban pattern was adapted to social and domestic habits, as well as to climatic and geographical preconditions.
- Indoor space was amazingly well adapted to the size of the households, due to the possibilities of extending and changing. Overcrowding was not a crucial problem.

There were also problems:

- The continuing building process with infilling of houses made the density too high, even if it had been adequate from the beginning.
- The density measured in persons per hectare increased even if infilling of new houses was stopped, due to extensions of existing houses and letting of rooms to tenants.
- The number of tenants was increasing. They did not have the same possibilities as houseowners to adapt the size and form of the indoor space to their needs.
- Two or more families in one house might cause friction and thereby a feeling of overcrowding.
- The increasing size of the settlement caused shortage of land for cultivation which provided a necessary contribution to the family resources.

During the Seventies, a large number of countries changed their policies towards squatter settlements. Ideas of resettlement and bulldozing were maintained during a long period, though "acceptance through ignorance" would be a more correct description of the policy actually carried out. The new policy was "acceptance through improvements". The squatter settlements were to be upgraded, primarily to reduce the health risk caused by wells which became polluted by pit latrines, a risk which increases with density. In George, the urban pattern with its qualities was maintained in the upgrading and the owners will continuously be able to adapt their indoor space to their needs. The problems in George, as in other squatter areas, are basically related to limited family resources. Scarcity of national resources caused the changes in national policies towards upgrading rather than the recognition of any qualities.

Summary

This paper is a contribution on the theme "Basic Need Related to Family and National Resources". An analysis is based on the study of a squatter area in Lusaka, Zambia. The focus is put on one particular aspect of housing - the need of space. The need of outdoor space is discussed in relation to density and urban pattern. It was found that the outdoor space was created to fit social and domestic habits as well as physical conditions. The indoor space showed to be amazingly well adapted to family size. Overcrowding was not regarded as a great problem.

Planning of Housing Developments and the Social Environment

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Ole Jensen, Cand. Psych., Danish Building Research Institute, Denmark.

English summary

The technical and functional housing standard is high in the Scandinavian countries. But the social activities are rather limited in many of the large housing developments of the latest decades.

The present article goes through two recent Danish housing studies, which have looked into the interaction between the physical setting and the social environment among the residents.

The results show that an active and close social environment can be furthered by a conscious planning of the physical environment near the dwellings and by the organizational structure, i.e. the way residents can participate in decisions concerning housing conditions in the development.

Background

Housing standards in the Scandinavian countries are among the highest in the world. In today's Denmark there is thus more than one room per person, and more than half the population live in dwellings built after World War II, mainly even after 1960.

The technical and functional standard of the dwelling is relatively high. The floor space ratio of newly built housing is low and the quality of outdoor areas is quite good.

A considerable portion of the rental housing from the mid-fifties was built as flats of prefabricated elements in - for Danish standards - rather large developments consisting of as many as a couple of thousand dwellings. See "Figure 1".

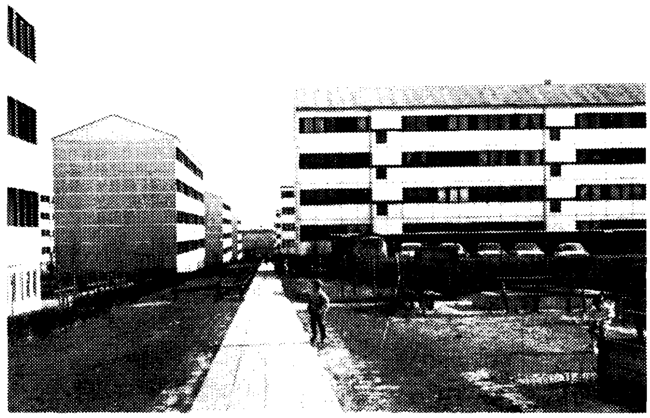

Figure 1. A typical Danish development from the 1960s.

During the 1960s a quite widespread public debate arose in newspapers, radio and television concerning the housing and living conditions in these developments. Briefly put, the debate - among other things - dealt with their lack of life and activity, their monotony, the uniform resident group and the alienation and loneliness of the individuals.

This debate should be viewed partly in the light of the fact that, on one hand, the most urgent housing needs had been taken care of, which also had been the exact aim of the big housing construction during those years, and, on the other hand, that the quality and size of the dwellings themselves had been improved. Consequently, there was room in the debate for the recognition that "to be housed" meant more than having a roof over one's head, hot and cold water, etc. In other words, housing was also a question of social living conditions.

Housing research in Denmark up until the 1960s had mainly been preoccupied with partial problems concerning function, plan and dimensions of the dwelling, in other words, the very aims which house building had started to fulfil in practice during the 1960s.

The scope and field of the housing research expanded during the '60s - among other things - as a consequence of the housing improvements and the above mentioned public debate.

In this research the idea of being housed was related to a series of needs which, over and above those derived from basic physiological and safety needs, also consisted of psychologically and socially determined needs such as contact, experience, and identity. The big, monotonous housing developments of the '60s often provided rather slight possibilities for needs like these to be met.

"Being housed" was to be seen as a process and an interaction between the residents and the total environment in the housing area.

In order to study these conditions, the Danish Building Research Institute had undertaken two studies which will be summarized below:

1: Satisfaction, well-being, and social norms in 12 nonprofit housing projects in the Greater Copenhagen area.
2: A housing environment study in a recent low-rise high-density development: "Galgebakken".

1. Satisfaction, well-being, and social norms in 12 nonprofit housing projects in the Greater Copenhagen area

In order to throw some light on the residents' interaction with the housing environment, a study of 12 housing developments from the '60s was undertaken.

The study includes approximately 1.800 - mainly - large family dwellings in ordinary blocks of flats, multi-storeyed houses, rowhouses, and atrium houses. It was carried out by means of questionnaires addressed to the housewives. The study deals with the residents' satisfaction with a number of concrete physical conditions in the development, which will not be further discussed at this point, because the present article will concentrate on the results concerning the social environment.

The social environment

The social environment in the housing developments of the '60s is illustrated in the study through an analysis of the residents' experience and evaluation of:
- contact relationships between the residents
- the restrictions which they put on each other
- the attitudes of the adults concerning the behaviour of children and youngsters
- possibilities of participation in the running and management of the development.

Contacts

The results of the study show that most of the residents say hello to each other, talk together a little, some once in a while look after someone else's children or run smaller errands for them, but few actually help each other substantially, eat together, etc.

In other words, the contacts between the residents are characterized by rather friendly, but quite superficial, uncommitted and somewhat dissociating attitudes.

The dwelling is more or less closed country for other residents. Most people express their satisfaction with the possibility of being able to be by themselves, and many people enjoy the contact they have with other residents. Meanwhile, it can be noted that the residents who experince the highest degree of general weelbeing, are those who have the most contact with other residents in the development.

It can be illustrated that the level of contact is influenced by several physical conditions, so that, for instance, the level is higher in atrium and rowhouses than in flats and multi-storeyed houses, and also higher in housing areas with relatively good recreational areas outside the dwellings.

Restrictivity

The residents of the more recent housing developments impose on each other rather heavy restrictions, e.g. with regard to activities outside the dwelling. Among other things, one is not allowed to decorate the facades and doors, change the recreational areas, keep their garden untidy, and put out laundry to dry visibly. The residents thus give themselves rather limited possibilities for using the outdoor areas freely, leaving their mark on them, and expressing their own wishes about them.

It can be demonstrated that attitudes can be less restrictive as a consequence of certain physical conditions such as low density of population and when the dwelling, terrace or garden is protected against overlooking, and when recreational areas and possibilities for outdoor activities are good.

Furthermore, the study shows that individuals who feel most comfortable as residents are apt to be less restrictive towards other residents.

Attitudes to the behaviour of children and youngsters

The conditions of the children and youngsters in the housing area are primarily set by adults and the attitudes they share concerning the behaviour of the young.

In principle, the adults share the belief that children and young persons should have a voice in the arrangement and use of recreational areas. Quite a few agree that the conditions of children and youngsters are poor. And yet, in practice, there is only a weak consensus about letting them change thes areas, build houses, move or paint the things in the playground, etc.

Once again, the attitudes vary with the physical conditions, so that residents in atrium houses, with a closed garden, are relatively more liberal, whereas those who live in ordinary flats are less liberal. In housing areas with open gardens and poor protection against overlooking, and where there is also good possibility of watching from inside the house what goes on outside, one finds a relatively restrictive attitude. In other words, "What one doesn't see, one doesn't care about".

The residents who are the most liberal with regard to the behaviour of children and youngsters, also display the highest degree of well-being concerning the housing conditions.

Participation

The study shows that the residents are attentive and interested concerning participation in the matters of their own housing area.

In co-operative housing associations, which is the king of housing organization that offers residents the best influence on their housing conditions, one finds the highest frequency of residents who experience and are satisfied with their participation.

Slightly more than half of the residents generally want a higher say in their own housing conditions.

Residents with children are comparatively more dissatisfied on the question of influence, which most likely should be seen in connection with the quite widespread dissatisfaction with the conditions offered to children and youngsters in this housing development.

In general, the residents are more content the more the administration of the development leaves them with possibilities of satisfying their wishes and influencing decisions which affect conditions in the housing area.

The social environment - an interaction

As mentioned above, this study shows that there is a connection between a large degree of well-being as residents and each of the following conditions: a high level of contacts, a low restrictivity, a liberal attitude toward children and youngsters, and the experience af having an influence.

Furthermore, the study illustrates the existence of an interaction between these social conditions. When there is a good contact between the residents, there are also fewer restrictions, a more liberal attitude to the behaviour of children and youngsters, and a lower degree of perceived influence. See "Figure 2".

In other words, the more people know each other, the more secure and confident they feel, the more liberal

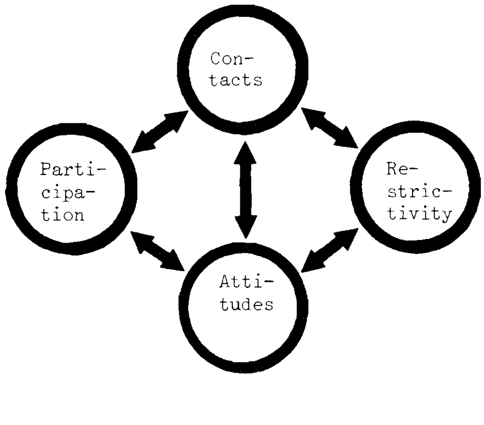

Figure 2. The figure shows the mutual interactions between **four** social conditions.

can one be towards each other and each other's children, - or vice versa: if residents do not talk to each other, they become alien and insecure to each other and restrictive in their mutual attitudes.

What is the more important: the physical or the social environment?

On the basis of the present study, one could not settle the question of whether the social or the physical environment is crucial for the well-being of the residents. Rather than being faced with a choice between the two, the results show that one should think in terms of "both-and".

The study reveals that the environment must at least satisfy two superior sets of needs.

One of them has to do with the idea that the housing environment - in addition to satisfying a number of basic physiological and security needs - should also offer residents the possibilities of being able to carry out easily a number of practical activities.

The other set of needs has to do with the residents' personal self-realization, in the dwelling or out in the open areas, and also socially in the relations to other residents and through influencing their own housing conditions.

2. A study of the housing environment in a recent low-rise high-density development: Galgebakken

On the basis of what was demonstrated in the first study about the relationship between physical conditions - first of all dwelling type and outdoor areas - and social environment, we carried out a second study in the low-rise high-density housing development of Galgebakken. Its purpose was to study in detail the interaction between the physical setting and the social environment, first of all the influence of the environment near the dwelling.

The physical setting of the housing development

Galgebakken is a nonprofit housing development consisting of 570 atrium or row houses and 74 one-room dwellings. Construction took place in 1973-74, and the site is about 15 kilometres west of Copenhagen.

The houses are placed in clusters ranging from 8 to 20 units and often with a combination of different types of houses in the same cluster. See "Figure 3".

In each cluster the houses are placed in two rows on each side of the common dwelling lane. Each house has its entrance door and front with the kitchen-dining room facing the lane and a small front area. The size of the houses ranges from 58 to 130 square metres.

The private, enclosed garden is placed on the other side of the house facing the similar gardens of the neighbouring cluster.

A small number of clusters make up a neighbourhood with a common neighbourhood lane into which lead all the dwelling lanes. There are 9 such neighbourhoods in the development.

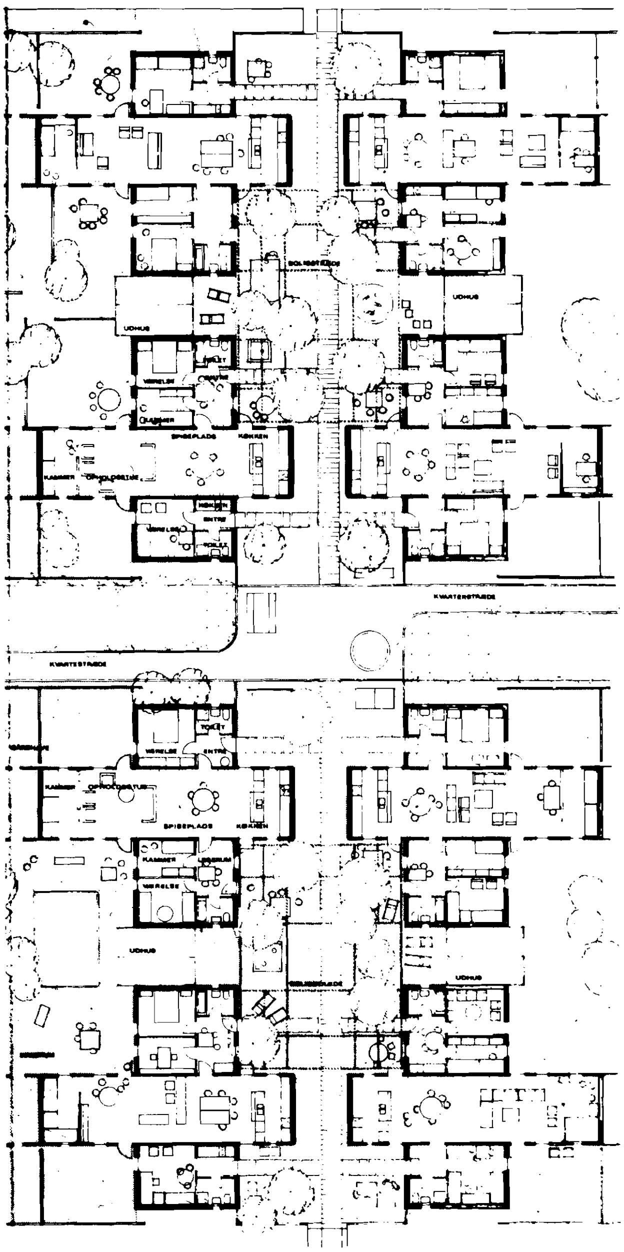

Figure 3. Plan of a dwelling cluster consisting of 8 atrium houses. The dwelling lane runs (vertically in the figure) between the houses.
Scale 1:650.

All the neighbourhood lanes lead into the communal lane, which is a wider common area as well as a lane running right through the built-up area to the Square, where one finds the communal facilities of the development: day care institutions for children and teenagers, community clubs, a shop for convenience goods and a common laundry.

On the outskirts of the development one finds a green common for ball games and other activities.

The housing area is traffic-safe. Parking grounds are placed on the outskirts of the built-up area and in two enclosed parking "pockets" stretching into the area.

Dwellings and households in the study

The study included 11 dwelling clusters, whereof six consisting solely of atrium houses, four had mixed sized rowhouses, and one cluster had a combination of both atrium and rowhouses. The six clusters of atrium houses had 8 houses each, whereas the clusters of the remaining two categories had either 16 or 20 houses each.

Altogether, the study included 100 households. Roughly 50% of them were married couples with children. Compared with other rental housing developments, Galgebakken has a higher percentage of functionaries and more persons with a higher educations and students.

The composition of residents varies somewhat in the clusters depending on dwelling type and size.

The study was carried out by means of questionnaires and intensive interviews with residents.

Social activities in the development

The study shows that social activities among the residents are significantly more comprehensive and rich than commonly seen in rental housing developments. Activities mostly take place within the clusters, but also in the development as a whole.

Inside the cluster the social environment is characterized by a frequent and close contact between the residents.

People help each other with practical things and problems, e.g. by looking after each other's children or baby-sitting in the evening. They also run errands for each other or help doing practical things in the house or garden.

75% of the residents regularly have meals together with other residents in the cluster, particularly in the summer time, when eating often takes place out in the dwelling lane.

A little less than 35% of the residents go in for a hobby or other spare time activities (such as sports) and 16% of the residents participate in different interest groups (such as a women's group) together with other cluster residents.

The residents in a cluster meet regularly in order to discuss matters of common interest. They decide on and carry out themselves changes in the lay out of the dwelling lane, such as new plantation or surface on the path, building of a playhouse or setting up of a sand box, putting up common dining tables or a grill, etc.

The dwelling lane as well as the private front areas, which are adjacent to the lane, were from the beginning laid out as rather unfinished areas, which the residents themselves were to furnish. Many residents have combined their front areas or even let them be part of the common dwelling lane. See "Figure 4".

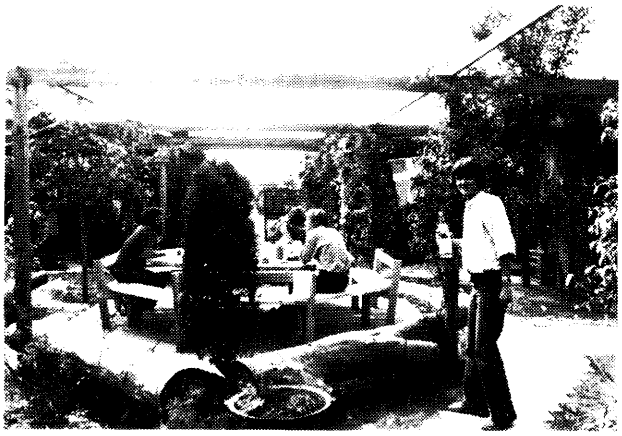

Figure 4. A picture of a section of a dwelling lane in a cluster of atrium houses.

At meetings in the clusters, matters concerning the whole development are also discussed, because all major questions concerning the development in general must first be discussed in each cluster before decisions can be made in the development as a whole. The cluster then sends its representative to the counsil of residents which decides on matters of general importance.

There are, of course, households and individuals who do not participate in the social activities which take place in the clusters - but they are a minority. Thus only 9% said that they never pay visits to or have visits from other residents in the cluster or the housing development.

Although social activities take place first of all within the single cluster, many residents also carry on extensive activities and social life with residents of the development at large.

42% of the residents hold private parties with other residents. 25% of the residents go in for hobbies or other spare time activities (such as sports) and 23% participate in interest groups (such as a women's group) together with other residents in the development outside their own cluster.

In addition to this, there are a number of activities in the development which many residents take part in more or less frequently, such as different kinds of clubs and more or less permanent communal activities (e.g. eating groups, communal parties). There is also work to be done in connection with editing Galgebakken's monthly newspaper and running the residents' own grocery.

And, finally, there is a substantial meeting activity in the development as part of the organization which was set up in order to give each resident a say in the affairs of the housing development, with the cluster meeting, mentioned above, as the basic element. - As Galgebakken is a section of a nonprofit housing association, which is a co-operative organization, the residents elect their own sectional committee to represent their interests, partly with regard to the daily operations of the development, and partly in the relationship between the section and the housing association, including decisions taken by the latter concerning the section.

In recent years there has been an increased meeting activity, because a majority of the residents at Galgebakken periodically have carried out a rent boycot of the annual increases, which had been proposed by the housing association.

Social activities among the residents will, naturally, always be influenced by the people who live in the development, i.e. their personal interests and social attitudes. At Galgebakken the housing association from the very beginning carried out a special hiring out campaign, in which it emphasized the possibilities given to the residents of that development of leaving their own mark on their close environment and having a say in the development's affairs. Some of the residents of Galgebakken, having been attracted by this campaign, can therefore be said to be rather conscious of the idea of "being housed" and "good housing".

The nearby physical environment, the organizational structure and the social environment

The results of the two studies show that both physical and organizational conditions influence the social environment of a housing development. These conditions each have their significance for the social environment, but to an even larger extent the important point lies in their mutual interaction.

In the planning of a housing area, the creation of an active and close social environment can be furthered by a conscious planning of the physical environment near the dwellings and in the set-up of the organizational structure of the development:

Physical environment:

- Small dwelling groups with 10-20 dwellings as the basic units of the development with attached small, common facilities,

  The placing of a small number of houses in a clearly delimited dwelling group gives the residents the possibilities for closer daily relationships to a limited number of people, and thereby a chance to become firmly rooted in a social group.

- Nearby areas (e.g. square, lane) around which the dwellings are gathered, and which the residents, in common, can arrange, leave their mark on, and dispose of.

  The gathering of houses in a dwelling group around a common area which the residents must pass in order to get to their own dwelling, has the consequence of making them meet more often and thereby creating a basis for further contact.

  See also below under "Organizational structure".

- The design and orientation of the dwelling is made so that rooms for everyday activities (e.g. kitchen) are facing and "open" toward the dwelling group.

  In this way one is better able to see what goes on in the area close to the dwelling group and immediately get in contact with other residents.

- An unfinished small front area for each dwelling, which can be given character by the resident himself.

  The front area of each dwelling directly adjacent to the common area of the dwelling group, is used quite much by the residents, e.g. for eating and simply being outside. When in the front area, the residents thus has a legitimate reason for being outside, and there is an easy access to contact with other residents in their front areas and persons walking by.

  The front areas and the common, traffic-safe nearby area of the dwelling group give especially the small children good possibilities for play. Through playmates, relationships between adult are also established.

  The possibilities for residents to design and influence the front area of the dwelling, individually or together with neighbours, give them a chance for personal self-realization an a stronger sense of belonging in their dwelling and dwelling group.

Organizational structure:

- The residents' participation in decisions concerning the housing area should be structured in accordance with the physical structure of the development, i.e. with the dwelling group as the basic unit. The participation concerning the dwelling group should be given a genuine quality and potential, i.e. autonomy with regard to the dwelling group's own common areas and facilities,

  Participation in the common decisions in the dwelling group concerning the lay-out and use of the group areas, and the actual work making changes, on one hand mean a chance for the residents of influencing their own living conditions, and on the other hand they get to know each other better and have a chance to work actively together. At the same time this often leads to a liberal attitude among the adults concerning the children's self-expression and play in the common areas, because the adults themselves are engaged in making things for the children.

  The residents' participation - in dwelling group meetings - in the process of discussing matters of general interest for the development as a whole, gives them a better insight in and more influence on the conditions in the housing area. It enlarges their interest in the development and its common facilities.

In all, a housing development planning which concerns itself with the physical design as well as the organizational structure, starts in the dwelling and the dwelling group, i.e. in the everyday environment near the individual resident.

A planning of this kind would probably be more easily carried out in a low-rise high-density housing project. This particular way of building has been stepped up in Denmark in recent years and now amounts to half of all new rental housing building.

The value of the social environment

One can expect that in the years ahead there will be an increased interest from various quarters in housing developments planned with possibilities for creating a good social environment.

A good social environment, of course, has a value of its own for the everyday life of the residents. For about half of the Danish population (including housewives, children, pensioners) the home environment is the most important setting for the everyday life.

A good social environment could also cut down on the amount of wanton destruction of property and thereby reduce the operational expenditure.

The social environment may, however, have its largest future impact as the principal component in the social network, which every individual needs to be rooted in, but which many people find it difficult to establish in times, when many conditions in society change more and more rapidly. If things develop in this direction, a good social environment in housing developments could lead to a reduction of public social welfare expenditure.

Dwelling Habits and Dwelling Standards - Results of an Interview Study on 308 Swedish Households

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Summary

A study of dwelling habits was carried out at the National Swedish Institute for Building Research in 1976. It furnished a fairly comprehensive, though not statistically representative, picture of dwelling habits, which we subsequently compared to the manner in which a dwelling is used, or should be used, as reflected in the Swedish Standards relating to this field.

In this paper we describe the development of the Swedish kitchen from the small compact unit of the thirties to the spacious and well-equipped ones of today. During this process of development the importance of the kitchen has grown as a result of the increase in floor area and the standard of the fittings and equipment.

The living room has to a large extent become the TV room. The television can be difficult to fit into the "status room" that one would still like the living room to be, and it easily paralyses all other activities. Many people have an ambivalent attitude to the TV that makes it more than just a furnishing problem.

Children need larger bedrooms than do adults. In the Standards the bedroom intended for the parents is larger than that for the (two) children, but in reality children who must share a room usually get the largest bedroom, and this may have other disadvantages. For this reason all the bedrooms of a dwelling intended for two persons should be equivalent in their area, furnishability and, if possible, location.

Introduction

In a dwelling-habit study carried out in 1976 at the National Swedish Institute for Building Research 308 households were interviewed, their dwellings were photographed and the furniture was drawn in on plans. The households varied in size and the members varied in age, as did their dwellings. The study furnished a fairly comprehensive, though not statistically representative, picture of the dwelling habits. This impression of the actual state of affairs was then compared with that of how a dwelling is, and should be, used, as reflected in the recommendations and prescriptions contained in the Swedish Standards relating to this field, referred to in the following as the Standards.

In the forties, fifties and sixties a number of dwelling studies were performed in Sweden with the purpose of checking and improving dwelling standards. An important component of these studies were questionnaires which required quantifiable answers. In the seventies, when the present study was being conducted, there prevailed an attitude of scepticism concerning this kind of survey, and it was felt that new avenuse of approach should be explored. It was considered, moreover, that because dwelling standards and planning are actually based on functionalistic grounds a functionalistic analysis of them can never be sufficiently independent.

We accordingly adopted a dual approach, and to the simpler questions of traditional type we added analytically more complex questions. We therefore have both detailed descriptions of each household and coded data that can be summed vertically and horizontally.

An attempt will be made here to indicate the background to the Standards and dwelling habits that are current today and to supplement this with a selection of the results of our own recent research. While it is true that the conditions about which we are writing are certainly closely linked with our Swedish material standard and our traditions, they are also consistent in some measure with changes of a more international nature. The development of television is one example.

In this paper comparison is made to minimum requirements for area distribution in a family dwelling worked out by IFHP*.

The importance of the kitchen has grown with its floor area.

The Swedish kitchen, today, is large and well-equipped in conformity with the Standards and with the preferences of the household; but it has taken half a century to reach this point. So far as we can see, the Swedish dwelling differs from those in most other countries chiefly in respect of the size of the kitchen and the importance assigned to it. IFHP recommends a small kitchen and location of the dining area for the daily meals in a large living room. It is at just this end that we began in Sweden in the thirties.

* International Federation for Housing and Planning, Standing Committee, Rent and Family income, Renewal of the Cologne Resolutions, Luxemburg, 1971.

The Stockholm exhibition held in 1930 marked the breakthrough of functionalism in Sweden. Besides sun, light and air a social dimension was introduced into the design of the dwelling. It was a difficult task to relieve overcrowding in the lower strata of society by dividing up the small area in accordance with the functionalistic model. The most important task was to arrange quiet and undisturbed sleeping quarters, and as many as possible - though not in the kitchen, on grounds of hygiene. The small compact kitchen - a German concept - fitted well into this impossible equation - theoretically. Meals would be taken in the living room. The living room was something new and the term was stamped in the weave.

Dwelling-habit studies showed, however, that it was only in middleclass families that meals were taken in the living room. Working-class families ate in the kitchen, as they had been accustomed to doing, however, cramped it may have been. In addition they performed, or wished to perform, most other household duties in the kitchen - never in the living room as it was thought.

Much was learned from the dwelling investigations, and in the Standards the kitchen was soon furnished with small areas for daily meals. Study of these kitchens showed that it was not only the housewife´s working place but also the room where the young children played and the older ones did their homework. Because the daily meals were taken there the kitchen became the place where the whole family came together.

In the early sixties the dining area in the kitchen, as prescribed in the Standards, was further enlarged in the more spacious dwellings, in the hope that guests might also be entertained in the kitchen. This is what in fact occurred. In our study carried out in 1976 we noted a tendency to use the kitchen also for meals on festive occasions, and besides this other activities shared with the visitors were being located there. With the large dining area prescribed by the Standards it became possible to introduce other furniture into the kitchen, since the dining table and chairs were by no means as large as the Standards recommended. The importance and the use of the kitchen was increasing with its floor area, and so far as we can judge from our study the limits for the activities that can be located in the kitchen have not yet been reached.

<u>The living room has become a TV room.</u>

The planning in the thirties, forties and fifties was carried out on a wave of optimism. A rapid development in standards was foreseen and the day was evidently not far off when everyone could be sleeping in bedrooms. But this was not to be, and the living room was converted to a bedroom at nights. It was an expedient solution, which efforts were made to conceal in the daytime. In spite of, or perhaps because of, the shortage of space in the apartment, there was a common desire to have a best room ("status room")*, which was always neat and tidy in readyness for the unexpected visitor and for use on festive occasions. Herein lay the reason for the reluctance to bring the meals into the livingroom.

The tradition of the best room , which meant that the largest room in the dwelling was almost never used in the daytime for everyday purposes, was highly irrational from a planning aspect. It seemed the logical step was to eliminate it by the design of the dwelling. If only weekday meals could be forced into the living room these deep-rooted habits might be broken. The concept of the small compact kitchen survived several studies on dwelling habits where a different situation was envisaged. In the fifties experimental apartments were designed with a small kitchen and the dining area in the living room. Studies carried out shortly afterwards showed, however, that the experimental apartments were not being used as intended in the plans.

Most households were eating in the extremely small kitchens, and the living room was still kept as the best room . The study was repeated in the sixties, by which time it was considered that the rational ideas behind the plans would have been recognized and accepted. In fact, no change in this respect was evident.

With the improvement in space standards the sleeping accomodation was shifted to the bedrooms and much of the entertainment of guests to the kitchen. The large widely used three-piece-suites could be given more space, and at last the dream of a proper best room would be realized. At this point the TV was brought in. It compelled not only some rearrangement of the furniture but also a break with old habits.

When the Swedish dwelling standards were reviewed at the beginning of the sixties, the TV was in the picture but a wait-and-see attitude prevailed. In the seventies many began to entertain doubts about the TV, or even to adopt a negative attitude to its predominance in the home. While dwelling standards were not, of course, the right medium for modifying

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* The English word best room is perhaps as near as one can get to the Swedish "finrum"; some dwelling habits, not surprisingly, have a characteristic national stamp. "Status room", a direct rendering of the Swedish "statusrum", has the same connotation, and it, too, is hardly heard among the general population, who tend to prefer the equivalent of "living room".

TV viewing habits it would seem that in the Standards issued from 1975 onwards the antipathy to TV was recognized simply by treating it like any other piece of furniture having no bearing with the seating in the room. How can TV viewing be accomodated with the Standard sofa with two easy-chairs opposite?

Most households in the investigation had their TV in the living room as recommended in the Standards. But they generally did not want it to be there because it paralysed any other kind of activity. This attitude was, of course, more accentuated in larger families.

Where possible - that is space was available - the TV was moved to a room not needed for sleeping in, or else to a multi-purpose basement room. "We spend much too much time looking at the TV" is a complaint heard in many housholds. TV viewing, which takes up the weekday evenings to the neglect of other things, is, it would seem, often the real reason why the TV is relegated to a room of minor importance, in the hope that it will then become less attractive. What eventually happens, however, is that the room containing the TV becomes well utilized, in terms of time. A living room where there is no TV, on the other hand, is easily reduced to a best room in the sense that it is used very little for everyday purposes, and in any case very little by any children in the household.

So far as we can see from the photographs and the furnished plans, the TV room, unlike the living room that was not used for TV viewing, became a multi-purpose room where children played and the grownups pursued various kinds of activities. TV viewing, just as housework in the kitchen, was a magnet around which all the members of the family gathered sometimes while engaged in various other occupations. The TV room, however, was furnished with simpler furniture facing the TV rather than, as in a living room with or without TV, placed around a coffee table. In the living room comparatively few seem to have accepted the implications of the long time devoted to TV viewing by converting it to a "viewing room".

Some households had more than one TV set. Besides the large colour TV in the living room or the common TV room, there was often one in the room of teenagers or in the parents´ bedroom. This may be one solution of the situation where the TV comes into conflict with other activities pursued in the same room. We suspect that the TV in the bedroom was often the old black and white set from the time prior to acquisition of the colour TV, and that it was not often used.

Attitudes to the TV vary and the household´s solution to this problem will depend to a large extent on the space available. With an average space standard where there is one reception room, the living room, the TV is, however, placed in there. The Standard sofa with two easy-chairs opposite is obviously inconvenient for TV viewing. We Have examined various types of seating with respect to the use and position of the TV without being able to draw any conclusions. We believe, however, that the increasingly common corner sofas have become so popular because they can be combined fairly easily with TV furnishing - in any case better than the formerly predominant Standard furnishing. It is nevertheless remarkable that there are so many variants, and there is little point in taking any particular one as a standard. Instead a large furnishable area is needed for these variants to be practicable.

Children need larger bedrooms than parents.

The requirements concerning the minimum area of bedrooms are the same today as it was 40 years ago. The Standards are still based on the needs and preferences of a family consisting of parents and children. The largest bedroom of at least 12 m^2 is intended for the parents. The Standard furniture is a writing desk, a cot, two chairs, a cupboard and two beds side by side, with their heads to the wall. This arrangement, referred to as twin-bed arrangement, guarantees a minimum room breadth of 2.70 m. The next largest bedroom, too, shall provide sleeping accomodation for two persons, with a comparable set of furniture, excluding a cot, but with a minimum area of 10 m^2 and a minimum breadth of 2.50 m. Any bedroom intended for one person shall be at least 7 m^2 in area.

These bedroom dimensions correspond to the IFHP recommendations. There it is considered that the parents need a larger room than the (two) children, with floor areas of at least 16 and 13 m^2, respectively.

We have found that in dwellings that were large enough for each child to have a room of its own the parents took the largest bedroom and there was no difficulty in distributing the area for sleeping accomodation, although larger bedrooms for the children were often desired. When, however, the children had to share a room they were often given the largest bedroom - the one intended for the parents. Sometimes the parents separated, each sleeping with one of the children in their respective bedrooms; the children then had their own rooms for daytime use. In some cases the parents moved into the living room. The older the children were the more common it was for those sharing a room to have the largest bedroom, and, moreover, for the household to depart in other respects from the intended arrangement.

The parents´ bedroom is often located beyond the living room, and it usually contains wardrobes, sometimes the dwelling´s principal storage space. The fact that children were still to a large extent given bedrooms containing most of the wardrobes or bedrooms beyond a living room an arrangement that was often considered inconvenient by the parents, may be regarded as further proof of a strong desire to have larger bedrooms for the children than the current Standards prescribe.

In view of the distribution of the sleeping accommodation from the standpoint of the individual households it would appear that these acted rationally in the context of the given conditions. It is true that there were variations, but these could be accounted for largely by household and dwelling size and the ages of the children.

The prescriptions of the Standards as regards the parents´ and the childrens´ bedrooms do not suit all households - not even half of those where the children have to share a room. It would obviously be better if all bedrooms in the dwelling were planned as parents´ bedrooms so far as area and furnishability are concerned. On the other hand they should preferably not be located beyond the living room, nor should one bedroom contain most of the dwelling´s wardrobes.

Fifty years ago there was a campaign in Sweden advocating one bed for each child. Today we should be able to set the goal at one room for each child. It will, however, be some time before this ideal can be realized for all. For the time being, therefore, the bedrooms should be designed for two persons. This requirement, moreover, would furnish the best guarantee that they will be large enough to be used for other purposes in the future. And we can then rest assured that the bedrooms will be large enough for one person.

Closing comments

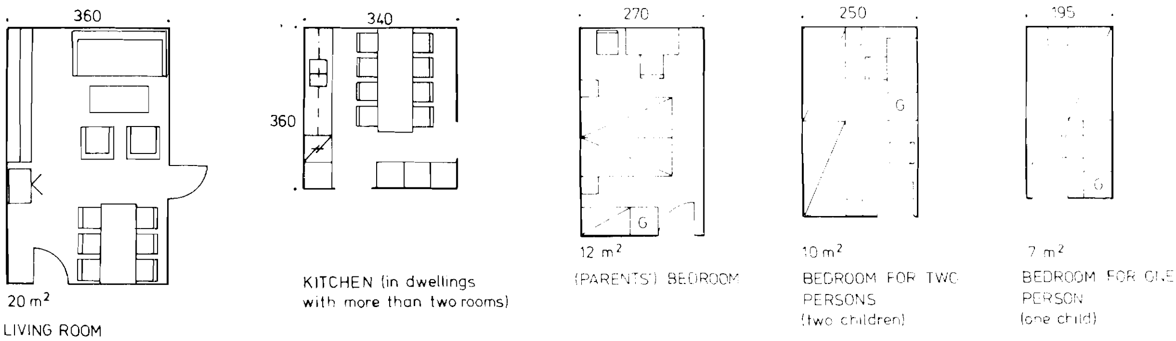
It was no accident that the radical architects of the thirties, with their roots in the middle class, came up with ideas that proved to suit the middle-class households better than others. From the aspect of the working-class household the function studies of kitchen and living room were based on false and incomplete data on eating habits, household duties and the like. Detailed standards or recommendations must be based on reality if there is to be any opportunity for the dwelling habits of the different households to be adjusted among themselves and adapted to the prescribed frameworks - the Standards. One example of this interaction is the development of the kitchen. When its importance came to be recognized the Standards recommended an increase in floor area, and when this area had been increased the status of the kitchen was raised further. Behind today´s Swedish Standards there is a process of adaption that covers almost four decades, and the Standards largely reflect the habits and preferences of the household. Differences in use may be ascribed largely to differences in available space - that is, the size of the household in relation to the size of the dwelling.

The studies of dwelling habits in Sweden have served as an important link between reality and Standard. They have recently been strongly criticised on scientific grounds. Some have complained that they lack theory, others say that the underlying theory is confused. It is obvious that there is plenty of room for improvement, and we believe that a more energetic international exchange of research than has been the case up till now would help in this direction.

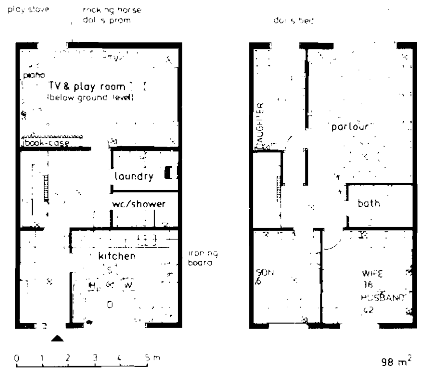
A living room arranged as a "viewing and listening room".

Photo from the kitchen in the semi-detached house on the next page. Compare the furniture in the kitchen in the photo whith that recommended in the Standards.

ROOMS AND KITCHEN PERFORMING THE MINIMUM REQUIREMENTS OF ROOM BREADTH, FLOOR AREA AND FURNISHABILITY IN THE SWEDISH STANDARDS FROM 1975 ONWARDS

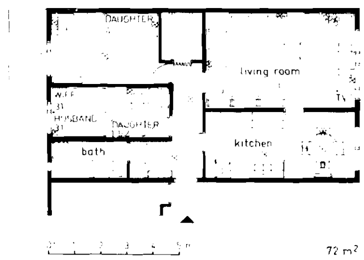


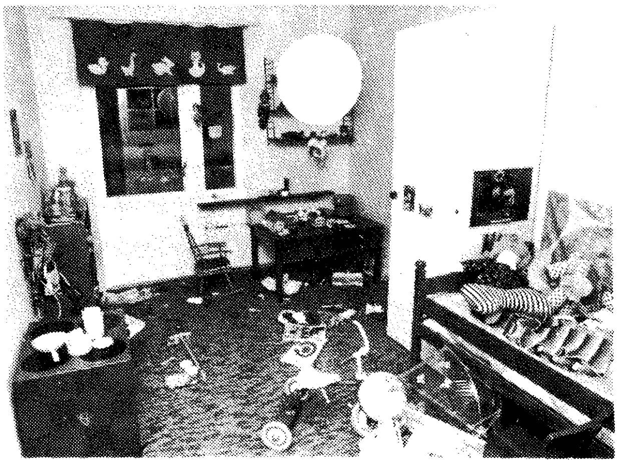
PARENTS AND TWO CHILDREN IN A SEMI- DETACHED HOUSE WITH FOUR ROOMS AND A KITCHEN AND A ROOM BELOW GROUND LEVEL (CELLAR ROOM)



This is a dwelling where all the rooms conform to current Standards as regards minimum areas and furnishability. The particular household represented above, and the other three- and four-person households interviewed in this type of dwelling, distributed the bedrooms as intended; the parents taking the largest room - each child getting a room of its own. The childrens bedrooms are small, but there is also the basement room which in most cases became a combined TV and playroom. Because of its location on the entrance level and its proximity to the all-important kitchen this basement room was much used especially by the children. The living room upstairs generally aquired a status of a "parlour" with little everyday use.

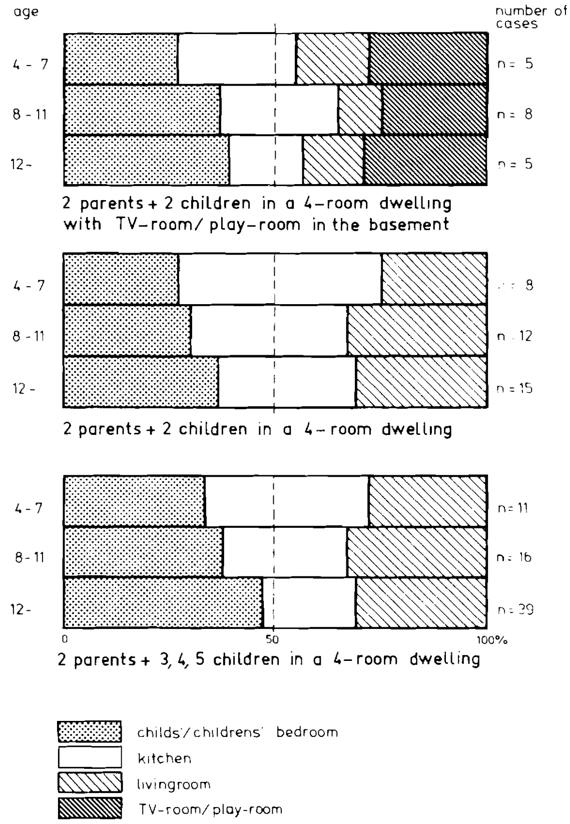
PARENTS AND TWO CHILDREN IN AN APARTMENT WITH THREE ROOMS AND A KITCHEN



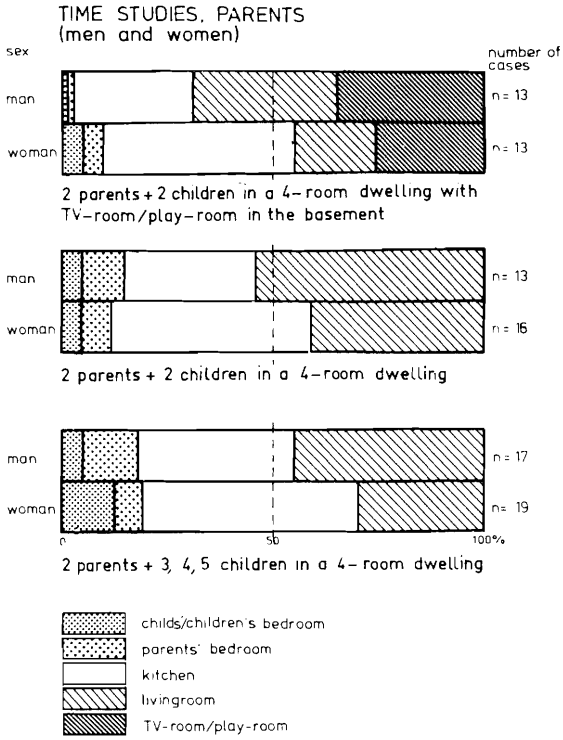


One half of all four-person households in the above type of three-room apartment departed from the distribution of sleeping accommodation as intended in the Standards. This is also true of all such households in three- room apartments. Neither of the bedrooms in this particular type of dwelling meet the minimum requirements. Where the Standards prescribe space for furniture and passage the children claim space for playing. In fact it seems that if the childrens bedrooms are small and narrow, as in this case, there is a stronger argument for giving the children the largest bedroom. In the above example the parents'bedroom was inconveniently crowded, and at nights the cot was moved into the kitchen. The preference for the twin-bed arrangement is evidently asserted in the face of all other difficulties.

TIME STUDIES, CHILDREN



Data on the time that the various members of the household spend in the vaious rooms were formely obtained by direct observation and from diaries; this procedure made great demands on resources and we therefore tried a much simpler, though perhaps less reliable approach: We simply asked the interviewees to mark on a scale what proportions of their waking hours various members of the household spent in the different rooms. We were surprised how consistent these subjective estimates were with our argument and theory, and also how closely they were in agreement with the findings of other time studies of more objetive nature.



Women spent a lot more time in the kitchen than men did. Young children spent much time in the kitchen too, but the older they were the more important the bedroom became. It is notable that children used their bedrooms much more than the parents did. You might say that the children's bedrooms were their living rooms, where they received their friends. In more crowded households where there were 5 - 7 persons the parents' bedrooms were used to a greater extent out of necessity.

A spare room or a room in the basement (or any other room below ground level) was often used as a TV room in combination with other activities such as playning. Then the TV room was much more in use than the living room without a TV, especially by the children.

This paper is a summary of one part of the project Dwelling Use and Dwelling Design, carried out at the National Swedish Building Research Institute by Stefan Dahlgren, Birgitta Eriksson, Louise Gaunt, Margareta Lindquist, Kenneth Orrbeck and Ulla Westerberg.

The following six reports has been published, all in Swedish (English translations of titles in brackets).

1. Metodrapport (Methods Report). Meddelande/Bulletin M 79:6

2. 158 småbarns bostadsanvändning (158 Small Children's Use of Their Homes). Meddelande/Bulletin M 77:1

3. 205 skolbarns bostadsanvändning (205 School-Children's Use of Their Homes). Meddelande/Bulletin M 79:7

4. Sammanställning av intervjusvar (Summary of the Interviews). Meddelande/Bulletin M 80:3

5. Bostaden i norm och verklighet (Actual Dwelling Use and Dwelling Use as conceived in the Swedish Dwelling Standards). Meddelande/Bulletin M 80:4

6. Möblerade lägenhetsplaner från 308 hushåll (Photos and Plans with Actual Furnishing from 308 interviewed Households). Meddelande/Bulletin M 80:5

Human experience of windowless environments in factories, offices, shops and colleges in Sweden.

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Introduction

Window functions. Windows perform a great many functions in the artificial environment we create indoors. They have multiple effects on the lighting of a room, and on the thermal environment. They provide visual and acoustic information from outside. They can affect the air quality and air change rate. They may be important as emergency exits. When there are good reasons for radically altering the design and function of a window, or for building rooms with no windows at all, it is important to know which functions of a conventional window are important so that adequate steps can be taken to redress the possible imbalance created by altering or removing them.

View out. Surprisingly little is known about the effects of windows on people (1). Hardy (2) studied subjective preference for the various kinds of view out obtained with windows of differing size and shape, but his study showed at the same time that view out is one of the least important aspects of the office environment. It should be borne in mind that Hardy studied people working in offices with windows, who could take them for granted. However, children did not seem to mind even the complete absence of windows in classrooms in studies carried out by a multi-disciplinary group at the University of Michigan (3). No adverse effects could be demonstrated. A parallel study of teachers' attitudes elicited only the trite observation that they appreciated the extra wall space for shelves, maps etc.

Windowless offices. A group of 139 female occupants of windowless offices in Seattle, USA, were interviewed by Ruys (4). Although generally satisfied with the size and lighting of their offices, 126 of them would have preferred windows. 70 of them thought that lack of windows affected their health or their work, or both. They cited the following six reasons for this view with about equal frequency: no daylight, poor ventilation, no weather information, no view, claustrophobia, depression. These reasons are commonly cited by people who have never worked in windowless rooms, i.e. they are common prejudices. A single-group study of this kind cannot reveal to what extent such prejudices have been confirmed or rejected by the actual experience of working without windows. In the present study of windowless environments, control groups with windows have been included, making it possible to test for this effect. However, due to the element of self-selection in any employed group, the absence of extremely negative reactions to windowless environments is to be expected - people holding strongly negative views will simply have changed their employment. The main purpose of the study was to investigate whether any specific aspects of window function were missed acutely by the deprived.

Job status. The provision of windows places restrictions on the size and shape of buildings and reduces site exploitation. Windows usually increase heating and cooling loads. Windows with good views are always in short supply. Thus windows are at present allocated, like other expensive rewards, on the basis of job status. The greater the intellectual content of the job, the greater the glazing area tends to be and the better the view. It is assumed that while students and higher management must have large windows, preferably floor-to-ceiling, shop assistants and office-workers could manage perfectly well without, and storeroom and factory workers must be quite indifferent. In the present study attitudes to windows are systematically compared between these groups, with and without windows wherever possible. A small group of blind workers was similarly included on the assumption that their perception of non-visual aspects of window function would be abnormally acute.

Method

Pilot study. A pilot study of the effect on attitudes to windows of working without them had already been carried out by one of us (DPW:5). Surgeons, anaesthetists, assistants and nurses were interviewed in the course of a more comprehensive study of the working environment in operating rooms in British hospitals. They were classed as preferring daylight, indifferent or preferring no daylight. The reply frequencies were compared between categories and between operating rooms with and without windows. Surgeons, anaesthetists and nurses were significantly ($P<0.001$) less positive to daylight when they were currently working in windowless operating rooms, i.e. they tended to accept the absence of daylight rather than reject it. Alternatively, those disliking windowless operating rooms tended to seek work elsewhere. However, since only a short part of the working week is spent in the operating room by anyone, it seems unlikely that their choice of hospital would have been influenced by the presence or absence of windows in the operating rooms.

Colour rendering. Daylight is often stated to be essential for the clinical judgement of skin tone. This is particularly important for anaesthetists in monitoring the patient's condition during an operation, for slight colour changes towards blue skin tones reveal a lack of oxygen in the blood which must immediately be remedied. Surgeons see the skin surface only very briefly.

Differences in attitude to daylight may be expected to be particularly marked between these two categories.

Response:	With daylight		With no daylight	
	Surg.	Anaesthet.	Surg.	Anaesthet.
Prefer daylight	30	31	29	45
Indifferent	10	3	36	38
Prefer no daylight	4	2	22	7
Total	44	36	87	90
Chi-square test:	(NS)		(P<0.005)	

Table 1. A comparison of surgeons' and anaesthetists' attitudes to daylight in operating rooms with and without windows.

The comparison is shown in Table 1. There were no significant differences in attitude to daylight between surgeons and anaesthetists working in conventional operating rooms with windows. Both categories were overwhelmingly positive to daylight, i.e. 75%. In operating rooms without windows, 33% of surgeons and 50% of anaesthetists would have preferred windows. This difference between categories is highly significant (P<0.005), i.e when both groups have tried to work without windows, anaesthetists appreciate daylight more than do surgeons. This lends empirical support to the importance of daylight for skin tone judgements.

Interview. The main study was carried out in Sweden. Since the pilot study had revealed differences between job categories and between subjects working with and without windows, these were the main dimensions of the study. Since even a simple 3-alternative question on preference for daylight had yielded useful results, fixed alternative questions were included in the main study. The interview was structured in the following way: first, a small number of neutral questions were asked verbally and the verbal answers were recorded by the interviewer as falling into one or more pre-determined categories of reply. This made it possible to compare spontaneous responses even though they were obtained in the subjects' own words. The interviewer was able to ask supplementary questions to clarify the subjects' meaning. Second, the subject was asked to rate on a five-category scale 47 specific aspects of window function. The scale ranged from 1, 'a great disadvantage' to 5, 'a great advantage', with 3 as 'a neutral, unimportant aspect'. The different aspects were presented as short, incontrovertible statements grouped under the following headings: lighting, weather, view-out, view-in, ventilation, noise, safety, manipulation. Examples of the statements, too numerous to set out in full here, are (lighting): 'Windows provide some variation in the lighting of a room during the day'.
(weather): 'You can see whether the sun is shining'.
(view out): 'You can see what is happening outside'.
(view in): 'People can see in through windows'.
(ventilation): 'Windows give rise to draughts'.
(noise): 'You can hear what is happening outside'.
(safety): 'You can get out through a window in an emergancy'.
(manipulation): 'Curtains and blinds must sometimes be adjusted during the day'.

The subjects had already had an opportunity to bring up and comment on these aspects of windows in the first part of the interview, in which everything they said in response to the following three questions had been carefully recorded:

1. What is your attitude to having windows where you work?
2. What are the main advantages of windows?
3. What are the main disadvantages of windows?

Answers to Question 1 were coded only on the same 5-category scale as the questionnaire. A number of further questions were asked about the effects they thought windowless environments had on them, or would have on them. Since the responses obtained in this way were much less numerous and were in any case highly speculative, they are not reported here. Details of the person, the job and the window, if any, were also recorded.

Target groups. Windowless environments were known to exist in Sweden in factories storerooms, offices, shops and lecture theatres. People working in these five categories of environment were interviewed wherever possible, all over Sweden. Control groups were similarly interviewed, usually within the same concern, in comparable employment but in rooms with windows. It proved impossible in the time available to interview a usable number of students or storeroom workers in rooms with windows, so the main comparisons between windowless/daylit conditions are for factories, offices and shops. The numbers of office workers interviewed with and without windows in the far North of Sweden (Umeå, latitude 64°N, equivalent to Godthåb in Greenland, i.e north of Hudson Bay) made possible a comparison with equivalent groups in the south of Sweden. Care was taken to interview as many people in small towns as in Malmö, Stockholm and Göteborg. Workers in power stations were classed with factory workers, and file clerks in archives with storeroom workers. A number of blind people in sheltered employment were also interviewed, mainly in offices and small workshops, with windows. (All interviews by IN)

Results

Question 1. In Table 2 the numbers interviewed within each category are set out, together with the mean value on the rating scale (1-5) for the answer to Question 1 within each group. 480 people were interviewed in all.

The Chi-square test for independence (6) can be used to determine the significance of the differences between the reply distributions obtained with and without windows, within each job category. The probabilities thus obtained are set out in the right-hand column. The differences between the reply distributions obtained for each job category can be similarly tested: in windowless rooms, between categories 1-6 of the table ($P<0.001$); between the categories with control groups, 2, 3, 4 and 6 ($P<0.01$); between offices in the north and south ($P<0.01$) and between shops, all offices taken together, and factories, 2, 3 + 4, and 6 ($P<0.05$). In rooms with windows, the overall test was between categories 2, 3, 4, 6 and 7. Neither this nor any of the other tests between job categories yielded a statistically significant result. These trends may be seen in Fig. 1: no differences between job categories in rooms with windows, large differences in windowless rooms. The direction of the trend is opposite to the conventional assumption about attitudes to windows mentioned in the Introduction, but emerges only among people who have experienced working without them. It may be seen that the blind tended to be the most positive to windows, again contrary to most expectation.

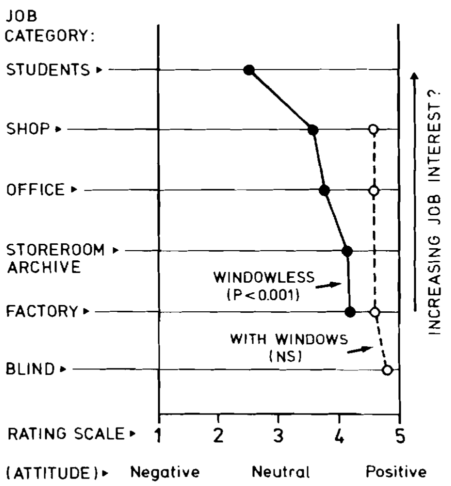

Fig. 1. Attitude to windows for the 6 different categories interviewed, with and without windows.

Question 2. The main advantages of windows mentioned spontaneously in response to Question 2 were daylight, weather information, fresh air and contact with the outside world, in decreasing order of frequency. In Fig. 2 the percentage mentioning daylight in shops, offices and factories are shown. Since there were no significant differences between job categories in windowless environments, the overall mean percentage is shown for all three categories. There were significant differences ($P<0.01$) between categories in rooms with windows. The differences between Northern and Southern offices were significant both in windowless rooms ($P<0.001$) and in rooms with windows ($P<0.01$), daylight being mentioned significantly more often by office workers in the far North.

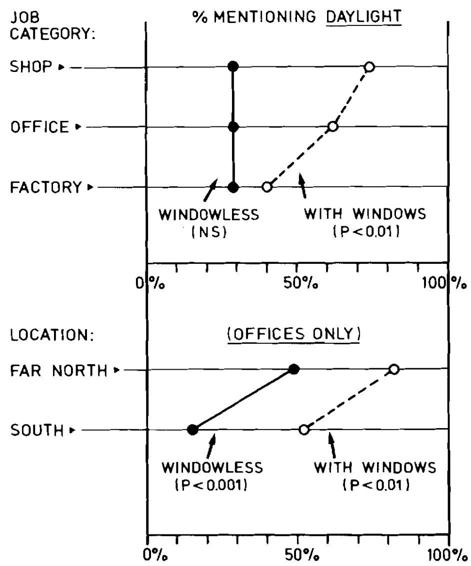

Fig. 2. Percentage of those interviewed spontaneously citing daylight as one of the advantages of windows.

In Fig. 3 the percentage mentioning 'weather information' in shops, offices and factories are shown. There were large and significant differences between these categories in windowless rooms ($P<0.001$), but not in rooms with windows. Obtaining information about the weather outside was mentioned as an advantage of windows significantly more often ($P<0.05$) in windowless factories than in factories with windows, but significantly more often ($P<0.02$) in shops with windows than in windowless shop premises, where assistants remarked that they could see by customers' clothes what the weather was like outside! There were no significant North/South differences in offices and no significant differences between offices with and without windows. Contact with the outside world followed much the same pattern as weather information and is not shown. Fresh air was hardly mentioned at all as an advantage of windows in shops, but often in offices and factories. In Fig. 3 it may be seen that differences between categories occurred both in windowless rooms ($P<0.01$) and in rooms with windows ($P<0.001$). Fresh air was more often mentioned spontaneously as an advantage of windows in offices with win- than in windowless offices ($P<0.05$), but more often in windowless factories than in factories that did in fact have windows ($P \approx 0.05$). (This perhaps reflects the fact that the 'fresh air' outside factory windows is fresher in theory than in practice, but may reveal a genuinely enhanced feeling of deprivation.)

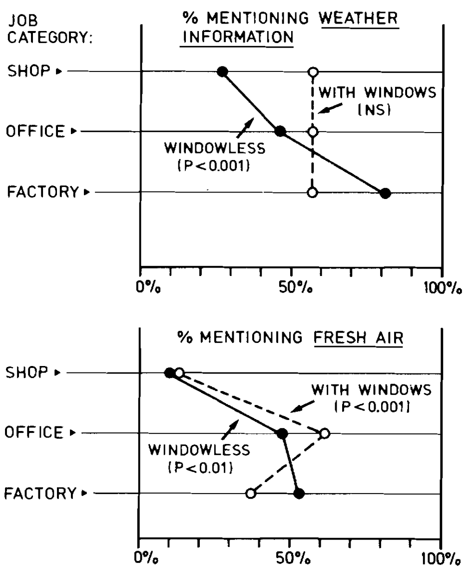

Fig. 3. Percentage of those interviewed spontaneously citing weather information and fresh air as advantages of windows.

Question 3. The main disadvantages of windows mentioned spontaneously in response to Question 3 were direct solar overheating, draughts and distraction from outside, in decreasing order of frequency, as shown in Fig. 4.

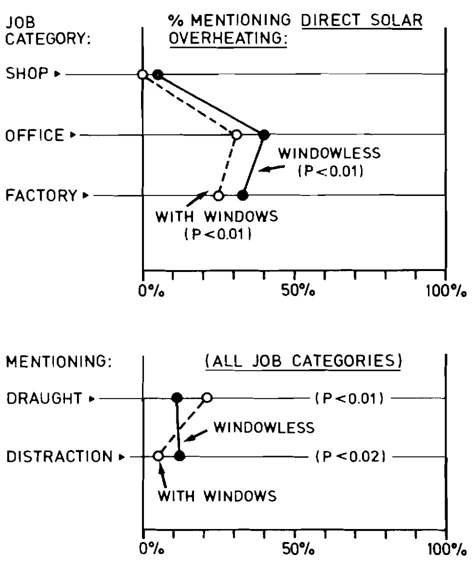

Fig. 4. Percentage of those interviewed spontaneously citing direct solar overheating, draughts and distraction as disadvantages of windows.

Direct solar overheating was hardly mentioned at all in shops, but more often in offices and factories. There were no significant North/South differences in offices or differences between windowless rooms and rooms with windows. The differences between categories were significant (P<0.01) in both types of room. However, there were no significant differences betweeen categories in the percentages mentioning draughts or distraction. Taking all three job categories together, significantly more people mentioned draughts spontaneously as a disadvantage of windows (P<0.01) in rooms with windows, while significantly more people mentioned distraction spontaneously (P<0.02) in windowless rooms.

Questionnaire: lighting. When the rating scale results from the questionnaire on specific aspects of lighting were examined, significant differences between Northern and Southern offices could be demonstrated. In offices with windows, people working in the far North placed significantly more emphasis on the variation introduced by windows (P<0.05) and on the time variation thus provided (P<0.01). In windowless offices, people working in the far North placed significantly more emphasis on the colour rendering (P<0.001), light distribution P<0.05), directional lighting (P<0.01) and time variation (P<0.001) that would have been provided by windows, than did people working in similar offices in the south of Sweden.

View out. Office workers in rooms with windows were significantly more positive to the following aspects of view-out: orientation in the building (P<0.05), height orientation (P<0.01), 'more to look at' (P<0.01), 'more space' (P<0.001), 'restful for the eyes' (P<0.01), 'trees, clouds, grass, etc' (P<0.001), explanation of external noise (P<0.01), than were workers in windowless offices. Shop assistants in shops with windows were significantly more positive to being able to see 'more space'(P<0.05), people (P<0.05) and trees, clouds, grass etc (P<0.05) than were their colleagues in shops without windows.

Weather. Office workers in rooms with windows were significantly more positive to being able to see sunshine (P<0.05), and wind (P<0.01), predict the weather (P<0.001) and estimate the temperature (P<0.05) than were their colleagues in windowless offices.

Noise. Workers in windowless factories were significantly more positive to being able to hear wind (P<0.05), people (P<0.01), outside activity (P<0.05) and what was happening outside (P<0.01), than were workers in factories with windows, who perhaps took these advantages for granted. The blind were significantly more appreciative of being able to hear rain (P<0.05), wind (P<0.001) outside activity (P<0.001) and what was happening outside (P<0.01) than were sighted workers in rooms with windows.

Ventilation. The blind were significantly more appreciative of smells from outside (P<0.05) than were sighted workers in rooms with windows. They were also more positive to the spatial variation of temperature provided by windows (P<0.01). Sighted workers in rooms with windows were on average more negative than positive to this aspect of window function. Workers of all categories in rooms with windows were significantly more positive to the variation of temperature during the day

(P<0.01) introduced by windows, than were workers in windowless rooms. This difference was significant in factories taken separately (P<0.05) but not in offices or shops.

No other significant differences between categories of job or room were found in the questionnaire replies. Any attempt to break down the material into further categories on the basis of the recorded personal, job and window details would be unprofitable, since they are to a large extent confounded with job categories. The collection of these details was intended to make possible an alternative, individual-oriented analysis of the replies if no group differences had been found.

Discussion and conclusions

Research hypothesis. The underlying research hypothesis in the present study was that it is difficult for people who can take windows and daylight for granted to analyse what it is that they appreciate. People deprived of windows and deprived of daylight were thought more likely to be able to assess subjectively the relative importance of different aspects of window function. This hypothesis has been amply confirmed by the different attitude to windows found in the North, in windowless rooms, and among the blind.

Reduced daylight. Differences between North and South Sweden were entirely confined to various aspects of daylight, appreciated more in the North where it is in short supply during the winter months. No fewer than five different aspects of daylight were evaluated more positively in the North. These aspects are probably important also in the South, although people who can take them for granted are not as aware of them.

No daylight. People working in windowless rooms were less, not more positive to windows than were their controls, exactly as was found in the pilot study of operating rooms. Either they have adapted or they are a self-selected group. Differences in attitudes to windows between job categories were most apparent in windowless rooms, again as was found in the pilot study. The trend is for those with the least interesting jobs to miss the stimulus of windows most. There were a number of instances of workers in windowless rooms missing particular aspects of windows, i.e. being more positive to these aspects than were people who could take them for granted: factory workers apparently miss weather information particularly, and the fresh air windows might be able to provide (Fig. 3). When asked specifically, they also seem to miss the further stimulus of being able to hear things from outside - wind, people, activity.

Blind. The blind, sensorily deprived already, would miss windows more than would comparable sighted workers. They appreciate particularly being able to hear rain, wind, the activity outside windows, and the smells sometimes admitted by windows from outside. This lends support to the view that windowless rooms may provide insufficient stimulation for people who are sensorily deprived - including deaf people - or who are engaged in boring and repetitive jobs. It is striking that shop assistants on this interpretation seem to be less bored than office workers. Contact with customers may provide sufficient stimulation to reduce their need for windows. The present results support allocation of windows in inverse proportion to intrinsic job interest.

Freedom of movement. One further important factor may be the freedom to leave the workplace and seek stimulation elsewhere, from windows in other rooms or from some other source. Students and shop assistants can move considerably more freely than can storeroom workers and factory workers, and the blind are least able to move easily about. This aspect of the total stimulation available to different job categories may have been important in determining their relative attitudes to windows. In most cases this consideration would again support allocation of windows in inverse proportion to job status, contrary to present-day practice.

Category	Windowless		Windows		P
					(±windows)
1. students	28	2.50	-	-	-
2. shops	22	3.59	23	4.57	0.01
3. s.offices	65	3.55	67	4.60	0.001
4. n.offices	37	4.11	34	4.53	NS
5. storerooms	30	4.13	-	-	-
6. factories	93	4.17	67	4.60	0.01
7. blind	-	-	14	4.79	-

Table 2. Attitudes to windows in workplace (1-5, Negative/positive) and significance of difference between rooms with and without windows for each job category.

Summary

Attitudes to windows are usually dominated by daylight and view-out considerations. The other functions performed by windows are often taken for granted, since window size affects primarily the above aspects. Only when windows are totally absent are these other functions likely to be missed. Attitudes to windows among people working in windowless environments were thought likely to reveal the relative importance of various window functions to the occupants of different categories of building. About 250 people working in windowless environments in factories, offices, shops and colleges documented their experience in carefully structured individual interviews. An equal number of people in comparable employment, often within the same organisation, but working in rooms with windows, were similarly interviewed and formed a control group. Statistically significant differences in attitudes to windows were found between categories of employment and across the window/windowless dichtomy within each category. Office workers in the far north of Sweden differed in their attitudes to windows from comparable office workers in the south of Sweden. A number of blind people were similarly interviewed on the non-visual aspects of windows. Their attitudes differed significantly from those of the rest.

Résumé

Les attitudes vis-à-vis des fênetres sont en général conditionnées par des considérations de lumière du jour et de vue. Les autres fonctions des fênetres sont souvent considérées evidentes, la dimension des fênetres influant en premier lieu sur les aspects ci-dessus. Ce n'est qu'en cas d'absence totale de fênetres qu'il est vraisemblable que ces autres fonctions manquent. On a supposé que les attitudes vis-á-vis des fênetres parmi les personnes travaillant dans des environnements sans fênetres pourraient révéler l'importance relative de fonctions diverses de fênetres pour les occupants de bâtiments de catégories différentes. Environ 250 personnes travaillant dans des environnements sans fênetres dans des usines, bureaux, magasins et centres d'enseignement ont donné leurs impressions comme documents dans des interviews individuelles, soigneusement structurées. Un nombre égal de personnnes dans des emplois semblables, souvent dans la même organisation mais travaillant dans des salles avec fênetres, a été interviewé de la même façon et a constitué un groupe de contrôle. Des différences statistiquement significatives quant aux attitudes vis-à-vis des fênetres ont été relevées entre les différentes catégories d'emploi et entre les groupes avec ou sans fênetres dans chaque catégorie. Les employés de bureau dans l'extrême nord de la Suède ont eu des réactions différentes de celles des employés de bureau dans le sud de la Suède. Un nombre de personnes aveugles a de même été interviewé sur les aspects non-visuels des fênetres. Leurs attitudes ont été significativement différentes de celles des autres.

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SUBJECT SUJET 4A

Energy conservation: Building envelope. Roofs, walls and openings

Economie d'energie. Gros-oeuvre du bâtiment. Toits, murs et baies.

THE ROLE OF THE BUILDING ENVELOPE

Professor Hans Granum, University of Trondheim, Norway.

Summary

In cold or medium cold climate the energy consumption in most buildings is highly depending upon the thermal quality of the building envelope. In relation to energy consumption the dominating properties of the envelope are the *thermal insulation* and the *air tightness*.

The paper sums up viewpoints on thermal insulation, the role of «free heat», thermal bridges and windows. Large savings are possible with very profitable investments in better insulation and better tightness, particularly in new buildings. Thermal capacity and shading devices are important to avoid overheating in warm climate.

Air leakage is a major source of heat loss, and good tightness is also important in connection with heat recovery in the ventilation system. Quantitative requirements for air tightness is recommended in building codes, and methods for measurements of air changes are important. There is often a striking difference in viewpoints, – and experiences from one country to others seem often difficult to transmit.

Résumé

Dans les climats froids ou moyennement froids, la consommation d'énergie, dans la plupart des bâtiments, dépend largement de la qualité thermique du gros oeuvre.

En ce qui concerne la consommation d'énergie les propriétés dominantes du gros-oeuvre sont *l'isolation thermique* et *l'étanchéité à l'air*.

Le document récapitule les points de vue sur l'isolation thermique, le rôle de la «chaleur libre», les ponts thermiques et les fenêtres. Il est possible de faire de grandes économies à peu de frais par une meilleure isolation et une meilleure étanchéité, spécialement dans les bâtiments neufs.

La capacité thermique et des dispositifs faisant de l'ombre sont importants pour éviter le surchauffage dans les climats chauds.

Les fuites d'air sont une source majeure de déperdition de chaleur, et une bonne étanchéité est également importante pour la récupération de chaleur dans les systèmes de ventilation. Les exigences quantitatives pour l'étanchéité à l'air sont données dans les codes de construction, et les méthodes pour mesurer les échanges d'air sont importantes.

Il y a souvent une différence frappante de points de vue – et les expériences d'un pays à l'autre semblent souvent difficiles à transposer.

Introduction

A large portion of the energy consumption in a building is due to room climatization, heating or cooling. The need for climatization depends of course on the outdoor climate. In many countries the room climatization accounts for 50–75% of the total energy consumption in most buildings. This consumption is largely a direct function of the thermal quality of the building envelope.

The exchange of energy is due to heat *transmission*, *air penetration* and to *radiation* through parts of the envelope. Windows are of special importance both on the negative and positive side of the energy balance. Fig. 1.

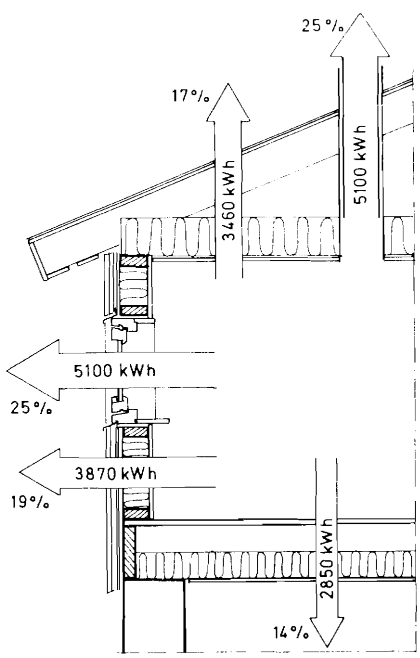

Fig. 1.
Heat loss from a 100 m² detached house, during a normal heating season Oslo

In relation to the energy consumption the dominating properties of the envelope are the thermal *insulation* and the *air tightness*. The envelope, however, also play other important roles (functions) which must not be forgotten, such as load bearing, durability against wear and weathering, visible appearance, sound insulation etc. Often the different functions are filled by different layers of materials with specialized properties acting together to fill the total complex function. There is, of course, often a relationship between the functions of the envelope and other elements in the building, or the building as a whole. Some aspects or properties of the envelope must therefore be discussed in a wider context. One example of this is the role of the thermal capacity. Another is design, management and regulation of heating and ventilating appliances, which is strongly influenced by the properties of the envelope.

These facts were reflected in a CIB-symposium on «Energy conservation in the built environment» in Copenhagen late spring 1979. In this symposium methods to improve the building envelope were treated in some 35 papers, while properties of the envelope in relation to installations, retrofitting, calculation methods, experimental buildings etc. were mentioned in a great number of papers in other sections of the symposium.

Thermal insulation

In traditional constructions the thermal insulation was included in the construction materials themselves. The construction materials, for example stone, brick or timber filled multiple functions, – load bearing and protecting as well as insulating. Even in combination with air spaces such traditional constructions have very poor insulation properties. Cheaper and cheaper fuel had made thermal insulation a matter of minor concern.

In the later decades a number of specialized and low priced *insulation materials* with 5 to 50 times better insulation properties than traditional materials, such as mineral wool and foamed plastics have been developed. Some of these materials were well established and marketed already 30–40 years ago. In some countries, as for instance Norway, these new products had a marked influence on the construction technique already from 1950-60, while in other countries it was the oil-embargo 1973/74 that first really opened the way for a new insulation practice. The consequence of higher energy price and better insulation possibilities is still not fully drawn, but there is a fast growing awareness of the great importance of good thermal insulation all over the world. New code requirements in most countries, based on the need of energy conservation help to improve the practice, but represent in many countries only the first step towards a rational economic solution. Tradition and structure of the material producing industries and the construction industry also make rapid changes in the construction practice difficult.

To find the optimal solution of the thermal insulation is in principle a fairly simple exercise, and may be based on well known and accepted cost-benefit analysis. It is a question of «life-cycle cost», taking in account as well the initial building cost, as the future running cost. Better insulation raises the initial cost, while the future heating cost goes down.

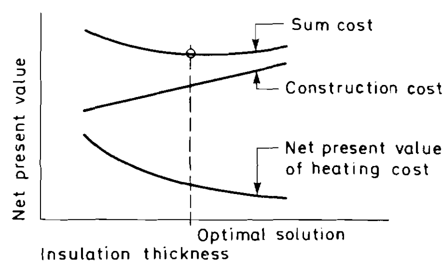

Fig. 2.
Optimization of thermal insulation

Without going into details with such methods it must be mentioned that they involve a number of parameters which need a careful consideration to give correct results.

The «problem» parameters are:

1. The real energy consumption which may be debited the construction in a normal year.
2. The future energy price.
3. The interest rate in real terms (discount factor).

The first parameter «debitable energy consumption» raises a number of important problems, such as

a) The role of the «free heat»: solar radiation through windows, person heat, «waste heat» from lighting, cooking etc.
b) The influence of thermal capacity under the real shifting radiation- and temperature conditions.
c) The influence of thermal bridges.
d) What is the «correct» indoor temperature?

In many countries heavy constructions (high thermal capacity) have been honoured in the building code by allowing higher U-values (k-values) i.e. less insulation than for light constructions. From the view-point of comfort this seems justified especially for summer conditions. In relation to energy consumption in cold weather however, high thermal capacity is not especially advantageous. The premium for high thermal capacity is therefore dropped in most newer building codes. Light constructions make lowering of the indoor temperature feasible during periods when the room is not in use, whereby considerable amounts of energy may be saved provided suitable heating systems. On the other hand, the storage capacity of the envelope constructions is of some value for better utilization of uneven solar energy input, not only through windows but also for radiation input to the surface of opaque constructions. Better calculation methods are necessary to allow designers to take such factors into full consideration. This might be a feasible topic for discussion during the present section of this congress.

The «free heat» plays a very important role for the annual energy consumption, and cover a major part of the heat loss, especially in well insulated buildings.

Better insulation has the effect of shortening the heating season, and allows the free heat to cover a considerably higher portion of the total heat loss than in less insulated buildings. An even more conscious utilization of free heat may be done by passive solar heating systems.

This system may be improved by insulating curtains etc. which reduce the night-time losses while the radiation during day-time is admitted. The window orientation and house shape also play a certain role. In many cases, however, functional and site considerations limits the possibility of utilizing passive solar heating systems.

Considerable effects may be reached by using selective reflecting surfaces («heat-mirrors»), particularly for window glasses. Such surfaces may act as a «radiation valve», letting the short wave visible radiation through, but reflecting almost completey the long wave thermal radiation.

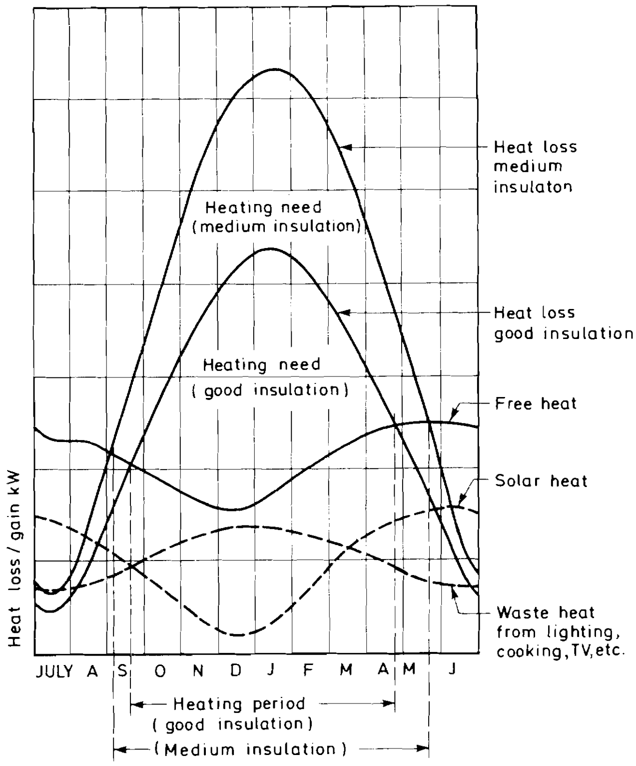

Fig. 3.
Heat loss and heat gain

The color of the exterior opaque surface also has a certain influence on the energy balance. Dark colors absorb more solar energy, and may therefore contribute to a higher utilization of the «free heat».

In general we have a fairly good qualitative understanding of the heat exchange processes, including the role of the thermal capacity, the surface radiation properties and the mechanism of multi-directional and dynamic processes interplaying with the environment. The processes however, are not easy to cover by simple mathematical models, and even comprehensive computer programs designed for better explanation of the heat exchange processes often show great deviation from each other and from observations in real buildings.

There is a clear need for more reliable and simple methods for correct calculation of the heat exchange through building envelopes. Work in CIB and other organizations, such as ISO, may help to develop and standardize better methods for such purposes.

Some of the submitted papers for the present section of this Congress are concerned with field trials and measurements in existing, well insulated buildings. Such observations are important to throw light over possible errors in theoretical calculations. Considerable deviations due to internal convection, faulty workmanship, misleading λ-values and other factors may be revealed. Examination by infrared photography may be very useful to detect faultiness in insulated constructions. There is some evidence that the real heat loss by transmission for mineral wool insulation may be somewhat lower than calculated by means of standard methods and use of listed λ-values.

On the other hand more rigid materials, or shrinking foams injected into cavities may cause internal convection and therefore perform badly.

Practical experience seems to be difficult to transmit from country to country. To quote an example: bad experience from the use of shrinking foams in cavities, which led to their condemnation in Scandinavia 20 years ago are reported anew in many fresh reports from North America and some European countries. Perhaps we are not good enough to transmit experience between each other!

Thermal bridges

As long as the thermal insulation is low, the effect of *thermal bridges* is moderate. The effect has mostly been associated with their adverse effect on the condensation problems. In well insulated constructions however, thermal bridges also may have a very considerable effect on the total heat loss. For concrete walls with interior insulation, where high quality insulation layers are penetrated by concrete decks and/or interior walls, the heat loss may increase with more than 50% when the effect of thermal bridges are taken in due account. Fig. 4. For steel casette or steel stud walls the effect is similar. The influence increases with better insulation. Therefore thermal bridges may no longer be neglected in low energy buildings. In fact, really good insulation may be more or less wasted if thermal bridges are overlooked.

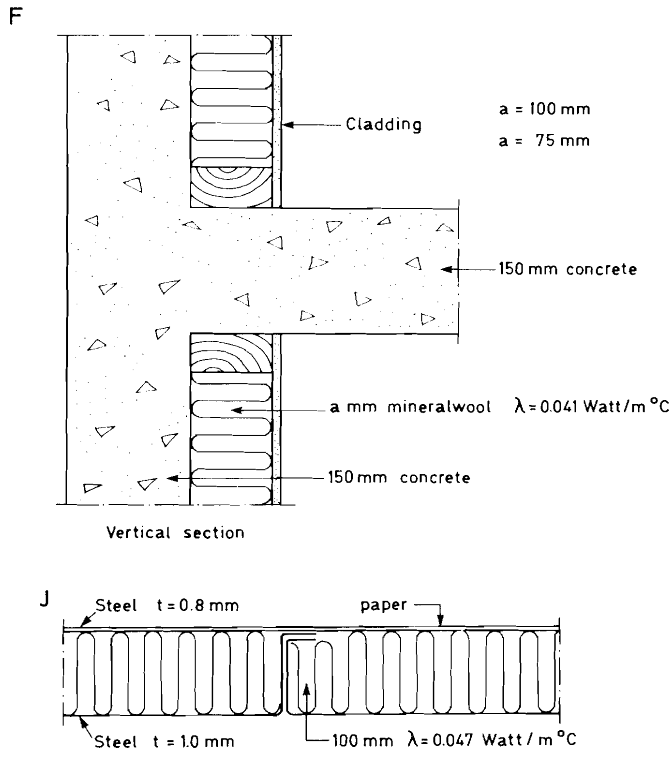

Fig. 4.
Thermal bridges.
Additional heat loss due to thermal bridges compared with the same wall without a thermal bridge.
Upper case, concrete decks c/c 2,70 m. Increased heat loss: 60%.
Lower case, steel cassettes 0,6 m. Increased heat loss: 75%.

The effect of thermal bridges may not be calculated by simple «hand» methods, but need fairly large computer programs based on finite element methods to give sufficiently accurate results. Because such methods are too costly and time-consuming to be used by the average designer in practical situations, it is proposed to work out tables or «catalogues» for the commonly occuring thermal bridges as a handy tool for the designer to find a good estimate of the various effects of «normal» types of thermal bridges. Some examples of such tables were presented in the mentioned CIB-symposium in Copenhagen. Similar methods will probably be recommended in a coming ISO-standard.

Windows

Among the elements of the building envelope the *window* requires unique consideration for many reasons. Its principal function is to transmit light and view, i.e. short wave radiation. At the same time, however, it affects the heat and moisture transfer, the air infiltration, the sound transmission, the visual appearance of the building, maintenance etc. Usually windows represent weak points in the thermal insulation of the envelope, and dominating sources of uncontrolled air penetration as well. On the other hand the windows allow large quantities of global radiation to pass into the building, where it may contribute to the heating, but also cause problems by overheating. The role is shifting over the day and the year, and depending upon directional orientation. In earlier days single glazed windows were commen even in cold climates. This practice is still prevailing in many countries in Europe and America, while in Scandinavia 3-glass windows are rapidly becoming the normal solution, and are considered economically profitable.

Efficient sealing methods make 2 and 3 glass windows almost equally easy to clean and operate as single glazed windows. New hinging- and sealing systems have also improved other properties. There also is a rapid development in selective reflecting coating of glass. Coatings which effect the visibility through the glass to a very small degree, may greatly improve the thermal insulation. Tripple glazing with 2 or 3 glasses coated with tinoxide, and filled with heavy gass in the sealed cavities give a U-value lower than 1,0 $\frac{W}{m^2k}$, i.e. considerably better than conventional brick cavity walls. Such a window still allows 60% of the global short wave radiation to pass into the building. Such windows therefore give a positive contribution to the heat balance throughout the heating season for most orientations.

In some climates and types of buildings «turnable» windows with a heat absorbing glass turned out in summer and in during the winter may be feasible.

An alternative to better insulating windows may be insulating curtains, which, properly used may give an ideal varying degree of insulation from day to night. One of the problems here is to make the curtains sufficiently air- and vapour tight so that condensation is avoided. Another problem is to make them sufficiently easy to use, and to learn people to use them!

Altogether window design is perhaps playing the most important and exciting role in the strive for energy conservation in buildings of all building elements.

Overheating

In many countries overheating is more of a problem than heating in cold periods. The problem is often excess heating by radiation through windows together with high environmental temperature. A cooling joule is more expensive than a heating joule. Even by cooling good thermal insulation is essential, and good shading devices are very important. Due to shifting outdoor conditions from day to night high thermal capacity plays a much more essential role than for the heating situation. The thermal capacity of the interior of the house, the decks and the internal walls, however, are more important than the thermal capacity of the envelope. Outside thermal insulation of the envelope is advantageous to get the best utilization of the thermal capacity, and to minimize the heat wave from solar radiation on the outer surface. Surface color, or rather radiation absorption quality, is also a factor to be considered. Up till now the work in CIB on energy consumption has been more concerned with the heating than with the cooling situation. It seems as the cooling problems ought to be given more attention in the future.

Potential savings – new buildings

The potential energy saving by improving the insulation properties of the envelope in new buildings is very large. At the same time it is economically profitable. Compared with the insulation standard required by the Norwegian Building Code of 1969 an improvement up to the economic optimal standard is estimated to yield a profit (internal rate of return in real terms) of 10–15% p.a. of the extra investment required for improved insulation. Improved thermal insulation will presumably give the best value for the money of nearly any possible measure for energy conservation. The annual saving in energy for heating compared with the old standard would be more than 50%. Similar, or higher savings may be possible in most countries in the cold or semicold regions of the world. Due to the frequency of moving, conservative tradition and financial difficulties of houseowners high internal rate of return may not be sufficient to secure better insulation. For this reason stricter requirements in the building codes have to be used as a tool in most countries. Although many codes still allow insulation properties considerably below the economic optimal, they surely will contribute to a very considerable improvement in the thermal quality of buildings in the coming years.

Existing buildings

Because new constructions in most countries annually amount to less than 2–3% of the existing building stock the improvement of the thermal quality merely through replacing of existing buildings by new ones is a slow process. Improving the thermal properties of existing buildings by additional insulation therefore is a very urgent problem. Normally adding insulation to existing buildings is more difficult and less profitable than improved insulation in new buildings. In some types of buildings, for instance one or two storey residential houses, additional loft insulation may be easy to apply, particularly on a «do it yourself» basis at a very reasonable cost and good profit. Cavity walls also may be easy to fill without too much risk. But in general additional insulation costs considerably more than if it had been done during construction.

Improvement of the thermal quality of existing buildings therefore as a general rule often must be associated with general maintenance or retro-fitting, and be taken over a long period of years to yield good profit. If an old window is in reasonably good shape it is always doubtful economy to replace it with a new window, even if this is thermally much better.

But as soon as a building need a «face lift» additional insulation usually should be considered, and often yields very good profit.

Airtightness

Uncontrolled ventilation due to air penetration through parts of the envelope and air infiltration into the insulation layers of the envelope are major sources of heat loss in many buildings. Air penetration is also a major source of condensation problems. All buildings need ventilation in varying degree depending on their use. The needed rate of ventilation is often specified as n = number of air changes pr. hour. Some types of buildings need a high rate of ventilation (n = 2–5) during the working hours, while others, such as residences, seldom need a higher rate than n = ½ by normal use. Air change rates of many times the necessary rate are often reported even with all intended ventilation equipment closed and sealed. The heat loss by uncontrolled ventilation in such cases is often much higher than the conduction losses. In such cases good thermal insulation, i.e. low U-values are more or less wasted.

Another problem is air tightness in relation to heat recovery in ventilation. Heat recovery in the ventilation system is often a very profitable investment, provided the building is sufficiently airtight so most of the air change actually passes the heat exchanger. For buildings with low requirements to air change rates, such as residential houses, this is particularly important.

Major sources of air penetration are joints between different building parts, such as around windows and doors or between roofs and exterior walls. But leaks also frequently occur through the building constructions themselves, particularly in connection with electric outlets, penetration of pipes and ducts, or in windows between frame and sash. Air infiltration into insulation layers also may be very harmful to the heat loss even if an inside windtight layer prevent the air from coming all the way through.

Proper design and workmanship are necessary to obtain good airtightness, but are often difficult to control. Better design and workmanship are to a large extent a question of education, but also to some extent a question of better materials and additional work.

Basic studies of airtightness of building materials and constructions were done in Norway 25–30 years ago, and exercised a considerable influence on the local building practice, but it was probably Sweden that was the first country to specify quantitative requirements to the air tightness in the building code (1977). As a norm has been set a maximum air change rate n = 3 by a pressure differential P = 50 Pa (over- or underpressure). The measurements may be done by fairly simple equipment and the cost for a test is low.

Simple and reliable methods to measure the air change rate under natural conditions (by tracer-gasses) have also been developed in many countries. In the mentioned CIB-symposium in Copenhagen was presented a paper (from Univ. of California, USA) which compared and interpreted results obtained by measurements of air change by 50 Pa superpressure and tracer-gas measurements by natural conditions. Infra-red thermography may be used to spot air leakages in existing buildings.

The field of airtightness is under rapid development. It's importance is well appreciated while practical, safe and low cost methods to obtain optimal airtightness will still be in progress, probably for many years.

Some of the submitted papers for the present section are concerned with airtightness problems. In wiew of its importances these problems may hopefully be hightlighted during our discussions.

Airtight houses may need mechanical ventilation systems to secure the minimum ventilation rate required for health and comfort reasons. We thus have a ring-effect which is typical for many building problems. For residential houses mechanical ventilation systems with heat recovery have not been commonly used and will obviously lead to increased building costs.

It is believed, however, that such extra investments may be profitable even for residences. For other buildings equipped with balanced ventilation for health and comfort reasons, an extra investment into heat exchangers is very profitable, yielding profits up to 50% for buildings with high ventilation requirements.

Consequences of improvements of the envelope

In the end should be pointed out that improvements of the building envelope obviously have very considerable influence on the design and use of the heating and ventilation systems. As an illustration can be mentioned that heating equipment need not necessarly be placed under

the windows, but almost anywhere in the building. Heat distribution is far less of a problem in really well insulated buildings than in old buildings.
The maximum heating effect and annual energy output from the supply system will be drasticly reduced, leaving less opportunity for costly investments into heating systems. This may favour simple and direct systems with low installation costs, possibly at the expense of the efficiency factors. On the other hand more attention must be given to the regulation and control of the technical systems.

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(CIB W67 Symposium, Copenhagen 1979)
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T. A. Markus: The window as a element in the building envelope, techniques for optimization.
Ø. Birkeland: Thermal bridges, energy losses.
K. Källblad and B. Adamson: Hand calculation method and estimation of heat consumption in buildings.
F. B. Siviour: Ranking energy saving ideas.

Energy Conservation in multistoreyed buildings

K.N.Agarwal*

Synopsis:

All over the world efforts are being made to conserve energy as far as possible. This is not only important from the point of reducing the drain on conventional fuel reserves but also due to hike in the price of petroleum products and unit cost of electrical power. A sizeable portion of electrical energy is consumed in multistoreyed office, hotel and commercial buildings for heating, cooling and lighting. A research project on the conservation of energy in multistoreyed building was sponsored by Ministry of Energy, Department of Power, Government of India.

The paper describes the pattern and quantum of energy consumption in multistoreyed office buildings. Various measures have been suggested to reduce power consumption for heating and cooling. These include revised standard of thermal insulation, optimum design of window and shading devices, raising the comfort limits of temperature and use of evaporative coolers. It is believed that at least ten percent of present level of energy consumption can be reduced by adopting some of the measures suggested. This is not likely to cause discomfort to the working personnel.

1.0. Introduction : In India multistoreyed buildings, public, private and government are of two types, one in which the internal environment for comfort is controlled by central heating and cooling plants and the other in which the thermal comfort requirements are achieved by unit air conditioners, radiators and evaporative coolers. Most of the buildings in our country are of second category. In these buildings heating and cooling consume a large portion of the total power consumption. A research and development project was undertaken to determine the pattern and quantum of energy consumption with a view to examine the scope of reducing power consumption in existing buildings and to provide guidelines for energy conservation measures in new buildings.

2.0. Pattern of Energy Consumption: In order to determine the extent of power consumption in multistoreyed buildings, survey was conducted in a few public and private buildings at different places like, Delhi, Bombay, Madras and Calcutta. In two of these buildings with a floor area of 50000 m^2 or so where about 5000 employees in different category work, the total monthly electric consumption is somewhat around 1.5 lakes units. It is observed that consumption rises during summer and winter months. During summer the bulk of consumption may be due to airconditioners and evaporative coolers, while during winter the bulk consumption may be attributed to heaters and radiators.

The monthly distribution of power consumption by different type of services were also calculated. The services are heating cooling, lighting and other essential services. Except for power consumption by essential services and lights other services showed seasonal variations. These variations are due to excessive use of radiators during winter and airconditioners during summer. This appears to be a wasteful spending of energy and therefore suggest an area where economy is possible in power consuption. Firstly by raising the limits of comfortable temperatures for cooling and heating and secondly by replacing as many as airconditioners as possible by evaporative coolers. These excessive use of radiators can also be limited.

3.0. Measures for energy conservation by building design

3.1. Limits of thermal comfort:

The limits of dry bulb temperatures for cooling can be increased from 25°C to 30°C with increased air motion, as for summer comfort in office buildings precise control of air temperature is not necessary. It has been observed that by increasing air motion from 0.5 metre/sec. to 1.5 metre/ sec, same comfort condition can be achieved as created by decreasing air

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temperature by 3.0°C. During winter months comfortable temperatures can also be lowered from 21°C to 18°C.

3.2. Thermal Performance Standard of Walls and roofs:

I.S.I.[2] has recommended certain minimum thermal performance specifications for walls and roofs. These are given in table 1. For buildings which are air-conditioned, revised thermal insulation standards are recommended. From the point of view

Table 1: Thermal Performance Standards

Building Component		Hot Dry U	Hot Dry TPI	Hot Humid U	Hot Humid TPI	Warm Humid U	Warm Humid TPI
U.C.	(i) Exposed Wall	2.2	125	2.2	125	2.5	175
	(ii) Roof	2.0	100	2.0	100	2.0	125
C	(i) Exposed Wall	2.0	100	2.0	100	2.5	175
	(ii) Roof	1.5	75	1.5	75	2.0	125

	U	S
Window (UC)	4.5	0.5
Window (C)	4.5	0.3

U.C - means unconditioned building

C - means conditioned building

S - Shade factors

U - Overall heat transfer coefficient, K.cal/hr° C.m.[2]

TPI - (Surface temp.-30) x 12.5.

From the point of view of energy conservation it is necessary to reduce the heat flow through exposed walls and roofs. The method employed for reducing heat flow through walls and roofs is given below.

Heat insulation of roof.

1. Heat insulating material can be applied externally or internally on the roof or ceiling respectively. In case of external application insulating material should be protected by water proofing treatment. For internal application these material can be applied either by an adhesive or false ceiling with an air gap may be employed. The optimum thickness of insulation both for flat and sloped roof for different type of insulating materials have been worked out. These are given in reference[3]. This will provide a ready reference for selection of insulating materials and their optimum thickness.

2. Thermal insulation of walls : Use of thermal insulating material is recommended on exposed walls only. Shading of walls is very effective and economical method of reducing heat ingress. Cavity walls, hollow bricks, light weight materials like cellular concrete can also be used provided structural requirement is satisfied. Light colour distemper may also be applied on the exposed side of the wall.

3. Design of window: Windows are generally provided in side walls for providing outside view, daylight and ventilation. Glass is the most commonly used material because of various advantages. From the point of view of energy conservation minimum glass area is mainly decided by Daylight requirement. The maximum glass area is limited by consideration in reduction of heat flow structure design and heating requirement during winter. Normally in office building the fenestration areas vary from .15 to 40 percent. From the point of view of adequate protection against solar heat during summer it is essential that a compromise be made between the percentage of glass area and the amount of shading. In view of the energy conservation the amount of heat gain through glazed window should not exceed 40 Kcal/hr m^2. For this value, the glazed area and shade factor can be worked.

Shading devices : There are many methods of reducing solar heat gain through windows. The effectiveness of these shading devices is evaluated in terms of shade factor and cost of the shading device. The measured values of the shade factor and increase in cost are given in table (2). The recommended value of shade factor for unconditioned building should not exceed 0.5 whereas for airconditioned building it should be less than 0.3. The required shade factor can be obtained by several combination of both external and internal shading. The computed values of shade factors for a combination of external and internal shading have been worked out [4]. From this it is possible to work out the type of shading device which will be most appropriate both from the point of view of cost and energy conservation.

Table 2: Measured Values of Shade Factors

S.No.	Type of Shading devices	Shade factor	% increase in cost over plain-glass window*
1.	Plain glass sheet (0.31 cm)	1.0	0
2.	Wire mesh outside with P.G.Sheet	0.65	11.0
3.	Painted glass (0.32 cm)		
	i) White Paint	0.35	3.1
	ii) Yellow Paint	0.37	3.2
	iii) Green Paint	0.40	3.2
4.	Heat absorbing glass (0.31 cm).	0.45	16.0
5.	Plain glass sheet with venetian blinds outside.		
	i) White colour	0.25	62
	ii) Light green colour	0.30	62
6.	Plain glass sheet with venetian blinds inside		
	i) White colour	0.35	62
	ii) Light green colour	0.40	62
7.	Plain glass sheet with curtain inside		
	i) Light colour	0.35	12
	ii) Dark colour	0.40	12
8.	Plain glass sheet with curtain outside		
	i) Light colour	0.30	12
	ii) Dark colour	0.35	12
9.	Plain glass sheet with louvers outside		
	i) 100% Shaded	0.14	83
	ii) 75% Shaded	0.34	67
	iii) 50% Shaded	0.56	48

* Cost of plain glass window is taken as Rs.33.50 per sq.m.

Table 3: Design data for evaporative coolers

S. No.	Fan diameter mm.	Pad area m^2	Water tank capacity Litres.	Cooling capacity tons.	Vol. cubic metres of the room cooled.
1	300	1.3	40	1.00	30 to 50
2	400	1.5	60	1.2	40 to 60
3	400	1.9	80	2.0	80 to 120
4	450	2.1	90	2.2	80 to 140
5	450	4.0	140	3.0	100 to 180
6	600	4.8	180	3.2	120 to 200
7	600	5.5	200	3.6	150 to 250

Use of evaporative coolers: Evaporative cooling is the cheapest method of cooling multistoreyed office buildings. Based on certain experimental studies conducted in this institute, design data for exhaust fan type of coolers are worked out and these are presented in table (4). The required cooling load of a building can be estimated from the knowledge of heat gain factors[5] and climatic data. For this computed cooling capacity in T.R, the size and number of coolers can be worked out from table (3).

The power consumption in these coolers is found to be 4 to 5 times lower as compared to unit air conditioner. The performance of these coolers have been compared with unit airconditioner during summer month, and found quite satisfactory.

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On The Design Of The Use And Discharge Of Water In Building

L'amanagement De L'utilisation et L'évacuation De L'eau Aux Bâtiments

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Summary

To ensure that a construction performs its duty in accordance with the present day concept of health, it must be designed in such a manner that all the supply and discharge systems are in harmony with the construction as well as with each other. The systems for the supply of clean water and discharge of used water constitute a part of the entire system in question. In the designing of these systems, particularly when the standard of life is kept in mind, it will be seen that economic harmony is a factor to which importance must be attached. In other words, it is essential to design equipment and installation within the framework of the present day civilization concept, in parmony with the realities of the country.

The subject is studied under the following sections:

1) analysis of the environment.
2) on analysis of man's habits in the use of water.
3) definition of the need for water.
4) discharge system.
5) preventive measures
6) conclusion.

Sommaire

Pour qu'un batiment soit conforme aux definitions hygiénique de ses fonctions, il faut que des systems sanitaires soit amenagé en concordance avec le batiment ainsi qu'entre même. Ce system comporte deux parties: la provision de l'eau propre et l'evacuation de l'eau utilisé. L'harmony économique est une probléme importante qu'on doit considerer quand le niveau de vie devient une variable dans le processus d'amenagement. En d'autres termes, il faut que les systems sanitaires soient amenagé en accordance avec les faits et les moyens du pays et aussi avec le niveau actuel de la civilisation.

De ce point de vue, le sujet est etudié dans les sections:

1) l'analyse des environments
2) l'analyse des habitudes humains, les necessités fondamentales
3) la definition de la necessité d'eau
4) l'analyse du system de canalisation
5) les precautions
6) conclusions.

1- Analysis of the environment

Architectural Environment is stated to be the physical sturucture comprising the environment, in the place and construction where the necessary function is created to reach a certain objective. [1].The most important objective, in other words, the starting point, is preparing the conditions wherein people can live a healthy life and the coming generation also can continue their livelihood, in the same healthy manner. On the other hand, the place where the above mentioned necessary action occurs, is seen as the synthesis of the natural, economic, social and legal environment. Apart from this, the efficiency of supply and discharge systems, that can also be defined as the circulation system of constructions, depends on the perfection of these environments.

As regards the means of supply evaluation by people, possibility of use and return to its natural circuit, water, one of the basic elements of life, can be, a) a source of energy, b) a source of discontentment among people and communities, c) a source of waste, d) a source of environment pollution.

From this respect, environment must not be regarded merely as a form of technological transfer; besides point of view of meeting the requirements and transferring all that is given to it, to their natural circuits again, it must be considered together with all the evalutions and also must be accepted as the supply of water, usage in the construction and the discharge of waste water in the environment.

2- Analysis of the habits in the use of water

At present, the expectations of a person from a building must be directed to meet physiological and psychological needs, as well as protection against contagious diseases, are tried to be fulfilled by means of installations and equipment, applied according to the presant habits , in connection with clean and dirty water.In these applications, social conformity is not taken into consideration. When the washing habits are studied, body care, cleaning and toilet customs of our society, trying to westernize itself, show some important basic differences in comparison with the west.

Washing habits of the west have originated from still water and these customs have led to the wash-stand and bathing-tub use today.

In our country, it is seen that this takes the form of washing with running water, a belief originating from religion. When toilet customs are taken into consideration, in the west the sitting position has led to the present day water closets; whereas in our country the change is towards water fitted stone lavetories. But the most significant difference is in the after-toilet cleaning, thas is, contrary to dry-cleaning, the habit of cleaning with running water. [2]

As a result of these customs, water is continued to be kept running until the and of a particular action.

3- <u>Determining the need for water</u>

Water conveyed into the building is distributed to various wet volumes. These wet volumes are classified according to the areas of function, as follows:
a) The area of the function of preparing and cooking food, b) the area of the function of body cleaning and care, c) the area of the function of body disciharge, d) the area of the function of house administration activities. [3]

The forms of installation and equipment usage necessary to materialize the actions in their areas of function, are shown in Figure.

The amount of water required for these areas of function, is given only approximately according to the place and manner of usage. To start with, the following values are used in the calculations: [4]

Water required for residences:

Drinking and dish washing, cleaning	20-30	litres/person/day
Washing	10-15	" / " / "
Lavetory	8-12	" / " / "
Bathing-tub	200-350	" / " / "
Shower	40-80	" / " / "
Residential gardens	1,5-2	litres/m2
Car cleaning	40-80	litres/car

According to the Turkish Standards No.1258, [5] the water requirement per person in residences, determined on minimum values is as follows:

Residences without bath	min. 60 litres/day
Residences with shower only	min. 60 litres/day
" with bath-tubs	min.100 " /day

It is pointed out that the amount of water required must be calculated separately according to special local features such as the garden of the residence, the dimensions of the building, the way of usage, the method whereby hot water is supplied. In the table of "water required in non-residential buildings", the values suggested for garden-sprinkle are 1,5 litres/m2, for car-cleaning 100 litres/car.

In the Damoc report prepared for Istanbul, [6] we see that, when Üsküdar is taken as an example for water required per person in 1980, the calculation comes to 125 litres per day, per person; this is approximately 59 % of the total need.

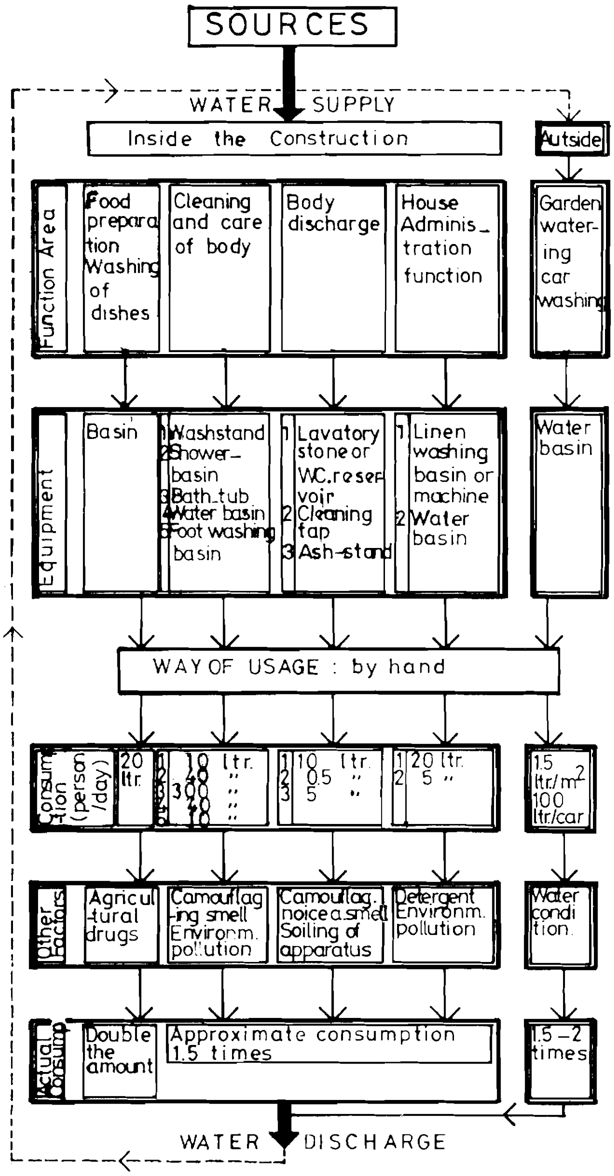

Figure Water disposel in Building corrected with funktion areas.

Besides this:

a) Psychology of the people, b) the ventilation system of the construction, c) Design of the equipment, d) Pollution of the surroundigns outside, have an influence especially on the function area of body care and cleaning as well as body discharge. In conclusion we can list the phenomenon of water consumption in these function areas as follows:

a) Fulfillment of the activity, b) Camouflaging the noise created during the activity, c) Camouflaging the smell arising from the ventilation system, d) Cleaning the dirt spread outside the equipment at the and of the activity (for example the dirt occurring as a result of the connection between the lavatory stone and cleaning tap). e) Use of water more than the amount planned because of the enlarged surface of soiled clothing when detergents are used.

Due to the habits of water usage pointed out in section 2, and to the relevant factors, it is evident that the water consumption is much more than expected and exceeds the accepted values, especially in the areas of body discharge, body care and cleaning. For example, if we assume that in a family of 5 members, the toilet alone is used 5 times more than necessary every day, we can conclude that 17 m3 water is wasted in one year, and that this amount is unnecessarily burdened on the environment; what is more, this 17 m3 amount of water is equal to the amount of water used in six months by one person in a residence having a shower.

4- Discharge systems

After the use of water is generally described as dirty and impure according to the characteristic feature of the place in which it is used and is driven away by means of a discharge system. In places where there is a drainage system, this water is connected directly to the drains, in places where this facility is not available, it is converted into a harmless state by mechanic, byological and chemical means within a separate system. On this subject there are also regulations in our country. [7],[8]

But considering in particular the fact that a very large percentage of the population of a country does not benefit from a general drainage system, the main problem is how to decrease the amount of vater to be purified in separate systems, and the way in which it can be used again after purification.

In other countries, studies are made to prevent the dirty water from burdening the separate purifying systems and thereby facilitate obtaining water that can be used again in places where there is no drainage system; the results of these works are sold at the market as industrial products.

In other words:

1) The problem is considerad only from the point of decreasing the water consumption by means of equipment designing. Here results are obtained by,
   - reusing a certain amount of water in the WC equipment up to a fixed number of times, by passing it through a filter adjusted into the equipment [9]
   - putting a cauterizing device in the equipment [10]
   - fixing an instantaneous cooling system in the equipment [11]
2) Emphasis is laid on studies to use the separate purifying systems as a source of ensuring verdure in isolated areas; whereby any connection of the purified water with the surrounding environment is prevented [12]

5- Preventive measures

It is obvious that under the conditions prevailing in our country, decreasing water consumption by means of equipment design mentioned above is out of the question; but reducing environmental pollution is possible by a wider application of the separate systems.

Yet we believe that by means of a different equipment design that is more suitable to the customs of the country. The consumption within the constructions can be reduced to a normal level. For example, if a foot-directed battery system generally used in hospitals, is applied to the wash-stand equipment in residences, consumption can be reduced to a great extent.

Considering the above studies, the primary measures that can be taken, to reduce water consumption, are:

a) Education. b) Channelizing and encouraging industrial production of equipment suitable to our customs. c) Proper use of detergents and similar cleaning mediums. d) Ensuring the functioning of other systems applied in the function area. e) Always considering the phenomenon of use, purification and re-evaluation as a whole and starting the design procedure.

6- Conclusion

In designing systems for the supply of clean water and driving away of used water, one must be conscious of the fact that, particularly the standard of living with all its details, must be taken into consideration and importance must be attached to economic conformity. In other words, health equipment and installations must be designed in a manner, taking into considenation conformity with the realities of the country, under the present concept of civilization. Water consumption is a cultural event. One must take it under control.

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Economic evaluations concerned with energy conserving improvements of the building envelope
- Some Hungarian examples -

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Summary: The paper reviews some of the recent economic studies carried out in the Institute for Building Economics and Organization concerning the building envelope or its structural parts. Depending on the purposes they served the studies have been classified into four groups, as follows:
- economic analyses aimed at preparing the decision on the development of building standards regulating the heat insulating capacity of the building envelope;
- economic evaluations aimed at the selection of the economically efficient window types;
- value analysis/engineering type of studies aimed at the development of the design solution of complex structural units of the envelope (external wall panels including the window and the bay-door);
- economic assessments concerned with experimental energy conservation projects.

The basic technique of the economic evaluations has been "Life-Cycle Costing". In a few studies L.C.C. has been combined with Value Analysis/Engineering methods.

Following a brief description of the essential features of the studies and the way of approach adopted in the different cases, a general view is given of the results by focussing on the most important conclusions drawn from them.

Résumé: La communication donne un aperçu des études économiques menées à bien récemment à l'Institut pour l'Economie et l'Organisation du Bâtiment concernant l'enveloppe d'immeubles et ses parties structurelles. D'après les objectifs poursuivis, les études sont classées en 4 groupes:
- analyses économiques ayant pour but la préparation de décisions concernant les normes servant à la reglementation de la capacité d'isolation thermique de l'enveloppe de bâtiments;
- évaluations économiques ayant pour objet le choix de types de fenêtres économiques;
- études appartenant au type de l'analyse/engineering de la valeur ayant pour but le développement de l'étude de solutions d'unités structurelles complexes de l'enveloppe (panneaux de murs extérieurs y compris fenêtres et portes-fenêtres);
- évaluations économiques concernant des programmes expérimentaux de la conservation de l'énergie thermique.

La technique fondamentale des évaluations économiques est le "Life-Cycle-Costing". Dans quelques études le L.C.C. est combiné avec des méthodes d'analyse/engineering de la valeur.

Après une description succinte des traits importants des études et de la méthode d'approche utilisée dans des différents cas, suit un aperçu général des résultats en concentrant sur les conclusions les plus importantes tirées des études.

The design solution of the building envelope has a decisive impact on the economy of a building. In the construction cost the share of the envelope represents a relatively high proportion: e.g. in case of multi-storey residential blocks the cost of the envelope varies between 25-35 % of the construction cost. On the other hand, the technical properties (such as the heat insulating capacity, the durability etc) of the envelope influence the operating and maintenance costs to a great extent.

These facts and the rapid increase of energy prices have induced the Hungarian authorities and research institutes responsible for the development of construction technics and the economy of buildings to focus their attention on the improvement of the building envelope with the aim of reducing energy consumption throughout the life-time of buildings.

This paper reviews some of the recent economic studies/analyses carried out in the Institute for Building Economics and Organization in relation to the building envelope or some part of it.

The basic method applied for the studies in question has been "Life-Cycle Costing". It means that solution alternatives have been evaluated by comparing the total/discounted amount of all relevant costs associated with each alternative during the expected life-time of buildings. Accordingly, the life-cycle costs taken into consideration comprised the first (construction) cost and the future costs of operating and maintenance discounted to a common point of time.

In a few studies life-cycle costing has been combined with the application of Value Analysis/Engineering methods with the aim of optimizing the cost/performance ratio. The performance of the "product" (i.e. the building envelope) has been analysed and assessed from the users' point of view, starting off from the functional requirements the product has to meet. Based on the degree of satisfying the various requirements design alternatives have been compared and ranked. Finally, the optimum solution alternative has been selected with regard to both, the functional performance of the product and the life-cycle cost associated with it.

Depending on the purposes they served, our economic studies concerned with the envelope may be classified into the following main categories:

1. Economic analyses aimed at preparing the decision on the development of building standards regulating the heat insulating capacity of the building envelope [1]

Due to the repeated and considerable rise in oil and energy prices, in the mid-seventies efforts were made at reducing the energy consumption of buildings. It was realized that the standard requirements concerning the heat insulating capacity of the envelope had to be revised and in order to reduce the heat loss of buildings more severe regulations had to be put into force. Nevertheless, the extent to what requirements had to be heightened could not be determined without thorough investigations concerning the economic consequences of such measures. These investigations were carried out in our Institute in 1974-75, in two phases.

In the first phase - based on a sample comprising 18 model buildings of different size, lay-out and structural system - we assessed the extent to what the heat insulating capacity of the envelope had to be improved in order to attain the minimum of the life-cycle cost. (It must be noted that in this case those kinds of future cost which could be considered independent of the changes in the heat insulating capacity - i.e. repair and maintenance costs - were not taken into account in the life-cycle cost.) At the same time we tried to identify the effects the various structural elements (such as the roof, the outer walls and the windows) produced on the heat insulating capacity of the envelope on the one hand, and on the first/construction cost of the building on the other.

The results of these analyses provided information for the preparation of a preliminary recommendation concerning the modification of the standard requirements.

In the second phase we checked the impact of the planned change of the standard requirements on both, the first costs and the heating costs of the model buildings. Heating costs were calculated with regard to the various ways of heating, i.e. by taking into account different heating systems and types of heating installations on the one hand, and different kinds of fuel on the other.

The analyses draw attention to the importance of the windows in reducing the heat loss of the buildings. That is why in a further study we dealt with the economic evaluation of alternative technical solutions of windows.

2. Economic evaluations aimed at the selection of the economically efficient window types [2, 3]

The evaluations were confined to the most widely used, standardized and mass-produced window types. The sample comprised windows of 3 different kinds of basic/structural material:

- wooden,
- plastic,
- aluminium.

Two alternatives of glazing were examined: double glazing with ordinary glass and special double glazing of improved heat insulation.

The most significant difference between the windows consisted in their air-tightness. This property had a considerable influence on the heating costs. When calculating the heating costs two kinds of fuel were taken into account: the cheapest kind (coal) and the most expensive one (oil). In compliance with the expected changes in energy prices a yearly price increase of 6% was taken into account in the calculation of the life-cycle cost. In the running costs all kinds of repair and maintenance costs were included.

A series of studies - discussed below - pertained to a room-size complex structural unit of the envelope, i.e. the external panel fit into the bay of cast in situ concrete load-bearing structures produced by means of tunnel shuttering (e.g. OUTINORD).

3. Value analysis/engineering type of studies aimed at the development of the technical/design solution of mass-produced external wall panels [4]

In the first phase of the investigation 9 different kinds of wall structures were compared and ranked from two aspects: performance and life-cycle cost. The size and the form of the windows and doors incorporated in the wall panels were the same in case of each alternative, whereas 2 different kinds of window/door structures were represented in the sample, namely: wooden and plastic ones.

The 9 alternative wall structures included:

- 3 different kinds of cast in situ light concrete walls (dross concrete, keramsite and no-fines);
- 2 types of precast concrete elements;
- 2 types of lightweight "assembled" panels (one of wooden structure, the other of a lightweight material called "betonyp");
- 2 masonry walls (made of "poroton" and cellular concrete small blocks).

The first step of the analyses was the establishing of a hierarchical, weighted list of the functional requirements. This task was carried out by a complex team consisting of 12 experts representing various professions (architects, structural engineers, sanitary engineers, economists, cost consultants, etc). Based on the list of requirements the functional performance of each of the alternative solutions was assessed and characterized by dimensionless figures (point numbers). The quantification was done by means of the so-called "value curves" commonly used in VA/VE procedures.

The next step was life-cycle costing, whereupon all the first and future costs associated with the various alternatives were taken into account. Finally, the alternatives were compared and ranked according to the value of the index numbers expressing the cost/performance ratio.

As a result of the analyses the best alternatives could be selected. In the next phase of the work - not yet finished - one of these alternatives (the "betonyp" panel) will be analysed into detail with the aim of rationalizing the design solution so that the first cost of the product be reduced without the detriment of its functional performance. This Value Engineering type of analysis will be carried out in close co-operation with the designer and the manufacturer of the product.

In recent years several experiments were carried out with the aim of reducing the energy consumption of buildings by means of improving the heat-insulating capacity of the external walls and the roof.

4. Economic assessments concerned with experimental energy conservation projects [5, 6, 7]

The experiments were realized partly in existing buildings partly in new ones. In both cases an additional heat-insulating layer (polistirol foam or mineral wool) was applied either on the external or on the internal surface of the wall/roof. If applied on the external surface the insulating layer was clad with some kind of weather-proof cover (e.g. asbestos cement sheets), whereas if applied on the internal side it was covered with dry-plaster sheets.

The effects of supplementing the structures with an additional heat-insulating layer were tested in one-family houses so that the results of the heat-loss measurings carried out in the improved buildings were compared with the heat-loss data registered in the same period in the so-called "reference" or "control" buildings. These latter were identical with the experimental buildings in every respect except the additional insulation. In this way the difference in the specific heat-loss due to the improvement could be assessed.

By comparing the cost of the additional insulation to the benefit resulting from the reduction of the heating costs the rate of return could be calculated. It should be mentioned that the costs and benefits associated with the improvements were calculated separately for the walls and the roof, thus it could be assessed how much the reduction of the heat transmission of 1 m^2 wall/roof by 1 W/Kh costed and how much the yearly benefit attributed to the improvement of each was.

Results and conclusions:

In a short paper like this one there is no room to give a detailed and comprehensive account of the issues resulting from the above studies. Nevertheless, we attempt to provide a general view of the results by focussing on the essential conclusions drawn from them.

The economic analyses concerned with the modification of the standard requirements regulating the heat-loss of the envelope have shown that by means of increasing the heat insulating capacity of the external structures to the recommended level the energy consumption of buildings could be reduced with 20 - 40 %, whereas the rise in the first/construction cost due to the improvement of the structures varied between 3 - 8 %.

The efficiency of energy conserving improvements of the envelope is influenced by several factors. In Hungary where besides central and district heating systems many less advanced methods of heating are used (such as individual stoves fired with coal, wood, gas or oil) the results of the cost/benefit analyses are considerably influenced by the way of heating to be taken into account in the various cases.

According to our calculations the improvement of the heat insulating capacity of the envelope proved to be the most efficient in cases where:

- the capacity/performance of the heating installations can be easily adapted to the variation of the heat requirement;
- the first cost of the heating installation is relatively high and by the reduction of

the heat requirement an essential part of the first cost can be saved (e.g. in case of central and district heating systems);
- the specific cost of the fuel is high (in Hungary there are considerable differences in the prices of the various fuels: coal is much cheaper than any other kind of fuel);
- the heat insulating capacity of the structural element can be increased without major technical difficulties and unfavourable cost consequences (this relates e.g. to flat roofs or the top floor under pitched roofs where the application of a thicker insulating layer causes no technical problem and requires relatively moderate extra costs).

The potential reduction of the heat loss hit the highest percentage in case of detached one-family houses. Nevertheless, if they are heated in intermittent cycles (i.e. discontinuously) and partially, the extra costs spent on the improvement of the envelope will be returned relatively slowly.

In multi-storey residential buildings of large-panel construction some 55-70 % of the heat loss goes off through the windows. Accordingly, the most obvious way of reducing the heating energy consumption is the improvement of the windows.

In case of windows the heat loss may be attributed to three main factors:
- heat transmisson through the frame,
- heat transmission through the glazing,
- filtration through the joints.

The initial results of the investigation supported the hypothesis that filtration was the most critical factor. Consequently the improvement of the air-tightness of the joints seemed to be the best way of reducing the heat loss. (It must be noted that in Hungary it is a long standing tradition to apply double glazing in the windows, thus the improvement of the glazing was not considered such an obvious and promising solution as in countries where simple glazed windows have been used in general.)

From the life-cycle cost analyses of the different window types the conclusion was drawn that - due to their superior quality as regards the air-tightness - despite their considerably higher first cost plastic windows were more economical on the long run than the wooden or aluminium ones.

On the other hand, both, the wooden and the aluminium windows can and should be improved by means of appropriate structural changes. In case of aluminium windows the heat transfering surfaces of the frame should be reduced by means of applying carefully shaped narrow profiles. As for the wooden windows, on the one hand, the manufacturing technology (e.g. the treatment of the wood) should be developed in order to produce frames of better quality and higher dimensional accuracy, on the other the air-tightness of the joints should be increased by means of applying better kinds of sealings, iron fittings etc. In course of the life-cycle calculations we also determined the marginal value of the extra cost expendable to the improvement of the window structure provided that the extra investment must be returned in less than 8 years. (The marginal value varies depending on the kind of fuel taken into account.)

As regards the improvement of the external walls the analyses have led to the following conclusions:
- The heat insulating capacity of multi-layer walls and sandwich panels is rather good even in their present forms and can be increased to the required level generally without major technical diffulties. Neither is the extra cost associated with the thickening of the insulating layer by a few centimeters too high.
- Among the masonry-type walls made of small size elements (so-called "walling hand-blocks") there are some types the heat insulating capacity of which is acceptable - even if they are of the usual "normal" thickness - due to the superior thermal properties of the elements themselves. (Such walls are e.g. the cellular concrete walls and those made of the so-called "poroton" hollow ceramic elements.)
- On the other hand, the walls made of normal solid bricks or cast stone small blocks have to be improved some way in order to attain the required level of heat transmission. The three possible ways of the improvement taken into account in the economic analyses were:
  - . the application of an additional heat insulating layer on the external or internal surface of the wall,
  - . the increasing of the wall thickness,
  - . the application of some additional heat insulation inside the wall structure (i.e. sandwich-type walling or the filling of the hollow cast stone elements with

some kind of insulating material).

As the fixing of an insulating layer on the external or internal wall surface is a highly-fabricated job and the protective coating is rather expensive, this solution cannot be recommended in cases where the potential saving of the heating cost is moderate (e.g. in one-family houses which are heated in intermittent cycles and where cheap kinds of fuel are used).

The extent to which the wall thickness can be increased is limited from both, technical and economic points of view. Therefore the solution lies either in inserting some kind of internal insulation into the wall structure or in substituting the nowadays used solid bricks and cast stone small elements with better products (such as e.g. hollow ceramic or cellular concrete light elements).

Based on the results of the economic analyses the regulation concerning the heat transmission of the building envelope has been revised and more rigorous standard requirements have been fixed. It should be noted that the introduction of the new standards will be implemented in two steps. At the first stage (i.e. in the transitional period lasting till 1985) the requirements are changed but moderately, while at the second stage the following standard values will be put into force as regards the heat transmission of external structures:

- roofs: 0,4 W/m^2K
- external walls: 0,7 W/m^2K
- the complete external façade (walls, windows and bay doors together): 2,0 W/m^2K on an average.

If the specific heat transmission of the windows is too high either the window/wall ratio or the heat transmission of the walls should be reduced.

The above requirements were taken into account in our economic studies concerned with the selection of the most favourable solution alternatives of room-size complex structural units of the envelope. (The complex unit comprised the wall/panel structure, the window and the bay door.) The results of the comparative evaluations carried out according to the principles of Value Analysis justified the expectation as regards the potential savings in both the first and the life-cycle costs. Nevertheless, while in the first cost the difference between the cheapest and most expensive solutions amounted to 103 %, in the life-cycle cost the maximum difference was but 23,4 %. The diminution of the difference could be attributed first of all to the choice of the window-door structures. As - despite their higher first cost - on the long run plastic windows/doors are more economical than wooden ones, in the life-cycle costs an essential part of the original cost differences got compensated.

From point of view of the life-cycle cost/performance ratio the rank order of the solution alternatives was established as follows:

1. cellular concrete walls of small blocks[x]
2. "poroton" walls of small blocks[x]
3. dross concrete monolithic walls[x]
4. no-fines concrete monolithic walls[x]
5. keramsite concrete monolithic walls[x]
6. cellular concrete walls of small blocks[xx]
7. "poroton" walls of small blocks[xx]
8. dross concrete monolithic walls[xx]
9. "HEP" precast r.f. concrete sandwich panels[x]
10. no-fines concrete monolithic walls[xx]
11. keramsite concrete monolithic walls[xx]
12. "betonyp" lightweight assembled panels[xx]
13. "KP" precast r.f. concrete sandwich panels[x]
14. "HEP" precast r.f. concrete sandwich panels[xx]
15. lightweight assembled panels of wooden structure[xx]
16. "KP" precast r.f. concrete sandwich panels[xx]

- - - - -

x with plastic windows/doors

xx with wooden windows/doors

- - - - -

It should be noted that in case of the lightweight assembled panels made of "betonyp" only one solution was taken into account, namely the one with wooden windows/doors. In the next phase of the study further solution alternatives of the "betonyp" panel will be designed and analysed into detail. It is hoped that by means of rationalizing the present solution and substituting the wooden windows/doors with plastic ones the "value" of this panel type can be considerably increased. The aim is to develop a product that can compete with the masonry-type walls made of cellular concrete and "poroton" small blocks.

It may be of interest as well that in the above rank-order formed according to the l.c. cost/performance ratios the "cheapest" alternative - i.e. the one requiring the lowest first cost - got but to the 6th place. On the other hand, the most expensive solution occupied the 13th place. The alternative offering the best performance came in to the 3rd place, while the one providing the poorest performance got to the 15th place. At the same time, the first cost of the "best" and the "worst" alternatives (i.e. the cellular concrete wall with plastic windows and the KP panel with wooden windows) was practically equal, while the difference in their life-cycle costs amounted to 23,4 %. All these seem to justify the necessity of complex evaluation methods by means of which the overall "value" of the technical solutions can be assessed.

Present problems - future tasks:

In order to increase the reliability of our economic assessments the quality of both, the technical and the economic input data should be improved.

In fact, rather often we have to base our evaluations on laboratory data and theoretic calculations which may more or less deviate from the empirical data obtained under real conditions. This has been the case e.g. as regards the heat transmission parametra of windows. To check the validity of the laboratory data on site experiments and measurings would be needed. First of all the extent of the filtration through joints should be investigated under real conditions, i.e. in existing buildings exposed to actual air-pressure conditions.

As for the reliability of the economic data to be taken into account in the economic evaluations the main problem lies in the uncertainty of the forecasts concerning future changes in energy, labour and material prices and in the other economic conditions (e.g. the rate of inflation, the development of the interest rates etc.) influencing the formation of the operating and maintenance costs. Therefore it seems to be advisable to calculate future costs in several alternatives, taking into account variable data resulting from optimistic, pessimistic and "realistic" forecasts. Bearing in mind that in this case - due to the relatively high number of the variable input data and the even much greater number of the alternatives that can be formed from their different combinations - the evaluations will call for more sophisticated and labour demanding calculation methods, one has to realize that their implementation should be facilitated by the application of computer techniques. One of our most important future tasks is to devise the appropriate, computer-aided methods of economic evaluations.

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A Dynamic Simulation Model for the Optimization of Solar Energy Flow Through the Building Envelope

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Summary

In this paper, building envelope, which is composed of opaque and transparent building components, is considered as a passive heating and climatisation system.

In the introductory section of the paper the design variables which take part in passive heating and climatisation process are studied.

The second section is devoted to a dynamic simulation model and related computer programme which can be used both to generate a design solution relevant to the building envelope and to evaluate its performance from the aspect of passive utilization of solar radiation. The computer program (ODIAS) is written in Fortran IV programming language.

The third section includes the application of the proposed model to Ankara region.

Sommaire

Dans cette communication l'envelope du batiment, formé des components opaques et transparants, a été considéré en fonction d'un systems de chaufage et de climatisation passive.

Dans la section d'introduction, les variables du design qui jouent un rôle dans le processus de chaufage et de climatisation passive sont examinées.

La second section a été consacré au modèle de la simulation dynamique et au programme computer concernant qui produissent une solution du design et qui évaluent sa performance en vue l'utilisation passive du rayonnement solaire.

Le programme computer a été écrit en langage du programme FORTRAN IV.

La troisième section de cette communication inclut l'application du modèle proposé à la région d'Ankara.

Introduction

Building envelope design should be developed to diminish the energy consumption for artificial heating and climatization. In the underheated period (UHP), the minimum heat loss through the building envelope implies the maximum passive utilization of the heating effects of solar radiation and necessitates the minimum supplementary artificial heating. In the overheated period (OHP), the minimum total heat gain implies the minimization of the heating effects of solar radiation and air temperature to the building envelope and, also, provides either a higher indoor comfort temperatures or minimum energy need for the supplementary artificial climatization.

The definition of the optimal building envelope from the passive heating and climatization point of view can be obtained by the enumeration of possible solutions according to the following design parameters of environmental system; orientation, shape factor (the ratio of building depth to building lenght), roof type (flat, shed, gable, etc.), roof inclination, external surface properties for solar radiation (absorptivity, transmissivity, reflectivity), thermophysical properties (overall heat transfer coefficients of opaque and trasparent envelope components and transparency ratios).

These parameters are effective on total heat gain and heat loss through the building envelope and subsequently in the utilization of the heating effects of solar radiation and air temperature. Therefore, the building envelope, as a whole, can be considered as the main determinant of the indoor climate.

The building envelope, which facilitates the creation of the climatic comfort conditions through the use of minimum supplementary artificial heating or climatization energy, can be qualified as optimum from the aspect of passively utilization of the heating effects of solar radiation and external air temperature.

The Dynamic Simulation Model

The problem of minimization of energy use in building has been studied generally by the aids of computer modelling methods in last decade. The performance of building envelope can be studied precisely in detail by the application of computer simulation techniques instead of using field measurements or physical and analogue models.

In this study the model which is described elsewhere |1|, has been computerized in order to investigate the range of different building envelopes in different conditions. The model (ODIAS) which simulates the thermal behaviour of the envelope can be used in either of two ways; The first is to define and enumarate the possible combinations of design parameters of the environmental system, the second is to study the heat gains and losses of the building envelope in different conditions.

As Hawkes and Stibbs stated; "The process begins with the collection of the required data which is input and is considered by some predetermined descriptive structure. Information is then taken from this store and is used by one or more analytical programs which produce the answers which are being sought and this is, therefore, output in an acceptable format" |2|.

The building envelope, which is taken into account in this model, has a rectangular shape with a constant floor area. The ratio between the edges of a rectangle can be differentiated in a given interval. The repertoire of the type of roofs are; flat, shed, gable and piched.

The geometrical data defining the building envelope are the floor area (m^2), height between ground level and the lowest edge of the roof (m), the type of roof, the inclination of the roof and the transparency ratios of facades. This passive description of building envelope constitutes the data of the analytical program. AREA, which produces the active description of building envelope in other words the number and characteristics of each component of building envelope and the volume of building as well. The external surfaces of the building envelope are annotated in the analytical program as follows;

o Enclosing walls 1, 2, 3, 4
o Roof . flat (including single surface) 5
. shed (including single surface) 5
. gable(including two surfaces) 5, 6
. piched(including four surfaces) 5, 6, 7, 8

The thermophysical properties of building envelope related to its opaque and transparent components are listed in Table 1. The third group of parameters defining the environmental system contains the location and the orientation of building. The ground on which the building is located is considered as a horizontal surface which has the same reflectivity all over it.

The heat flow through building envelope has been calculated according to the characteristic days of the UHP and OHP periods provided that the windows are considered to be closed in OHP period. Most of the calculations are devoted to the definition of the relationships between the geometry of building envelope and the geometry of the movement of the sun. The sun's movement is simulated at hourly intervals for the characteristic days of UHP and OHP periods during the daylight hours. Thus a simple range of forms, enclosing identical amounts of floor area and with a range of transparency ratio, a range of wall construction, a range of glass types and a range of orientations can be studied by the proposed model. In Table 1 and in Figure 1, the geometrical, thermophysical and geographical data which define the environmental system are listed and combinatorial procedure which enumerates the possible environmental systems is shown in graphical format.

geographical data	geometrical data	thermophysical data
o location o orientation o reflectivity of ground	o floor area o height o shape factor o roof type o roof inclination	o k_o, overall heat transfer coefficient of opaque component (for the range of wall constructions) o k_g, overall heat transfer coefficient of glas (for the range of glas types) o transparency ratio o a_o, absorptivity of opaque surfaces o a_D, T_D, absorptivity and transmissivity of transparent surfaces

Table 1. The parameters of the investigated environmental system.

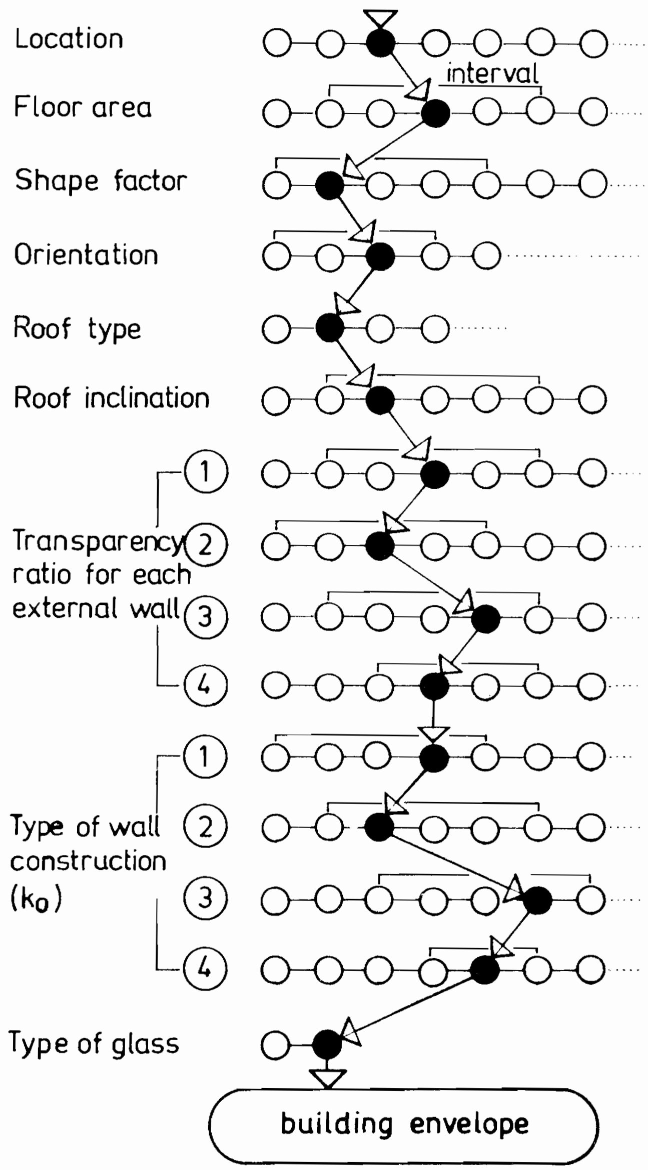

Figure 1. Enumeration of possible environmental systems.

The input data of the program;

- o floor area (m^2),
- o the minimum height between floor and the lowest edge of the roof,
- o the range of orientations,
- o elevation from the sea level,
- o reflectivity of the ground,
- o external heat transfer coefficient,
- o the range of shape factors,
- o variation range and intervals for overall heat transfer coefficient of opaque facade components,
- o the range of roof inclinations,
- o the roof types (flat (1), shet (2), gable (3), piched (4))
- o the range of tranparency ratios of each external wall,
- o absorbtivity of opaque facade components,
- o the properties of different types of glasses
  - . transmissivity of glass component for direct solar radiation (T_D)
  - . absorptivity of glass component for direct solar radiation (a_D)
  - . absorbtivity and transmissivity of glass component for diffuse solar radiation (a_y, T_y)
  - . Overall heat transfer coefficient of glass component
- o the climatic data for the UHP and OHP periods;
  - . characteristic days of the UHP and OHP, sky diffuse factor, cloudiness, number of daylight hours, indoor air temperature, sunrise and sunset hours.
  - . altitude angle of the sun,
  - . azimuth angle of the sun,
  - . intensity of direct normal solar radiation,
  - . external air temperature.

The Computer program ODIAS which was developed in Computer Centre of İTÜ, are coded in FORTRAN IV programming language. The input data are read in by card-reader and the outputs in numerical format can be obtained by lineprinter.

The output data of the program;

- o the design parameters of each environmental system
- o daily total heat flow through building envelope
- o daily average hourly heat gain or loss of the unit volume of building.

The Application

The model ODIAS has been applied to a single storey building in Ankara.

The input data can be listed as below;

- o characteristic day of OHP : 21 July
- o characteristic day of UHP : 21 January
- o elevation from the sea level:902.0m
- o orientation : north (0^o), east (90^o), increament = 45^o
- o floor area : $150m^2$
- o height : 3.0m
- o shape factor : 0.5
- o roof type : flat, shed, gable, piched
- o transparency ratio : %20-%40 increament = %20
- o roof inclination : 15^o-30^o, increament = 15^o
- o k_o, overall heat transfer coefficient of opaque component : 1.0-2.0kcal/m .h.C^o, increament = 0.5kcal/m^2.h.C^o
- o k_g, overall heat transfer coefficient of glass : 5.2kcal/m^2.h.C^o
- o reflectivity of ground : 0.2
- o a_o, absorbtivity of opaque surfaces : a_o = 0.4, a_{roof} = 0.7
- o comfort value of indoor air temperature : UHP = 21^oC, OHP = 25^oC
- o the properties of the different type of glasses shown in Table 2.

A part of output which is obtained at the end of the application of the model is given in Table 3.

type of glass	incidence angle of the sun										
	θ^o	0^o	10^o	20^o	30^o	40^o	50^o	60^o	70^o	80^o	90^o
I	a_{D1}	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.0
	T_{D1}	0.9	0.9	0.9	0.9	0.89	0.87	0.82	0.77	0.44	0.0
II	a_{D2}	0.53	0.53	0.54	0.54	0.55	0.56	0.56	0.53	0.32	0.0
	T_{D2}	0.41	0.41	0.41	0.41	0.39	0.37	0.33	0.28	0.18	0.0

Table 2. Variations of absorbtivity and transmissivity of glass with the incidence angle of the sun.

Conclusion

In general the predictive models can be used in three ways in Architectural design |3|;

- o the solution can be improved by iterative appraisals thus the satisfactory solution can be reached at the end of the process.
- o the best solution among the potential solutions can be defined by the predictive models employed in the evaluation stage.
- o the relationships between the variables of the system can be studied systematically in order to help the designer in decision making process.

The predictive model which simulates the thermal behaviour of the building envelope can be used for the last two purposes; Firstly, the building envelope which has optimal performance and constitutes a passive climatization system can be defined by the model. If some of the design parameters such as orientation, the type of roof, the inclination of roof or transparency ratio of facades etc., are not controlled by architect, the optimum building envelope can be defined according to the given constraints.

Secondly, the relationships between the building envelope and performance variables can be explored in certain conditions in order to understand the behaviour of the environmental system. Although the results obtained by the application of this type of models can only be used in certain conditions, they give an insight about the system which architects deal with. The more sophisticated computer models which simulate the behaviour of the environmental system much more relevant to the real world then the present models, are no doubt on the way of development now. Thus, the improvements in methods will be enlarged the applications in the field of environmental evaluations.

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Heating effect of Solar Radiation in the UHP
Type of glass: 1

NCALP	IEGO	ICATI	IB	SO1	SO2	SO3	SO4	O1	O2	O3	O4	O5	O6	O7	O8	SUM	AKUSA
1	0	1	1	20.00	20.00	20.00	20.00	1.00	1.00	1.00	1.00	1.00				-165556.12	-15.7
1	0	1	1	20.00	20.00	20.00	20.00	1.00	1.00	1.00	1.00	1.50				-202006.51	-18.7
1	0	1	1	20.00	20.00	20.00	20.00	1.00	1.00	1.00	1.00	2.00				-234444.89	-21.7
1	0	1	1	20.00	20.00	20.00	20.00	1.00	1.00	1.00	1.50	1.00				-174334.54	-16.1
1	0	1	1	20.00	20.00	20.00	20.00	1.00	1.00	1.00	1.50	1.50				-206776.53	-19.1
1	0	1	1	20.00	20.00	20.00	20.00	1.00	1.00	1.00	1.50	2.00				-239223.31	-22.2
1	0	1	1	20.00	20.00	20.00	20.00	1.00	1.00	1.00	2.00	1.00				-175112.57	-16.6
1	0	1	1	20.00	20.00	20.00	20.00	1.00	1.00	1.00	2.00	1.50				-211557.36	-19.6
1	0	1	1	20.00	20.00	20.00	20.00	1.00	1.00	1.00	2.00	2.00				-244001.74	-22.6
1	0	1	1	20.00	20.00	20.00	40.00	1.00	1.00	1.00	1.00	1.00				-176346.34	-16.3
1	0	1	1	20.00	20.00	20.00	40.00	1.00	1.00	1.00	1.00	1.50				-208792.73	-19.3
1	0	1	1	20.00	20.00	20.00	40.00	1.00	1.00	1.00	1.00	2.00				-241237.11	-22.3
1	0	1	1	20.00	20.00	20.00	40.00	1.00	1.00	1.00	1.50	1.00				-175532.16	-16.7
1	0	1	1	20.00	20.00	20.00	40.00	1.00	1.00	1.00	1.50	1.50				-212376.55	-19.7
1	0	1	1	20.00	20.00	20.00	40.00	1.00	1.00	1.00	1.50	2.00				-244821.53	-22.7
1	0	1	1	20.00	20.00	20.00	40.00	1.00	1.00	1.00	2.00	1.00				-183515.58	-17.0
1	0	1	1	20.00	20.00	20.00	40.00	1.00	1.00	1.00	2.00	1.50				-215560.37	-20.0
1	0	1	1	20.00	20.00	20.00	40.00	1.00	1.00	1.00	2.00	2.00				-248404.75	-23.0
1	0	1	1	20.00	20.00	20.00	20.00	1.00	1.00	1.50	1.00	1.00				-176585.69	-16.5

IEGO : roof inclination, ICATI : roof type, IB : shapefactor, SO1, SO2, SO3, SO4 : transparency ratios, O1, O2, O3, O4, O5, O6, O7, O8 : overall heat transfer coefficient of opaque components, SUM : daily total heat flow through the building envelope, AKUSA : average hourly heat gain or loss of the unit volume of building.

Table 3. The output of the program ODIAS

Building Facade Design From the Standpoint of Solar Radiation and Air Temperature Control

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Summary

In this paper, a method for designing building facade elements from the aspect of passive utilization of the combined heating effect of solar radiation and air temperature is introduced. The method aims the determination of the optimal overall heat transfer coefficients for the opaque components (walls) of facade elements in reference to overall heat transfer coefficient of transparent components (windows), transparency ratios, and the solar radiation proporties of facade elements. The method has been developed by Dr. Eşher Berköz and its application to Ankara region which is also included in this paper, has been carried out by Zerrin Yılmaz.

Sommaire

Cette communication présente une methode pour le design des élements de facade des bâtiments en founction de l'utilisation passive de l'effet combiné du rayonnement solaire et de la température de l'air. Avec cette methode, la détermination du coefficient de transmission thermique des components opaques (murs) se fait en réference au coefficient de transmission thermique des components transparents (fenêtres), et aux facteurs d'absorbsion, de réflection et de transmission du rayonnement solaire de l'élement. Cette methode a été développée par Dr. Eşher Berköz et l'application de la methode pour la région d'Ankara réalise par Zerrin Yılmaz.

Introduction :

The conflict between increasing energy demand and diminishing energy sources forces the architect to be concious about building facade design.

Intensity of solar radiation on a building facade changes with facade orientation. Hence, the combined effect of solar radiation and external air temperature, which is expressed as sol-air temperature, also varies with facade orientation. Sol-air temperature is dependent upon the solar radiation properties of facade components as well.

Due to the combined effect of solar radiation and external air temperature, the rate of heat flow through a facade element consisting of opaque and transparent components, is dependent upon the thermophysical and solar radiation properties of the element. It is obvious that, under passive heating and climatization conditions, indoor climate changes with total heat gain (or loss) through the building envelope, which comprises heat gains (or losses) through the facade and roof elements. Therefore, both thermophysical and solar radiation properties of the building facades are a group of basic determinants of the indoor climate and also of the demand for supplementary artificial energy.

Overall heat transfer coefficients (U) of opaque and transparent parts and transparency ratio (x) of the element constitute its main thermophysical properties. Solar radiation properties of the facade components are absorptivity (a), transmissivity (T) and reflectivity(r). For opaque components transmissivity is not valid.

The combinations of the values of thermophysical and solar radiation properties, which facilitate the maintenance of indoor comfort temperatures (air and surface) by using minimal supplementary artificial heating and climatization energy, can be qualified as optimal combinations. Such combinations define the facade elements which have the optimal contributions to the passively utilization of the heating effects of solar radiation and air temperature. In other words, they define the optimal facade elements which provide permissible inputs to the total heat loss of the building envelope in the underheated period and to the total heat gain in the overheated period from the aspect of the climatic comfort.

In order to simplify the determination of the optimal combinations, the transparency ratios and solar radiation properties of facade elements are to be selected initially. And, subsequently, the optimal overall heat transfer coefficient, which should be possessed by opaque facade component and is a constituent of the combination defining the optimal facade, must be computed in reference to facade orientation and its solar radiation properties.

A method for the determination of optimal thermophysical properties :

The method which is summarized in this section is based upon the preceding analysis and comprises the following steps :

1.) Gathering the regional climatic and physiographic data: atmospheric conditions, solar radiation data, air temperature variation, ground reflectivity, durations of underheated and overheated periods.

2.) Selection of indoor design conditions: comfort values of indoor air and surface temperatures.

3.) Selection of design days: characteristic days of underheated and overheated periods.

4.) Selection of the variation range and intervals of the following design variables: orientation of the facade element, absorptivity of the opaque facade component, type of glass and its solar radiation and thermophysical properties (a_g, T_g, r_g, U_g respectively), transparency ratio (x).

5.) Computation of average sol-air temperatures for opaque facade components (t_{mo}) on the selected design days.

Hourly values of sol-air temperatures influencing the opaque components (t_{eo}) can be computed by means of the following formula [1].

$$t_{eo} = t_o + \frac{I_T \cdot a_o}{h_o} \qquad (1)$$

where

t_o = external air temperature, °C

I_T = intensity of total solar radiation on the component surface, W/m^2

a_o = absorptivity of the surface

h_o = external surface heat transfer coefficient, W/m^2

Then, average sol-air temperatures for the characteristic days of underheated and overheated periods are

$$t_{mou} = (\sum_1^{24} t_{eou})/24 \qquad (2)$$

$$t_{moo} = (\sum_1^{24} t_{eoo})/24 \qquad (2a)$$

respectively

where

t_{eou} : hourly sol-air temperatures relevant to opaque component on the characteristic day of underheated period, °C

t_{eoo} : hourly sol-air temperatures relevant to opaque component on the characteristic day of overheated period, °C

6.) Computation of average sol-air temperatures for transparent facade components (t_{mg}) on design days.

Sol-air temperatures for transparent components made of single or double glass sheets can be calculated on hourly basis by the following equations.

for single sheet of glass; [2]

$$t_{egI} = t_o + I_D\left(\frac{a_{gD}}{h_o} + \frac{T_{gD}}{U_{gI}}\right) + I_d\left(\frac{a_{gd}}{h_o} + \frac{T_{gd}}{U_{gI}}\right) \qquad (3)$$

for double glass combination with an air space in between;

$$t_{egII} = t_o + I_D\left[\frac{T_{12D}}{U_{gII}} + \frac{a_{oD}}{h_o} + a_{iD}\left(\frac{1}{h_o} + \frac{1}{h_s}\right)\right] + I_d\left[\frac{T_{12d}}{U_{gII}} + \frac{a_{od}}{h_o} + a_{id}\left(\frac{1}{h_o} + \frac{1}{h_s}\right)\right] \qquad (4)$$

where

t_o : external air temperature, °C

I_D, I_d : direct and diffuse solar radiation intensities on the surface, respectively, W/m^2.°C

U_{gI},U_{gII}: overall heat transfer coefficients for single and double glass, respectively, W/m^2.°C

a_{gD},a_{gd} : absorptivity of single glass for direct and diffuse solar radiation, respectively

T_{gD},T_{gd} : transmissivity of the single glass for direct and diffuse solar radiation, respectively

T_{12D},T_{12d} : transmissivity of double glass combination for direct and diffuse solar radiation, respectively [3]

$$T_{12D} = \frac{T_o \cdot T_i}{1 - r_o \cdot r_i} \qquad (5)$$

r_i,T_i: reflectivity and transmissivity of the inner sheet of glass considered seperately

r_o,T_o: reflevtivity and transmissivity of the outer sheet of glass considered seperately

a_{oD},a_{od} : absorptivity of the outer sheet for direct and diffuse solar radiation respectively, in case of its being a component of the double-glass combination [3]

$$a_{oD} = \frac{[1-(r_o+T_o)][1-r_i(r_o-T_o)]}{1-r_i \cdot r_o} \qquad (6)$$

a_{iD},a_{id} : absorptivity of the inner sheet for direct and diffuse solar radiation respectively, in case of its being a component of the double-glass combination [3]

$$a_{iD} = \frac{[1-(T_i+r_i)]T_o}{1-r_i \cdot r_o} \qquad (7)$$

h_o : external surface heat transfer coefficient; W/m^2.°C

h_s : combined heat transfer coefficient of air space, W/m^2.°C

Then, average sol-air temperatures relevant to transparent components can be computed by the following equations, for the characteristic days of underheated and overheated periods, respectively

$$t_{mgu} = (\sum_1^{24} t_{egu})/24 \qquad (8)$$

$$t_{mgo} = (\sum_1^{24} t_{ego})/24 \qquad (8a)$$

where

t_{egu} = hourly sol-air temperatures relevant to transparent component on the characteristic day of underheated period, °C

t_{ego} = hourly sol-air temperatures relevant to transparent component on the characteristic day of overheated period, °C

7.) Computation of the optimal overall heat transfer coefficients of opaque facade components.

This step should be carried out in two subsequent stages.

a.) In the first stage, the required overall heat transfer coefficients for opaque components (U_o) should be computed for both design days seperately.

From the climatic comfort point of view, the desirable difference between the comfort value of indoor air temperature (t_i) and the weighted mean value (t_{si}) of inside surface temperatures of the components of the facade is 3°C [4].

Therefore, the permissible heat loss in the underheated period (Q_{eu}) and heat gain in the overheated period (Q_{eo}) through the unit area of the facade element for a unit period of time are to be

$$Q_{eu} = (t_i - t_{si}) \cdot h_i = 3 \cdot h_i \qquad (9)$$

$$Q_{eo} = (t_{si} - t_i) \cdot h_i = 3 \cdot h_i \qquad (9a)$$

where

t_i: comfort value of indoor air temperature, °C

h_i: internal surface heat transfer coefficient, W/m^2.°C

The optimal facade element should provide a heat loss or gain not exceeding the permissible level, at least.

The permissible heat loss (or gain) through the facade element is the sum of the heat losses (or gains) through its opaque and transparent components.

Therefore, under the steady state condition, the rate of permissible heat flow through the unit area of facade element can be formulated, as follows, in connection with its transparency ratio and the overall heat transfer coefficient of the opaque component by employing the daily average sol-air temperatures as outdoor design temperatures.

$$Q_{eu} = U_{ou}(t_i - t_{mou})(1-x) + U_g(t_i - t_{mgu})x \qquad (10)$$

$$Q_{eo} = U_{oo}(t_{moo} - t_i)(1-x) + U_g(t_{mgo} - t_i)x \qquad (11a)$$

where,

Q_{eu}, Q_{eo} : daily average hourly permissible heat loss and gain on the characteristic days of underheated and overheated period, respectively, W/m^2

t_i : comfort value of indoor air temperature, ^oC

t_{mou}, t_{moo}: average sol-air temperatures for the opaque component on the characteristic days of underheated and overheated periods, respectively, ^oC

t_{mgu}, t_{mgo}: average sol-air temperatures for the transparent component on the characteristic days of underheated and overheated periods, respectively, ^oC

x : transparency ratio of the facade element

U_g : overall heat transfer coefficient of the transparent component (glass), $W/m^2.^oC$

U_{ou}, U_{oo} : overall heat transfer coefficients of the opaque component, $W/m^2.^oC$

Since they would enable to keep the rate of heat flow at the permissible level, U_{ou} and U_{oo} can be designated as the required values for underheated and overheated periods, respectively. Equations (9),(9a),(10) and (10a) yield the following relationships:

$$U_{ou} = \frac{3h_i - U_g(t_i - t_{mgu}).x}{(t_i - t_{mou})(1-x)} \qquad (11)$$

$$U_{oo} = \frac{3h_i - U_g(t_{mgo} - t_i).x}{(t_{moo} - t_i)(1-x)} \qquad (11a)$$

b.) In the second stage the required U_o values of overheated and underheated periods should be compared by taking the durations of these periods into account. And, the lower value is to be selected as the optimal in reference to the transparency ratio, orientation, type of glass and the absorptivity of opaque component which are under consideration.

It is obvious that, in order to provide an extensive application opportunity for architects, the steps from 4 through 7 should be repeated in accordance with the variation ranges and intervals selected in step 3 for the related design variables.

The application of the method:

The above given method has been applied to the facade elements in vertical position for Ankara region.

The application are based upon the following conditions and assumptions:

- average atmospheric conditions and solar radiation data provided by the Turkish State Meteorological Service.
- January 17 and July 17 are the characteristic days of underheated and overheated periods respectively.
- comfort value of indoor air temperature is 21^oC
- absorptivity of opaque surfaces for solar radiation is 0,4
- the transparent component consists of double sheet of glass with an air space in between and both glass sheets are of the same quality ($T_n = 0.41$); Figure 1 shows the variation of T_{12D}, a_{iD} and a_{oD} with the incidence angle of the sun.
- durations of the underheated and overheated periods are 70% and 30% of the year, respectively, for the region under consideration.

The results of the computations are expressed graphically. In Figure 2 daily average sol-air temperatures of opaque and transparent components are summerized for both characteristic (design) days. Figures 3 and 4 show the variations of required overall heat transfer coefficients of opaque components (U_{ou}, U_{oo}) with orientation and transparency ratio, in case of the transparent component is double glazed, on January 17 and July 17, respectively.

The required overall heat transfer coefficients of the underheated period can be designated as the optimal values by basing upon the duration of this period in order to assure minimization of supplementary artificial heating and climatization energy demand.

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[1] Anon. ASHRAE Handbook of Fundementals, American Society of Heating, Refrigerating and Air-Conditioning Engineers, New York, 1977.

[2] Mackey, C., Watson, E.B. Summer Weather Data and Sol-air Temperature - Study of Data for New York City, ASHVE Transaction, Vol.51, No.1267, 1945, p.p.75-91.

[3] Threlkeld, J.L. Thermal Environmental Engineering, 2. ed., New Sersey, 1970.

[4] Givoni, B. Man, Climate and Architecture, 1. ed., London, 1969.

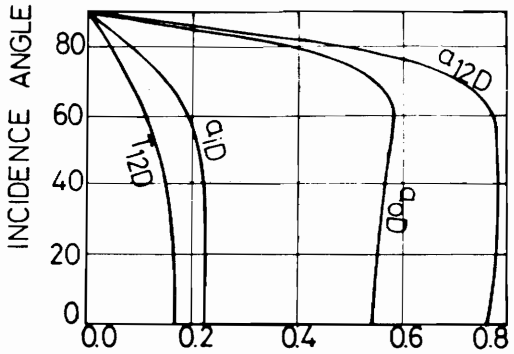

Figure 1: Variation of the solar radiation properties of double-glass with incidence angle.

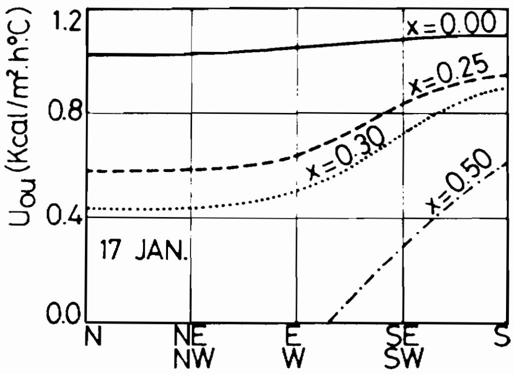

Figure 3: Variation of the required overall heat transfer coefficients of opaque components with orientation and transparency ratio.

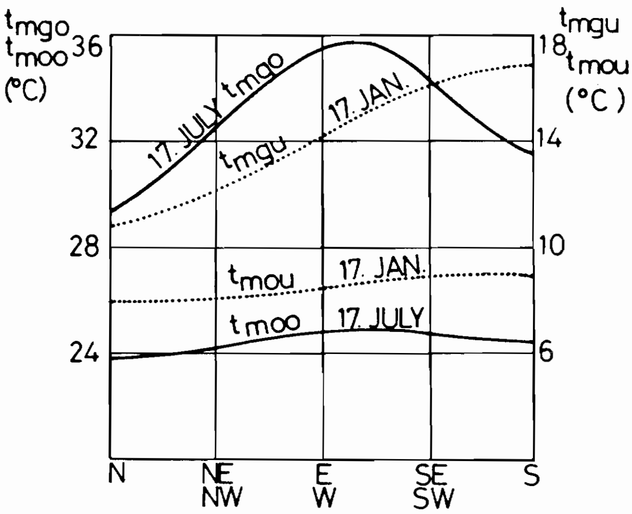

Figure 2: Variation of daily average sol-air temperatures for opaque and transparent components with orientation.

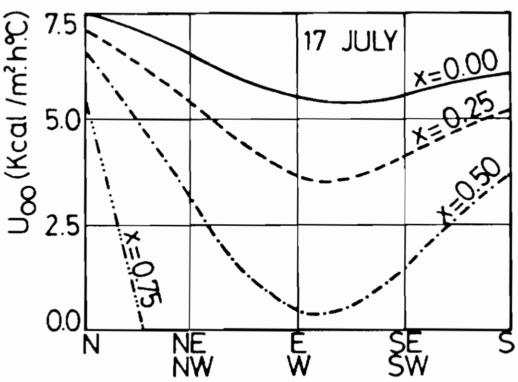

Figure 4: Variation of the required overall heat transfer coefficients of opaque components with orientation and transparency ratio.

OPTIMISATION ENERGETIQUE DES FENETRES

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1. Introduction

En 1977 le Conseil National des Recherches a lancé un projet de recherche sue l'énergie auquel ont partécipé les Industries, les Universités, les Instituts et les Laboratoires du C.N.R.
Dans le cadre du groupe de recherche "Economie d'energie dans le chauffage des immeubles on a engagé le thème "perfectionnement énergétique des fermetures".

Ce groupe de recherche a analisé de différentes façons les deux aptitudes de perméabilité à l'air des joints et d'isolation thermique qui caractérisent la capacité de conservation d'énergie de ces éléments.

Un des objectifs fondamentaux qu'on s'est fixé a été celui d'attribuer à ce travail un but de recherche des valeurs minimums acceptables du niveau des capacités de ces éléments, des relatives méthodologies de contrôle et d'évaluation , ainsi que de méthodes de calcul simplifiées pour pouvoir les insérer dans le contexte de normes pour le calcul du besoin thermique des immeubles.

Ce travail illustre les résultats obtenus dans trois des domaines traités dans le cadre général du travail dont on vient de parler.

2. RECHERCHE EXPERIMENTALE SUR LA CAPACITE DE PERMEA - BILITE A L'AIR DES FERMETURE EN CONDITIONS SEMI-NATURELLES

Pour réaliser cette recherche on a tout d'abord monté sur le côté d'une cellule à régime thermique contrôlé, différentes fermeture de dimensions semblables et de typologies courantes en Italie(deux battants égaux à axes verticaux, avec volet roulant et caisson uni au châssis), à vitres simples et avec garniture complémentaires d'étanchéité sur les joints qui peuvent s'ouvrir.
On a ensuite contrôlé la perméabilité à l'air des fermetures à une température intérieure égale à la température de l'ambiance, et à une température extérieure égale à -10 C à partir du procédé de la norme UNI-EN 42 [1] avec une surpression extérieure jusqu'à 300 PA ce qui correspond à la catégorie A2 définie par les directives UEATC [2].

On a examiné les types de fermetures suivants:
N. 2 en pvc
N. 2 en acier
N. 1 en bois
N. 1 en alluminium.

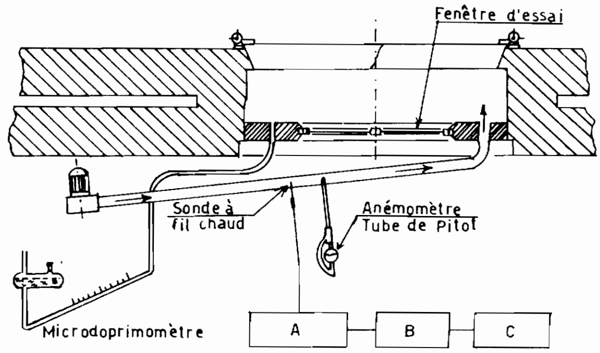
Quelques-unes de ces fermetures ont été montées sur un mur en briques, d'autres sur un mur en béton armé. Toutes les fermetures ont été montées au moyen d'un maillet, sauf la fermeture en acier qui à été placée sur un faux chassis en acier sans maillet. La fermeture en bois a été montée sur un faux chassis en acier.
Toutes les fermetures ont été soigneusement montées en général suivant les instructions du fournisseur, ou bien on a varié le montage, en général en pis (par ex. sans les garniture et les scellages prescrits.). Toutes les fermetures essayées étaient du type à deux volets verticaux avec dispositif d'obscurcissement roulant, et une surface qui pouvait s'ouvrir d'environ 2 m^2 ; elles se situaien dans la meilleure catégorie de perméabilité suivant les directives UEATC.
Le Tableau I synthétise les résultats en reportant moyenne (entre essai à pression croissante et décroissante) de la perméabilité à 100 Pascal (10mm de colonne d'eau), en faisant une distinction entre la fermeture elle-même, le caisson, les joints entre le châssis fixe et la maçonnerie et la permèabilitè totale (à cause des incertitudes expérimentales ces valeurs ne coincident pas toujours exactement avec la somme des trois premières). Toutes les valeurs se rapportent à 1 m^2 de surface qui peut s'ouvrir. Sans entrer dans les détails des raisons pour lesquelles les résultats sont différents entre eux, on peut faire les observations suivantes de caractère général:
-les caissons sont presque toujours source de déperditions, de valeur même 2-3 fois supérieure à celle de la fermeture elle même; la plupart de ces déperditions sont dues aux joints entre le caisson et la maçonnerie, qui sont parmis les détails les moins soignés; des dèperditions de cette entité sont tel les à faire descendre d'une catégorie l'evaluation de la fermeture:
-les joints entre le châssis fixe et la maçonnerie peuvent être responsables, s'ils ne sont pas exécutés de façon correcte, de déperditions telles que meme les fermetures de catégorie supérieure ne peuvent pas être classées. A ce propos, à coté du soin du montage, même la nature du joint a son importance: certains joints peuvent être rendus presque étanches plus faciliment que d'autres; au contraire, certains joints(eventuellement les mêmes, voir essais 7-10) sont plus sensibles que d'autres ou aux négligences de montage. Sur la base des données ex-

TABLEAU I PERMEABILITE A 100 Pa (m^3/hm^2)

essai	fermeture	catego rie	maçonnerie	feuil- lure	faux châssis	exécution	ferme- ture	caisson	joints fixes	total	catégorie résultante
1	PVC	A2	Briques	non	Bois	contrôlée	16	---	---	57	non class.
2	PVC	A2	Briques	non	Bois	négligée	16	---	---	101	non class.
3	Acier	A2	Briques	non	non	contrôlée	15,5	---	---	30,5	A1
4	Acier	A2	Briques	non	non	négligée	15,5	---	---	59,-	non class.
5	Bois	A3	Briques	oui	Acier	contrôlée	3,5	1,-	27,-	31,5	A1
6	Bois	A3	Briques	oui	Acier	amégliorée	3,5	1,-	14,-	18	A2
7	PVC	A3	b.a	oui	---	contrôlée	4,5	8,5	13,5	12	A2
8	PVC	A3	b.a	oui	---	négligée	5,-	7,-	non me- surable	non me- surable	non class.
9	PVC	A3	b.a	oui	---	contrôlée	4,-	7,-	7,-	14,-	A2
10	PVC	A3	b.a	oui	---	négligée	3,5	8,5	110	118	non class.
11	Alluminium	A3	b.a	non	---	contrôlée	3,5	6,5	9,5	26,5	A1
12	Alluminium	A3	b.a	non	---	négligée	5,-	9,-	66	76	non class.
13	Acier	A3	Briques	non	Acier	contrôlée	4,-	15,-	11,5	17,-	A2
14	Acier	A3	Briques	non	Acier	négligée	5,5	18,5	13,-	30,-	A1

périmentales recueillies aussi bien dans le programme décrit que lors de précédents essais de qualification des éléments (voir chapitre 4) et sur la base d'algorithmes de calcul proposés par la littérature , on a présenté une méthode d'évaluation des infiltrations d'air dans les immeubles qui permettait de vérifier les valeurs admissibles déterminées par la loi italienne sur la limitation des consommations énergétique dans le secteur du bâtiment. (3)

Fig.1 Mesure de la perméabilité à l'air



A= Unité anémométrique
B= Unité auxiliaire
C= Voltmètre digital

3. RELATIONS ENTRE PERTES ACOUSTIQUES ET PERMEABILITE

Dans le cadre de la mise au point de nouvelles méthodologies de côntrole actuellement utlisées des performances de tenue à l'air, on a considéré la possibilité de relier les pertes acoustiques aux infiltrations d'air. C'est dans ce but qu'on a vérifié "enparallèle" l'isolement et la perméabilité à l'air de fermetures dont on a reproduit en laboratoire la condition de montage en oeuvre, ainsi que différentes conditions de tenue crées artificiellement afin de pouvoir disposer d'une vaste gamme de capacités.

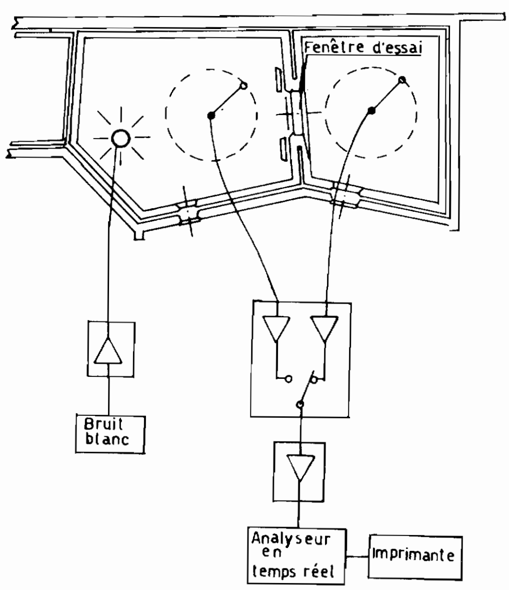
L'installation d'essai réalisée pendant l'année en cours et les équipements utilisés sont schématisés dans la Fig. 1.

Cette installation d'essai permet de réaliser des mesures de perméabilité à l'air selon les régementations italiennes et européennes.

Ainsi que montre la Fig. 2, cette installation était placée à l'intérieur des chambres pour mesures l'isolement du bruit à partir des modalités prévues par la norme ISO 140.

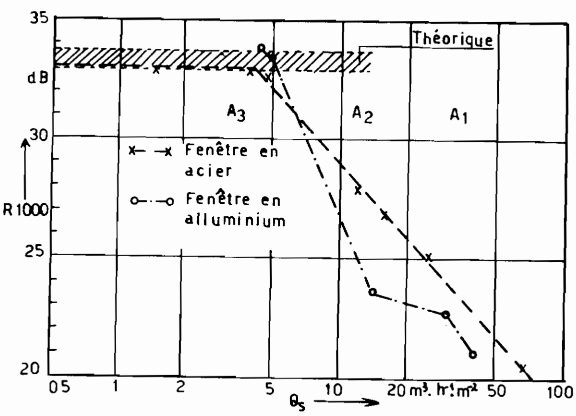
La Fig. 2 montre aussi les instruments utilisés.

Fig.2 Mesure du pouvoir isolant du bruit



Dans une première phase on a choisi 2 fermetures métalliques: une en alluminium et une en acier, les deux du type à deux battants, de dimensions 2m x 2m imposées par les dimensions de l'ouverture.
Sur chacune des deux fermetures on a réalisé différentes conditions de tenue: au moyen de scellages plastiques appliqués tout le long du périmètre, on a fait arriver la tenue jusqu'aux limites de possibilité de mesure, alors que , dans l'autre sens on a augmenté la perméabilité en élargissant les fentes selon le besoin. Le scellage de la feuille au châssis mobile était effectué, pour la fenêtre en acier, avec une garniture en caoutchouc et, pour la fenêtre en alluminium, au moyen d'un mastic au silicone.
En ce qui concerne la perméabilité on a pris comme donnée récapitulative, la valeur de la performance en correspondance à la différence de pression de 100 Pa puisque c'est en correspondance de cette pression que se rapportent les droites qui délimitent les zones de classement.
En ce qui concerne le pouvoir isolant du bruit, étant donné que la perte dépend de la fréquence, on a pensé que pour une meilleure caractérisation de la performance, il fallait considérer les points où le phénomène est le plus évident; on a donc adopté comme donnée récapitulative l'isolement du bruit qui correspond aux bandes d'octave de fréquence nominale 1000 Hz (moyenne des valeurs aux 3 bandes de 1/3 d'octave 800, 1000 et 1250 Hz).
On a ainsi obtenu une serie de couples de grandeurs qui ont été reportés sur le tableau II et sur le diagramme de la Fig. 3 où, en fonction de la capacité à 100 Pa (Q_s) par rapport à la surface de la fermeture, on a tracé la marche du pouvoir isolant du bruit à 1000 Hz (R_{1000}) . Sur ce même graphique on a indiqué en abscisse les valeurs limites à 100 Pa pour les 3 zones de classement.

Fig. 3 Pouvoir isolant du bruit en fonction de la perméabilité à l'air



TAB. II Compararaison entre la perméabilité à l'air à une pression de 100 Pa (Q_s) et le isolement du bruit à une fréquence de 1000 Hz (R_{1000})

	Condition d'essai	Qs ($m^3 . h^{-1} . m^{-2}$)	R_{1000} (dB)
Fermeture en alluminium	1	4,4	33,8
	2	4,8	33,5
	3	14,2	23,6
	4	29,8	22,8
	5	40,5	21,1
Fermeture en acier	1	0,9	33,4
	2	1,5	32,9
	3	2,3	33,1
	4	3,5	33
	5	4,0	32,8
	6	4,8	32,6
	7	12,2	27,9
	8	16,2	26,9
	9	25,4	25,2
	10	67,5	28,6

Sur la base des résultats obtenus il est possible de faire ces considerations:
- la valeur de portée d'air au-delà de laquelle on commence à vérifier la tombée de pouvoir d'isolement, se trouve aux limites de la zone A3, qui qualifie les fermetures de meilleures capacités en ce qui concerne la perméabilité à l'air. Il est donc plutot évident qu'il faut reconnaitre par voie acoustique cette caté gorie de fermetures par rapport aux deux autres;
- avec des prestations de catégorie A2, on peut avoir, à la limite, des pertes de pouvoir d'isolement de 7 à 8 dB, alors que dans le limites de la catégorie A1 les pertes atteignent des valeurs de 12 à 13 dB. Cela signifie que les fermetures classées comme étant acceptables aux effets de la perméabilité, même si dans la catégorie la plus basse, peuvent présenter, du côté acoustique, un comportement nettement insuffisant.

4. Récupération de données existantes sur la perméabilité à l'air des fermetures

Pratiquement toutes les données qui concernent des essais d'attestation et de correspondance aux normes de deux laboratoires publics italiens, ont été réalisées sur le système SGSS (Système de Gestion des Fiches sur les Fermetures). Le système permet, avec peu d'obligations, de selectioner les éléments du point de vue de chaque catégorie en elle-même, ou de plusieurs catégories présentes en même temps. Il faut dire que les élaborations effectuées ont démontré à plus forte raison une valeur historique de l'évolution de la performance de tenue à l'air, car les applications évaluées se révèlent remarquablement différentes au cours du temps, même dans le domaine des mêmes choix technologiques. La valeur statistique de cette récolte de données apparait plus limitée à l'heure actuelle, en ce qui concerne ce qui a été dit. On reporte dans les fig. 4, 5,6,7 les points expérimentaux obtenus pour chacune des technologies de construction des châssis - qui prévalent en Italie, c'est à dire en bois, aluminium, acier et PVC: la perméabilité à l'air s'exprime en m^3 /hm^2 et on reporte la distinction entre les fermetures sans garnitures et celles ayant un type quelconque de garniture.

Ensuite on résume les considérations qui ont surgi pendant l'examen des données:

- la plupart des fermetures essayées se trouve dans les catégories A2 et A3 de perméabilité à l'air;
- on a remarqué une amélioration progressive des capacités de perméabilité des fermetures; des données de perméabilité plus élevée sont en effet plus fréquentes dans les expérimentations qui datent déjà d'il y a quelques années;
- on n'a pas remarqué, à un niveau global, une nette influence due à l'usage de garnitures.

Sur un nombre limité d'essais on a observé que des fermetures ayant un bon comportement (A2), ont ultèrieurement amélioré leur performance d'etancheité avec des garnitures;

- on a généralement trouvé un bon accord entre les données expérimentales provenant des différentes laboratoires.

Fig. 4

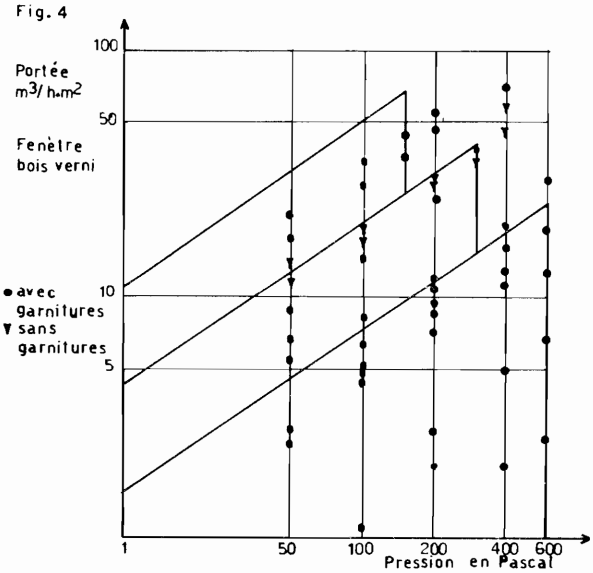


Fig. 5

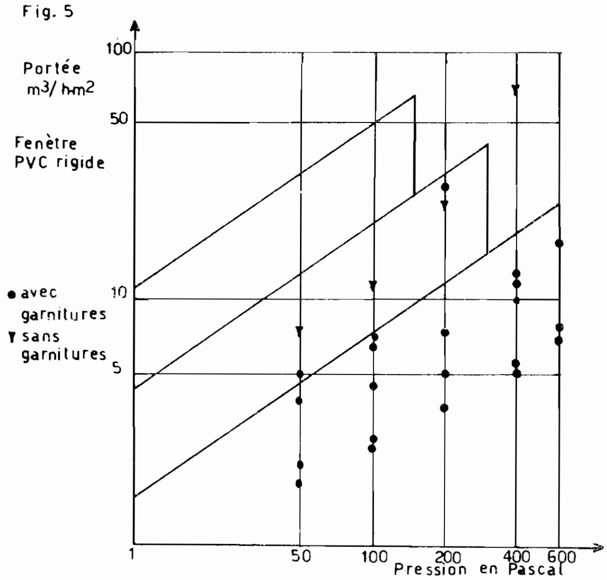


Fig. 6

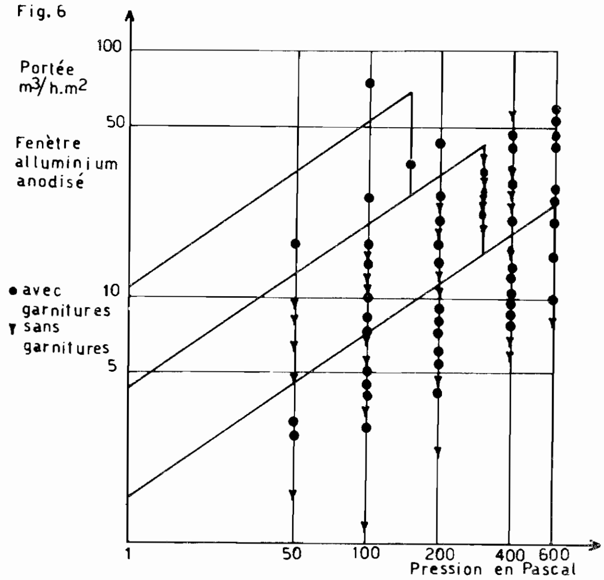
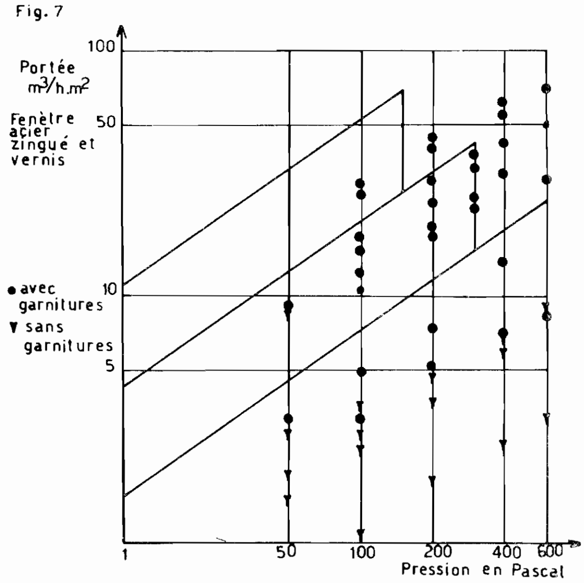


Fig. 7



5. EVOLUTIONS DU PROGRAMME

Au cours de l'année 1979/80, on prévoit une recherche sur le comportement thermique des fermetures dans des conditions de semi-naturel à travers l'utilisation de méthodes calorimétriques (ASTM C. 236-66) (5) et thermographiques finalisés principalement à l'évaluation des performances d'isolement thermique des joints d'intégration.

On prévoit enfin deux objectifs complémentaires au travail déjà fait et ci-dessus dècrit:

- le transfert sur l'utilisation des méthodologies d'évaluation de la perméabilité, en particulier en ce qui concerne la méthode de liaison pertes acoustiques/perméabilité, mais aussi de l'outillage qui a déjà expérimenté en laboratoire avec des adaptations opportunes;
- la mise en fonction d'un programme d'évaluation d'interventions de bonification sur des fermetures qui existent déjà, en particulier à travers l'usage de garnitures, mais aussi d'éventuelles solutions technologiques pour améliorer les caractéristiques de l'isolation thermique, aussi bien du point de vue de l'économie d'énergie que de la fiabilité et de la longue durée.

Summary

In this study carried out within the framework of the "Progetto Finalizzato Energetica" by the Italian C.N.R. we report the results of air-tightness performance evaluation for the types of frames commonly used in Italy. The tests were carried out in assembling and working conditions simulating reality. Furthermore we also describe how we gathered the data relative to permeability of joints which can be open, made available by ten-years' certification tests.

We eventually report the experimental results obtained from an assessment of the possibilities to correlate air-thightness of frames with soundproof properties.

Résumé

Dans ce travail qui se situe dans le cadre de la réalisation du "PROGETTO FINALIZZATO ENERGETICA" exécuté par le Conseil National des Recherches Italien on décrit les resultats obtenus à propos de l'évaluation de la capacité de tenue à l'air des typologies de fermetures d'emploi commun en Italie, menée en conditions de montage et de service qui reproduisent les conditions réelles .

On décrit en oûtre l'activité conduite pour le repérage de données de perméabilité des joints des fermetures qui peuvent s'ouvrir, et qui depuis disx ans disposent d'essais d'attestation.

On présente enfin les résultats expérimentaux qui proviennent d'une vérification des possibilités de relier la tenue à l'air des fermetures aux propriétés d'isolation acoustique.

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Successful passive energy conservation
- a highly insulated, traditional Danish house

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Resumé: Description d'une maison qui a fait épreuve d'une tres faible consommation d'énergie pour chauffage, grace a une isolation thermique plus forte que normalement. La maison est traditionel dans le sens que la construction peut etre executé par n'importe quel entrepreneur danois.

Summary: Description of a house design which has proved a very low consumption of energy for heating. This has been achieved mainly through the use of better thermal insulation than usual. The house is traditional in the sense that it may be built by any Danish contractor.

This case study describes a house which was built in 1978 in Humlebæk approximately 30 kms north of Copenhagen, Denmark.
The house was sold as soon as it had been built and it has from the beginning been occupied by the owner. It it thus in the commercial sense an "ordinary" house - just as the architectural impression of the house is similar to that of other well designed houses commonly built in Denmark.

A highly insulated 410 mm cavity wall

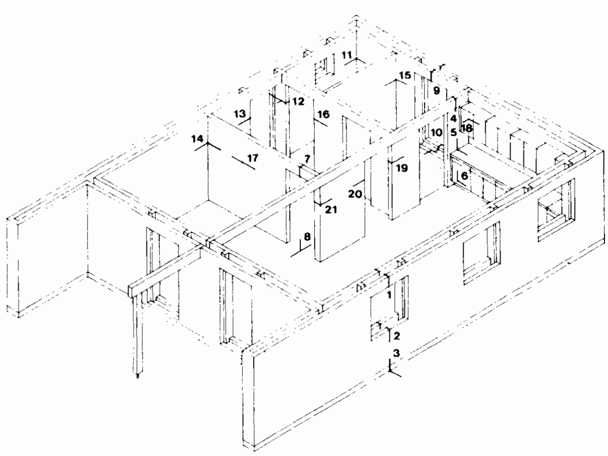
The main aim of the research study which originated the building of the house was to develop a comprehensive set of design details for a highly insulated 410 mm cavity wall built with Danish standard bricks and to the extent possible without cold-bridges.
Cavity walls are extensively used in Denmark. Until the so called energy crisis set in, a common thickness for cavity walls made with bricks was 290 mm. This thickness could be augmented to 350 mm (1½ brick) without deviating from known techniques and details. A thickness of 410 mm (equal to a quarter-brick more) however made it necessary to develop a new wall-tie and several new design details.
The increased thickness of the insulation to fill the cavity was no problem, as mineral-wool batts were available. A double layer of 95 mm thick batts fits the cavity.

The Danish standard brick - and modular co-ordination

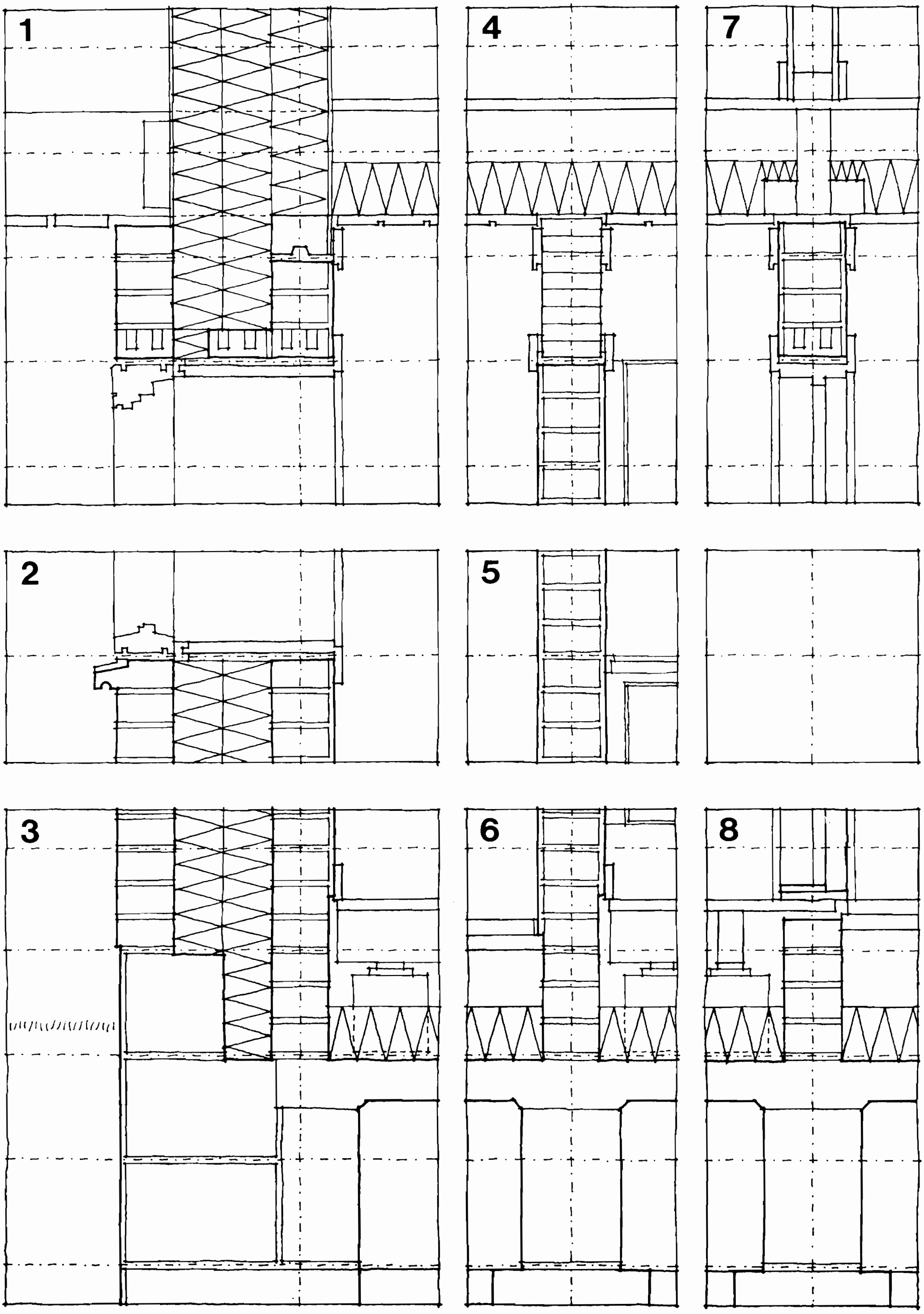
The Danish standard brick is not modular, but brickwork made with the standard brick can be modular. The size of the Danish brick is 55 mm (h) x 108 mm (w) x 228 mm (1). Measured centre joint to centre joint three courses will equal 2M (200 mm). Horizontally one brick will correspondingly build 224 mm, a half brick 120 mm and a quarter-brick 60 mm. One-and-a-quarter brick will thus equal 300 mm or 3M. The majority of brick patterns are based on quarter-brick increments and it is therefore as a rule easy to make brickwork dimensions coincide with modular dimensions.
In the house design used for the case study the brickwork is modular, and modular windows, doors, cupboard components, roof trusses etc. have been used. The design details shown may be used for other house designs as long as plan lay-out increments are 3M and vertical increments 2M.

Energy savings

The details of the house are shown in the illustrations on the following pages.
For the case study the house was built with a pitched roof. The upper storey contains bedrooms and a bathroom and is insulated with 300 mm of mineral-wool.
The plan lay-out allows for the use of several different systems for heating. For the case study the house was electrically heated in order to facilitate measurements of not only the total energy consumption, but also the distribution of the consumption on heating, cooking etc.
The winter 78-79 was quite severe in Denmark, but the house here described required only 6000 kWh for heating, equal to approximately 800 liters of oil, if oil-consuming boilers are supposed to function at 75 percent efficiency. This energy consumption is to be compared with the 3000 to 4000 liters of oil often used for heating older houses of similar size.



Isometric drawing of the lower storey which has masonry walls. The span is 72M and the length of the house is 84M. The vertical multimodule is 2M and the horizontal multimodule is 6M.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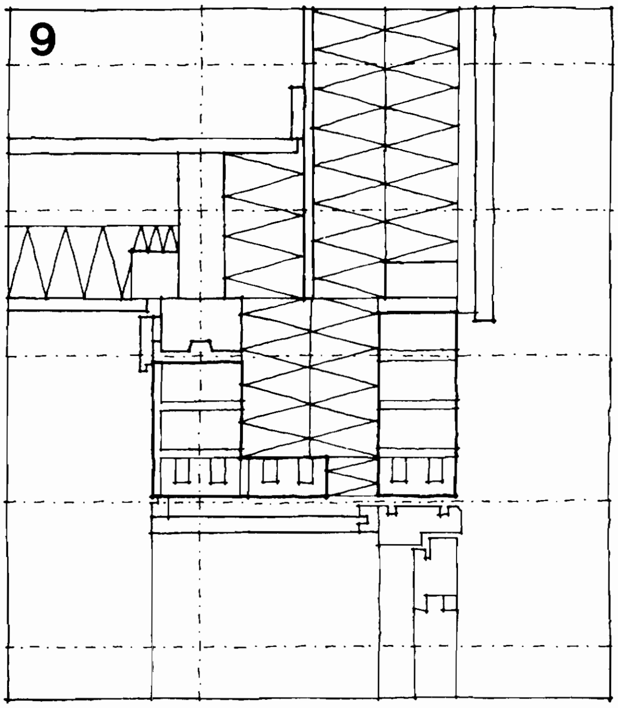
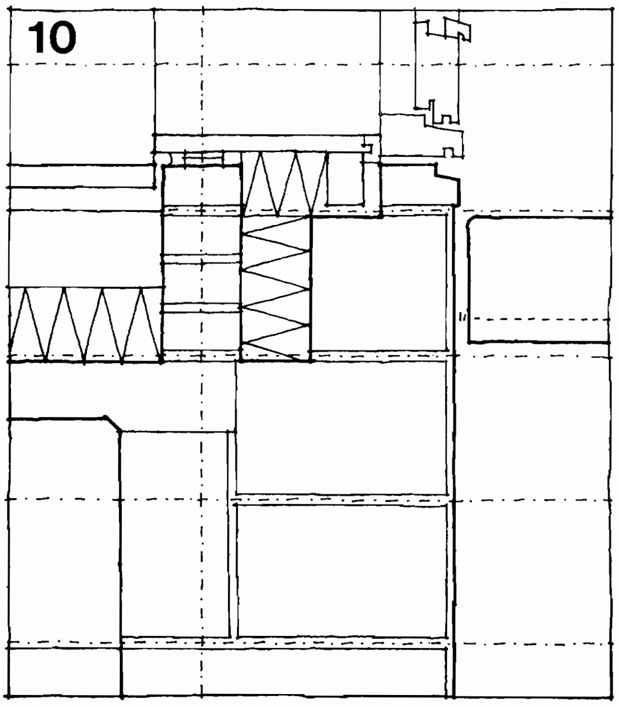


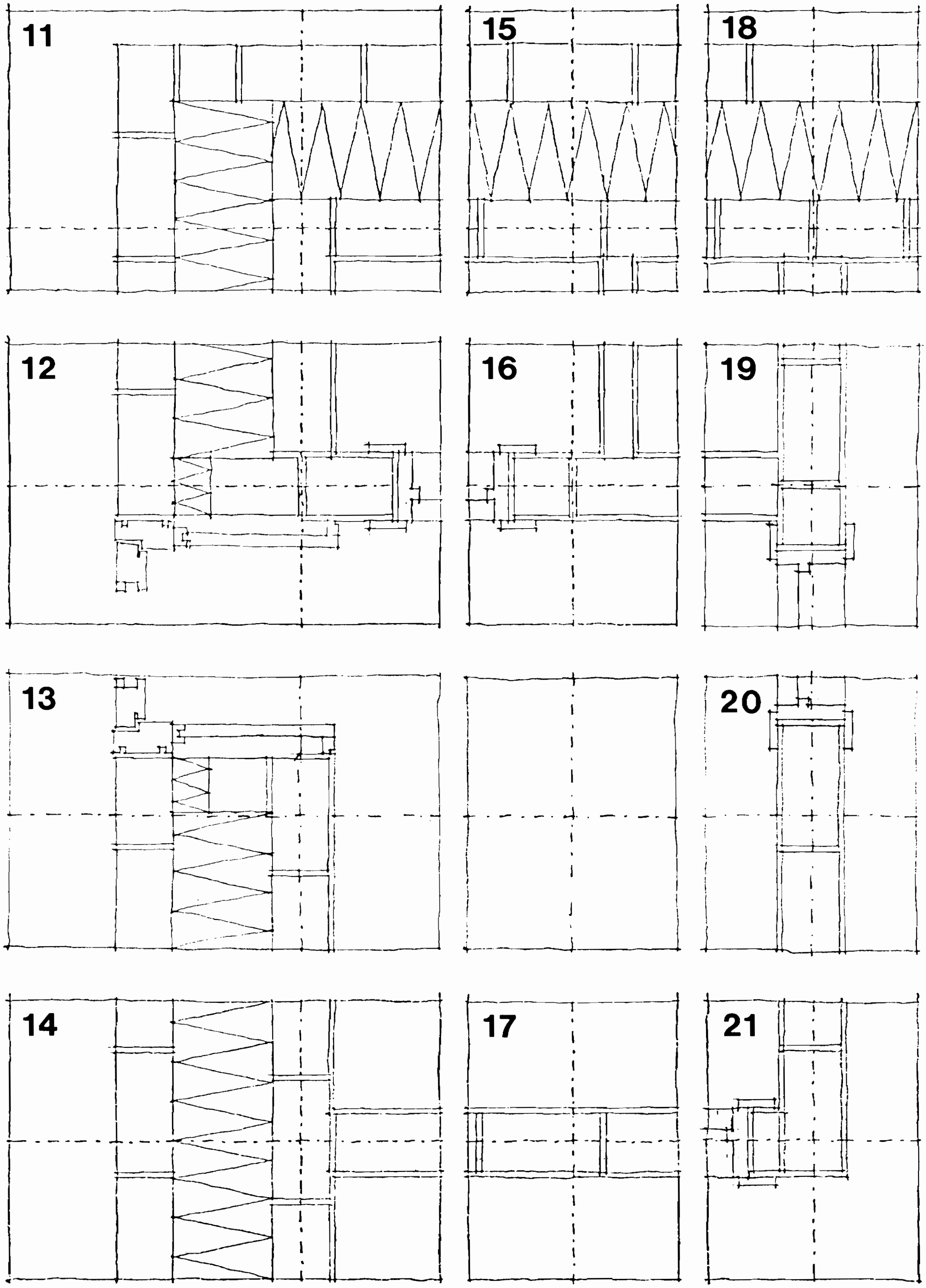


Details 1-10 show vertical sections and details 11-21 show horizontal sections. Not shown on the details are damp-proof courses, wall ties and the sealants and thermal insulation used around doors and windows.

The pictorial presentation has been elaborated by H. Zachariassen, M.A.A., on the basis of Systematic Survey of Key Joints, a draft report by CIB W24/IMG.

Summing-up

A report is available in Danish, with illustrations of more details, a description of structural aspects and the new wall-tie, and month-by-month statements about the energy consumption for heating, warm water, cooking etc. (SBI-rapport 121. SBI-lavenergihus, model 79).
A second generation design of the house described here is underway. A main issue will still be passive energy conservation. For example through the use also of heat-accumulating floors and walls and window shutters of a new design. But also the second generation design will be "traditional" in the sense that it can be built by any Danish contractor and inhabited "as usual". It is planned that a next project should encompass a dozen clustered houses, so that also the influence living habits may have on the energy consumption can be registered.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LA PROTECTION THERMIQUE DES BÂTIMENTS ET L'ECONOMIE D'ENERGIE

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ABSTRACT

The results of some author's recent researches regarding the hygrothermic behaviour of building exterior members (walls,roofs,terracis,joinery,etc),carried out in situ are presented in this paper.

The tests were performed for both winter and summer conditions and pursued the improvement of building thermic protection in view of obtaining saving of energy in service conditions.

RESUME

Le travail présente les résultats des recherches récentes de l'auteur effectuées en conditions de laboratoire et in situ et qui concernent le comportement hygrothermique des éléments extérieurs de construction (murs,toitures-terrasses,menuiseries,etc.).

Ces recherches se rapportent aux conditions climatiques d'hiver et d'été dans le but de l'amélioration de la protection thermique des bâtiments pour obtenir des économies d'énergie dans l'exploitation.

Les tendances actuelles et de perspective du développement de la construction des bâtiments dans les pays à climat froid et tempéré sont les suivantes :

- la réduction du poids propre des éléments extérieurs (murs, toitures-terrasses,etc.),par l'utilisation de matériaux à densité apparente réduite et à protection thermique élevée,ce qui conduit aussi à la réduction de l'épaisseur des éléments;
- l'adoption de compositions en couches multiples de ces éléments (non homogènes du point de vue thermique dans une ou plusieurs directions);
- l'emploi de matériaux à haut degré d'étanchéité à l'eau et à la vapeur d'eau,à côté de matériaux à grande perméabilité.

Ces nouvelles solutions,ayant un comportement hygrothermique différent de celui des structures classiques homogènes,ont imposé des recherches pour l'établissement des caractéristiques hygrothermiques principales . Ces recherches ont visé les objectifs suivants :

a) la réalisation d'économie de combustible et d'énergie électrique dans l'exploitation des bâtiments;

b) la diminution des coûts des investissements par l'établissement de dimensions économiques pour les éléments extérieurs de construction,ainsi que pour les installations de chauffage central et de climatisation des bâtiments,ce qui mène,en même temps,à la réduction des consommations spécifiques en matériaux de constructions;

c) la réalisation du confort thermique;

d) l'accroissement de la durabilité des bâtiments.

Les récentes recherches de l'auteur,qui seront exposées maintenant,ont été réalisées en régime thermique permanent et variable,en laboratoire et in situ.

Dans les pays européens à climat tempéré,on recommandait pour les murs extérieurs des habitations jusqu'en octobre 1975,une résistance minimale nécessaire à la transmission de la chaleur de 0,6..0,8 m^2 °C/W [1] .Dans l'établissement de ces valeurs on tenait compte surtout du critère de la réalisation d'un confort thermique minimal et de la nécessité d'éviter l'apparition de la condensation de la vapeur d'eau sur la surface interne des murs extérieurs,mais on n'accordait pas une attention spéciale au critère de l'économie de l'énergie.

On visait pourtant l'amélioration de l'isolation thermique pour des raisons économiques en réalisant un minimum de coûts d'investissement et d'exploitation.On a constaté que,dans cette étape,à cause de l'orientation vers l'obtention de conditions minimales,on avait construit des bâtiments qui n'ont pas correspondre à celles-ci soit parce que la conception ou l'établissement des dimensions des éléments extérieurs ne correspondait pas,soit parce qu'on avait utilisé dans l'exécution des matériaux à qualités thermiques inférieures à celles qui avaient été établies,soit à cause de certaines déficiences dans l'exécution des murs ou des bâtiments.La partie vitrée des murs dépassait de beaucoup les nécessités d'éclairage et était souvent adoptée pour des raisons esthétiques.

La crise énergétique mondiale des dernières années a imposé avec force l'orientation vers la réalisation de protections thermiques améliorées des éléments extérieurs des bâtiments existants ou qui sont en cours d'exécution.

On a adopté ainsi, pour les bâtiments existants, des solutions d'isolation thermique supplémentaire, appliquées sur la surface extérieure ou intérieure des murs.

En Roumanie, on préconise, pour commencer, l'emploi d'isolations thermiques intérieures composées de deux couches de plâtre de 15 mm d'épaisseur chacune, entre lesquelles on place deux couches de bandes de carton traité formant une maille hexagonale de 20 mm de côté et de 20 mm d'épaisseur (l'épaisseur totale de panneau préfabriqué étant de 70 mm). Le panneau a, sur sa partie intérieure (orientée vers la zone chauffée) une forte et permanente barrière de vapeur de perméance à la vapeur inférieure à la valeur de 0,03 g/m^2h mm Hg. Cette barrière de vapeur est nécessaire pour éviter l'apparition de la condensation à l'intérieur du panneau, ainsi qu'à sa surface de contact avec la couche d'air non ventilée, d'une épaisseur de 3 cm., qui sépare le mur existant du panneau d'isolation thermique supplémentaire. La couche d'air contribue, dans ce cas, à l'accroissement de la résistance totale à la transmission de la chaleur et permet, en même temps, le drainage au cas du traitement d'un bâtiment existant à la condensation superficielle intense.

Dans ce cas, la résistance thermique supplémentaire, formée par la résistance à la perméabilité thermique du panneau supplémentaire et par la couche d'air de 3 cm., est :

$$R_{pa} = 0{,}69\ m^2h^oC/Kcal = 0{,}59\ m^2\ ^oC/W$$

A l'avenir, on s'occupera aussi de l'utilisation d'autres types de panneaux à isolation thermique supplémentaire : en polystyrène expandé, polyuréthane, laine minérale, etc., qui puissent mener à une augmentation de la résistance thermique d'au moins deux fois par rapport à la situation présente, en obtenont par ce moyen une économie correspondante de combustible dans l'exploitation des bâtiments.

On a utilisé aussi, pour les immeubles d'habitation exécutés jusqu'à présent en Roumanie, les grands panneaux préfabriquées à 3 - 4 couches du type sandwich, dotés d'une isolation thermique en polystyrène expandé, laine minérale ou béton cellulaire autoclavé, l'isolation thermique étant placée entre deux couches de béton armé en agregats naturels ou en béton léger de granulit. Les panneaux ont un pourcentage de ponts thermiques variable qui va jusqu'à 20% en fonction du système constructif adopté et du fait que le panneau peut être plein, à fenêtre ou à fenêtre et porte-fenêtre.

Les recherches expérimentale effectuées par l'auteur, dans un laboratoire d'essais hygrothermiques sur de grands panneaux préfabriqués, ont établi la valabilité de la relation suivante dans le calcul de la résistance à la perméabilité thermique moyenne pondérée pour le panneau en entier :

$$R = e.R_{II} \qquad (1)$$

où:

e - le coefficient de correction en fonction du pourcentage p de ponts thermiques totaux, égal avec :

$$e = \frac{100 - p}{100} \qquad (2)$$

R_{II} - la résistance à la perméabilité thermique des éléments de construction ayant plusieurs couches, formés de matériaux homogènes parallèlement au flux thermique

A l'aide de la relation (1) on a calculé la perméabilité thermique moyenne pondérée (R_p) en fonction de la résistance à la perméabilité en champ courant (R_c) et en fonction du pourcentage de ponts thermiques totaux pour les panneaux préfabriqués du type sandwich, utilisés dans les immeubles d'habitation. On a établi :

- l'influence négative des ponts thermiques totaux est très importante en ce qui concerne la R_p (par référence à la R_c) et, respectivement, en ce qui concerne la consommation de combustible dans l'exploitation des bâtiments;
- l'augmentation de la R_c a une influence relativement faible sur l'amélioration de l'effet négatif des ponts thermiques totaux.

On présente, dans les figures 1 et 2, les résultats expérimentaux, obtenus en régime thermique permanent ($\theta_i = 18\ ^oC$; $\theta_e = -18\ ^oC$), concernant la variation de la température de la surface intérieure et de la résistance à la transmission de la chaleur (R_o) dans une coupe caractéristique du panneau, comme il suit :

- dans la figure 1 pour un grand panneau préfabriqué de façade (plein), ayant un pourcentage de ponts thermiques totaux de 8,4% ;
- dans la figure 2 pour un même panneau (identique quant aux dimensions et à la structure), mais ayant une fenêtre et un pourcentage de ponts thermiques totaux de 14,1%.

Voilà la composition des panneaux, en allant de l'intérieur vers l'extérieur :

- une couche de béton armé d'une épaisseur de 12,5 cm.;
- une feuille de polyéthylène de 0,2 mm ;
- du polystyrène expandé de 8,4 cm.d'épais - seur ;
- une couche de béton armé de 6 cm.d'épais - seur.

On relie la couche intérieure à la couche extérieure en béton armé par des ponts thermiques totaux en béton à agregats naturels. Au cas où il n'y avait pas d'influence des ponts thermiques totaux,la valeur de la R_o serait de 1,98 $m^2h^oC/Kcal$.

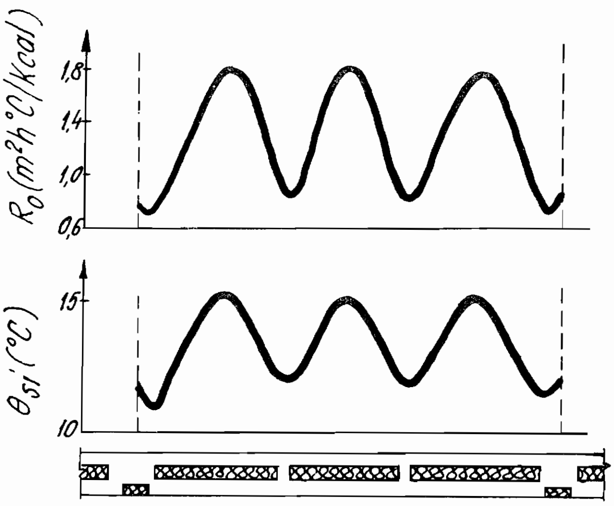

Figure 1.-La variation de la température de la surface intérieure (θ_{si}) et de la résistance à la transmission de la chaleur (R_o) pour un panneau prefabriqué de façade(plein)

Pour les ponts thermiques totaux ayant une largeur de 5 cm et des distances de 90 cm,on obtient la valeur maximale au milieu de l'espace qui les sépare et sur une portion réduite et,par conséquent,l'influence des ponts se manifeste dans tout l'espace qui les sépare.

Pour les mêmes ponts,mais qui sont placés à une distance de 45 cm,la valeur de la résistance maximale à la transmission de la chaleur atteint à peine la moitié de la ré - sistance correspondant au champ courant.

Nous estimons donc comme inadéquate la définition donnée jusqu'au présent dans la littérature de spécialité [2] sur le champ courant comme étant la zone où la variation de la temperature de la surface de panneau ne dépasse pas 0,5 °C.Le champ courant est caractérisé par les mêmes températures de surface et les mêmes résistances à la transmission de la chaleur qui correspondent à une zone où l'influence des ponts thermiques totaux ne se manifeste pas.

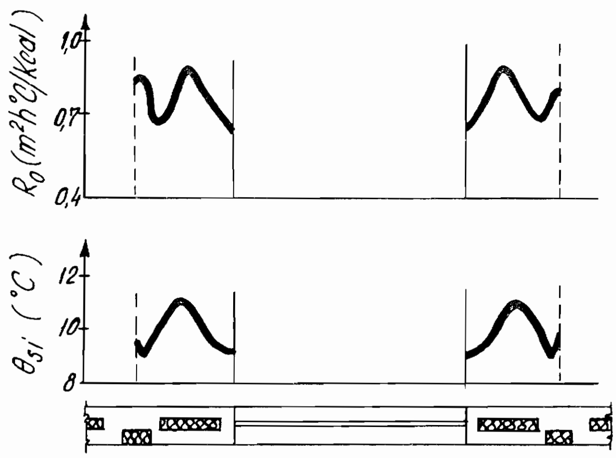

Figure 2.- La variation de la température de la surface intérieure (θ_{si}) et de la résistance à la transmission de la chaleur (R_o) pour un panneau préfabriqué à fenêtre.

Il résulte des exemples présentés ci-dessus que,pour obtenir des économies d'énergie dans l'exploitation des bâtiments,il est néces - saire d'agir dans le sens de la réduction ou de l'élimination des ponts thermiques et de l'utilisation,dans le même temps,d'isolations thermiques efficientes,de façon que la résistance des grands panneaux pour les immeubles d'habitation soit d'au moins R_{oc}=2..3 $m^{2o}C/W$.

En général le problème de la protection thermique est étudié en régime thermique permanent.Cela constitue une simplification,parce que en réalité la transmission de la chaleur à travers les éléments extérieurs de construction a lieu en régime variable [3] . Dans ce cas le calcul des processus de pro - pagation de la chaleur est rendu très difficile par la complexité du problème d'une part les facteurs météorologiques varient conti - nuellement,d'autre part le chauffage de l'intérieur du bâtiment varie lui-aussi,de sorte que les hypothèses considérées dans les calculs se réalisent en réalité rarement.

Toutes ces observations nous ont déterminé a entreprendre des recherches expérimentales [3] pour établir la manière dans laquelle a lieu la transmission de la chaleur en régime variable à travers les éléments extérieurs des bâtiments.Nous en avons tiré les conclusions principales suivantes :

1.- Dans le cas du régime de chauffage intermittent(en saison froid),la transmission de la chaleur entre l'air intérieur et l'air extérieur a lieu simultanément par l'accumu - lation ou la perte de chaleur du mur extérieur massif,le mur constituant ainsi un volant thermique.On constate en même temps qu'il n'y a pas de relation directement proportionnelle entre les valeurs du flux qui entre ou qui sort du mur et la différence de température entre l'air intérieur et l'air extérieur.Le régime de chauffage intermittent n'assure pas des conditions de confort similaires aux conditions assurées par le régime de chauffage permanent des bâtiments.

2.- Dans la période où pendant l'hiver le soleil réchauffe directement la façade,on con - state une diminution du flux thermique qui sort par le fenêtre ou par le mur,pour la même différence de température entre l'air intérieur et l'air extérieur.

3.- Dans certaines conditions et pour un certain degré de vitrage,la consommation de combustible dans l'exploitation des bâtiments peut être plus élevée dans le chauffage intermittent que dans le chauffage permanent.Si les installations de chauffage central intérieur sont dotées d'un réglage automatique individuel pour chaque corps de chauffe,on peut économiser 24,1% de la consommation annuelle de combustible sur le compte de l'intégration des apports thermique au nécessaire de chaleur du bâtiment.Ces apports sont dus à l'énergie électrique ou aux gaz naturels consommés à l'intérieur de l'immeuble,à la présence des personnes dans l'immeuble et aux rayonnements solaires(dont le poids dans la réduction de la consommation de combustible est de 15%) [4].

4.- Les relations de calcul de la littérature [5] concernant le coefficient d'amortissement des oscillations des températures extérieures et le déphasage ont été vérifiées expérimentalement par l'auteur pour des éléments de construction massifs,à l'aide d'un procédé et d'un appareil adéquat [3].On a établi ainsi que la relation donnée pour le coefficient d'amortissement est correcte uniquement pour les murs homogènes,pour les hypothèses suivantes : les oscillations sinusoidales extérieures ont une période de 24 heures,pendant que la température de l'air intérieur reste constante.La relation donnée pour le déphasage est incorrecte dans tous les cas. L'indice de l'inertie thermique D et le coefficient d'amortissement ne caractérisent pas l' inertie thermique de l'élément de construction (respectivement l'accumulation thermique ou le refroidissement) et,par conséquent,ils ne peuvent pas être pris en considération dans les calculs faites pour l'établissement des dimensions des installations de chauffage central.Nous avons établi donc la relation correcte de calcul de l'indicateur de l'inertie thermique.En même temps il faut souli - gner que,ainsi que la littérature [5] nous les indique,le coefficient d'amortissement ne peut être utilisé dans la détermination de la stabilité thermique des éléments extérieurs de construction [6].

5.- Pendant l'été,la protection thermique doit assurer l'économie d'énergie des installations de climatisation (là où elles e - xistent) ou le confort thermique à l'inté - rieur de l'immeuble.

Pendant l'été on constate la prépondérance de l'échange de chaleur qui a lieu à travers la fenêtre par rapport à celui qui a lieu à travers la partie pleine du mur (dans une pièce d'habitation) [3].
Cette conclusion est valable pour les murs pleins de compositions différentes,ayant un degré de vitrage qui dépasse 30% et pour les pièces des immeubles d'habitation orientés dans n'importe quelle direction.

Dans la figure 3 on présente,d'une façcon schématique et synthétique,ces nouvelles conclusions concernant la manière de transmission de la chaleur pendant l'été à travers la partie pleine du mur extérieur et pour les conditions climatiques indiquées dans la figure, notamment :

- pour une journée à ciel serein,lorsque le mur reçoit les rayonnements solaires directs (fig.1 a_1) et lorsqu'il ne les reçoit pas (fig.1 a_2) ;
- pour une journée à ciel nuageux pendant le jour (fig.1 a_3) et pendant le soir et la nuit (fig.1 a_4),lorsque la température de l'air extérieur devient plus réduite que celle de l'air intérieur.On observe que,dans ce cas, le flux thermique à travers le mur suit un sens unique : de l'air intérieur vers l'intérieur du mur.

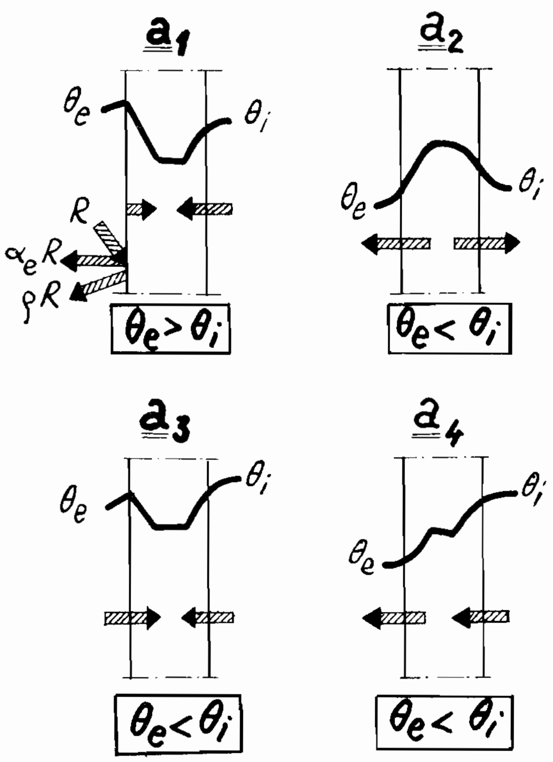

Figure 3.- La transmission de la chaleur à travers le mur extérieur massif d'une pièce d'habitation pendant l'été (jour à ciel serein : a1 -lorsqu'il reçoit le rayonnement solaires;a2 - lorsqu'il ne reçoit pas de rayonnement solaire;jour nuageux :a3 - pendant le jour;a4 - pendant le soir et la nuit).

La transmission de la chaleur par la fenêtre est de manière indiquée dans la littérature de spécialité.

En conclusion,compte tenu des résultats des recherches exposées ci dessus,il est nécessaire de rendre optimum le degré de vitrage des murs extérieurs plein en tenant compte des conditions de transmission de la chaleur pendant l'hiver ainsi que pendant l'été et de prendre des mesures pour protéger les fenêtres contre l'action des rayonnements solaires pendant l'été,sans lesquelles on ne peut réaliser le confort thermique et la réduction de la consommation d'énergie dans l'exploitation des bâtiments.

Les futures recherches expérimentales,qui serront réalisées à l'aide d'une installation d'enregistrement numérique automatique des données,qui seront ensuite traitées sur un calculateur,concerneront le comportement hygrothermique en régime variable des éléments extérieurs de construction et apporteront de nouvelles données pour l'amélioration des solutions de protection thermique des bâtiments et la réalisation des économies d'énergie dans l'exploitation .

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'he reduction of energy consumption in the ıeating

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Summary

As a result of the stringent changes on the energy sector several legal decrees have been issued in the Federal Republic of Germany within the framework of the energy saving law. The decree for thermal insulation establishes the requirements as to the constructional thermal insulation, whereas the decree governing the heating plants and the operating of heating plants prescribes legal regulations regarding the insulation of the pipings, the loss of exhaust gas and the regulating installations as well as the servicing, maintenance and control of the heating plants.

Résumé

La réduction de consommation d'énergie dans le secteur du chauffage

En considération des changements incisifs dans le secteur d'énergie, plusieurs décrets légales ont été rendus dans la République Fédérale d'Allemagne dans le cadre du loi sur l'économie d'énergie. Le décret de l'isolation calorifuge détermine les exigences en vue de l'isolation calorifuge des bâtiments, tandis que le décret des installations de chauffage et du fonctionnement de chauffage stipule des réglementations légales concernant l'isolation des conduites, pertes de gaz de fumée et dispositifs de réglage ainsi que la manipulation, l'entretien et la surveillance des installations de chauffage.

Introduction

The situation on the energy sector has fundamentally changed in the course of the last years. The times of cheap and sufficiently available energy are gone. Now as before the further development of the energy market is involved with a lot of risks. Therefore we must try to consume energy in a more economical way and to better exploit the energy quantities being at our disposal. Consequently it is a responsibility of utmost priority to use energy more economically and efficiently. Due to this reason the "Law for energy savings in buildings" (EnEG) was issued already in 1976 in the Federal Republic of Germany.

It is the aim of this law to avoid, both in case of heating and cooling of buildings, losses of energy in consideration of economical factors. The rightness of this point of departure is proved by an analysis of the energy consumption in the Federal Republic of Germany, which shows that about 45% of the final energy is consumed in the field of "household and small-scale consumers". And here by far the greatest share, namely 85%, is consumed for the heating of buildings.

The requirements as to the thermal insulation of the buildings as well as to the condition and operation of the heating plants are not regularized by the law itself but by respective legal regulations.

The "decree on an energy savings thermal insulation of buildings" (decree governing the thermal insulation) has come into force on November 1, 1977, whereas the "decree on energy saving requirements at heating systems and hot water plants" (heating systems decree) and the "decree on energy saving requirements for the operation of heating systems and hot water plants" (decree for the operation of heating plants) were passed on September 29, 1978.

The fact that for the purpose of reifying the requirements stipulated in this energy saving law (EnEG) three decrees had to be compiled proves that the saving of energy in buildings does not only include the improvement of thermal insulation but necessarily also measures in the field of heating and sanitary technique. Therefore the law commits the following parties to provide measures for a more economical consumption of energy:

1. the planning and executing architects
2. the professional engineers of the heating and sanitation sectors
3. the manufacturers of heating installations and hot water plants
4. the purchasers resp. the building owners in their function as users of these plants.

Decree on thermal insulation

Compared with the previously valid regulations this decree exacts a considerably improved thermal insulation.

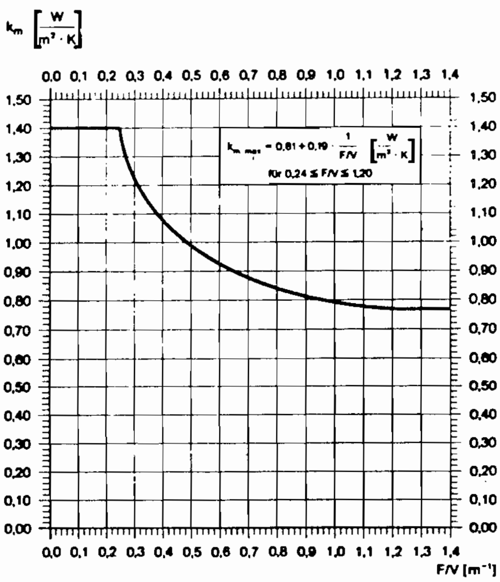
The buildings deal within this decree are

- buildings with normal indoor temperatures
- buildings with low indoor temperatures
- buildings for sports and meeting purposes.

However, in this connection, only the buildings with normal indoor temperatures will be dealt with.

As a general principle the decree on thermal protection for buildings (new buildings) with a normal indoor temperature of at last 19°C allows two procedures of proof.

The proof according to No. 1 of the enclosure 1 of this decree is also called 'envelope procedure', as for the whole building envelope a maximum average heat transmission coefficient $k_{m,max}$ as a function of F/V, the proportion of the heat transmitting envelope area F to the heated volume V enclosed by F (please see figure 1) was fixed.



F/V in m^{-1}	$k_{m,max}$ in $W/m^2 \cdot K$
≤ 0,24	1,40
0,30	1,24
0,40	1,09
0,50	0,99
0,60	0,93
0,70	0,88
0,80	0,85
0,90	0,82
1,00	0,80
1,10	0,78
≥ 1,20	0,77

Fig. 1: Maximum average heat transmission coefficient $k_{m,max}$ as a function of F/V

This admissible value must always be higher than the actually existing average heat transmission coefficient k_m. k_m is the result of the following equation:

$$k_m = \frac{k_W \cdot F_W + k_F \cdot F_F + 0{,}8 \cdot k_D \cdot F_D + 0{,}5 \cdot k_G \cdot F_G + k_{DL} \cdot F_{DL}}{F}$$

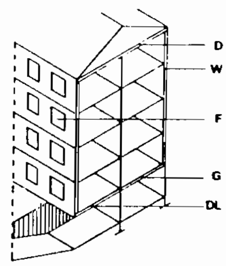


Fig. 2: Specification of the parts enclosing the building

F is here the heat transmitting envelope area of the building:

$F = F_W + F_F + F_D + F_G + F_{DL}$ in sq.m.

F_W = external wall area adjoining to the outside air. The outside measurements of the building are applicable. Measurements have to be taken from the upper edge of the site or, if the lowest ceiling is lying above the upper edge of the site, from the upper edge of this ceiling up to the upper edge of the highest ceiling or of the upper edge of the effective insulating layer.

F_F = window area (windows, French windows); this area is calculated on the basis of the windows clearance.

F_D = heat insulated roof or upper floor areas.

F_G = ground area of the building as much as it is not adjoining to the outside air; it is determined on the basis of the outer measurements of the building. Either the ground floor on the soil is computed or, in case of unheated basements, the ceiling of the basement. If the basement is heated, the ground area of the building F_G should not only include the ground floor of the basement but also those wall surfaces bordering the soil.

F_{DL} = floor area delimitating the building downwards against the outside air.

k_W, k_F, k_D, k_G and k_{DL} are the heat transmission coefficients in W/m^2K pertaining to the different areas.

Contrary to the usual practice to determine the k-values for individual constructional parts, this procedure permits the exchangeability of the insulating layers in the area of all constructional parts enclosing the building . However, all individual constructional parts themselves and, in addition, the external walls including the windows and French windows have to meet certain minimum requirements.

The procedure according to No. 2 of the enclosure 1 of the "decree on thermal insulation" stipulates admissible heat transmission coefficients for the different constructional parts as well as average coefficients $k_{m,W+F}$ for the external walls including the windows and French windows in dependence of the ground area of the building. $k_{m,W+F}$ is determined as follows:

$$k_{m,W+F} = \frac{k_W \cdot F_W + k_F \cdot F_F}{F_W + F_F}$$

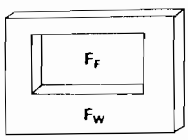


Fig. 3: Specification of the external wall-parts

Regulation on heating plants

The differing choise of plant components (central heating furnace, heat distribution plant, regulating equipment) has a considerable influence on the consumption of energy.

The "regulation on heating plants" applies to heating systems as well as to plants for the supply of hot water with a nominal thermal output of more than 4 kW.

For the determination of the nominal thermal output it has to be proceeded on the heat requirements having to be ascertained according to DIN 4701 "Space heating rules for calculating the heat requirements of buildings". By that it shall be prevented that a too high dimensioning of the heat producer as well as to highly adjusted firing powers will cause avoidable standstill or readiness losses. The exhaust gas losses - relative to the respective heating power - are limited; at the same time care has to be taken that the losses in the operation field are limited, too.

For heat distribution plants a minimum thickness of the insulating layer is recommended. So, f.e., pipings with a nominal internal diameter of up to 100 mm have to be insulated against heat losses in such a way that the insulating layer thicknesses, relative to a thermal conductivity of the insulating material λ = 0,035 W/m·K must amount to at least 2/3 of the nominal internal diameter of the pipings. For pipings with greater nominal internal diameters at least an insulating layer thickness for the nominal internal diameter of 100 mm must be applied.

Furthermore for central heatings the installation of a regulating apparatus is prescribed. So all plants have to be provided with instruments for the heat control in each room by means of thermostats and all plants, feeding more than two flats, with instruments to influence the heat input in dependence of a time-programme and the weather conditions.

Heating operation regulation

The energy consumption of heating and hot water plants is decisively influenced by the way they are operated. Inexpertly operation, f.e. wrong adjusting of the regulating equipment and omitted maintenance of the central heating furnace cause considerable heat losses. Besides the responsibility of the owner regarding the service and maintenance, in the "heat operating regulation" the limitation of exhaust gas losses and their control in dependence on the nominal thermal output are stipulated. The annual control of the exhaust gas losses by the chimney-sweeps is a good and sufficiently exact mean for the judgement of the thermal efficiency of central heating furnaces and, at the same time, an important contribution to the environmental protection.

The "heating operation regulation" applies both to new and old plants with a nominal thermal output of more than 11 kW. In this connection the term "plant" is to be understood as the sum of all installations and equipments, which serve for the heating or the preparation of hot water.

Outlook

In consequence of the permanently rising energy prices the point of time is in sight from which on a number of the requirements stipulated in these regulations will not be justifiable any more as far as its economy and efficiency are concerned, as the necessary investments cannot be amortized any more within the usual service life by means of heating cost savings. Due to this reason an amending regulation is being prepared with the aim to increase the respective requirements. Furthermore the energy saving law will be changed to the effect that, to a limited extent, requirements can be made as to the thermal insulation of existing buildings.

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Field trials in well insulated houses

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Summary

Insulation should save energy. To quantify this, twenty-four houses which were well insulated and occupied, have been instrumented and studied for 2 years. Energy and temperature records have been analysed and the occupants' ventilation habits assessed. The results show the importance of the free heat contribution in a house. The results also reveal the growing importance of water heating and ventilation. Water heating was the largest single energy use (3,500 kWh/year) compared with the modest space heating use of 2,400 kWh/year. Temperature patterns suggested that occupants chose to have one comfortable room and the rest of the house varied with outdoor temperatures. The actual temperature distribution within the house was a function of the type of house.

Resumé

L'isolation doit économiser l'energie. Pour quantifier ceci, vingt-quatre maisons, bien isolées et habitées, etaient munies des instruments et étudiées pendant 2 années. Les enregistrements du temperature et de l'energie sont analysées et les habitudes de ventilation des habitants sont estimées. Les resultats montrent l'importance du chaleur gratuit dans une maison. Ils font connaître l'importance croissant du chauffage de l'eau, et du ventilation. Le chauffage de l'eau etait le consommateur le plus grand de l'energie (3,500 kWh/an), en comparaison avec la consommation modérée du chauffage de l'espace (2400 kWh/an). Les distributions de temperature indiquent que les habitants font le choix de une pièce confortable, et que le temperature dans les autres pièces changent avec les temperatures exterieures. Les distributions particuliers de temperature dans les maisons etait fonction du type de maison.

Introduction

Simple insulation techniques offer the opportunity to reduce our domestic space heating energy to less than a third of that used at present. However, the occupants of such houses may change their living style and have their houses warmer, or ventilate them to a higher standard. To quantify these factors studies were undertaken in 24 highly insulated occupied houses in Scotland. These houses are situated in a sheltered area 12 miles west of Aberdeen and are part of a recent development which includes 478 similar prefabricated Scandinavian houses. Our survey included the three most popular house styles and contained 10 detached houses, 9 end of terrace houses and 5 mid-terrace houses. The experiment was organised by the Gordon District Council, the North of Scotland Hydro-Electric Board and the Electricity Council.

All the houses have three bedrooms, are well insulated and double glazed. Details of their construction are given in table 1. The houses are all weather-stripped but the windows have an adjustable ventilation grille mounted high in the wooden frame. In practice this is little used by the tenants. Under average wind speed the ventilation rate is 0.2 air changes an hour with closed vents, rising to 0.3 ach with the vents open. The kitchen has its own extract fan.

Space heating is provided by direct-acting, wall-mounted natural convector panels. Each panel has an

Table 1 House details

House Type	Det. House	Mid-Terr.	End-Terr.
Floor area m^2	109	99	99
Fabric heat loss ($18^oC\ \Delta t$) kW	1.88	1.38	1.61
Ventilation loss ($18^oC\ \Delta t$) kW ($\sim$ 1 ach)	1.68	1.62	1.62
Heater sizing kW	8.4	6.6	6.6
Average winter temperature:			
bedroom ^oC	16	14.2	15.1
hall ^oC	13.9	15.7	15.3
living room ^oC	17.1	18.4	18.0
Average bedroom rel. hum. %	61	58.5	59.3
Space heating kWh/year	2424	2407	2575
Total useful electrical gains (heating + 50% cooker + 30% hot water + miscellaneous)	5727	5046	5537
Mean internal/external Δt ^oC	9.6	11.0	10.5
Average open windows over winter per house	1.66	1.03	1.14

adjustable, integral thermostat, which maintains the required room temperature by means of proportional control. In 20 of the houses the tenants supplemented the heating system by adding a coal-effect radiant electric fire in their living room. Hot water is provided by a 136 litre (30 gallon) water cylinder heated by a 3 kW top entry immersion heater.

Typical family size was 4, 2 parents and 2 children, although the family size did vary from 2 to 7. The occupants received a small payment for the inconvenience introduced by the trials but they paid their own bills based on the normal electricity tariffs.

The electricity supply to each house was monitored in three separate circuits. One circuit was connected to all the electric panel radiators. A second circuit recorded the electricity used to heat the domestic hot water. The third circuit supplied the remaining electricity used for cooking, lighting, television and domestic appliances. Room temperatures were continuously recorded by thermographs sited at three points in the house, the living room, the hall and the main bedroom. Continuous humidity measurements were taken in the main bedroom and in a small number of houses extended to include the loft for 10 weeks. Knowledge of the thermostat settings was from a spot check carried out by an independent market research organisation who measured the actual living room temperature, noted the thermostat setting, and collected basic data on family size and occupants' use of the house. Ventilation characteristics were recorded by daily observation of the number of rooms which had at least one open window at the time of the survey. This was done once a day between 9 and 12.30, or 1400-1630. Sunshine air temperature and wind speed were recorded from a temporary weather station set up on the site.

Temperature patterns

Three important temperature patterns emerged. The first was the seasonal variation in temperature distribution throughout the house. Average living room temperatures tended to stay constant, or rising slightly in colder weather (figure 1). Bedroom temperatures

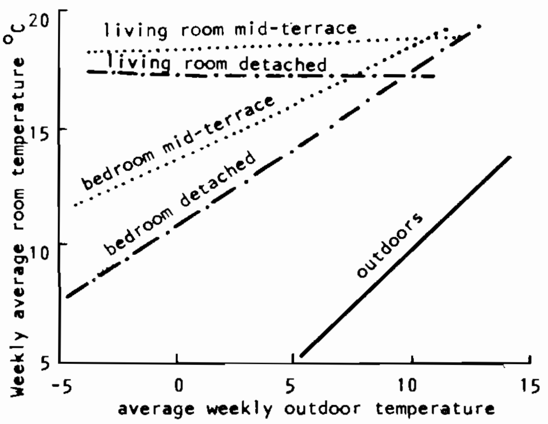

Figure 1 Seasonal variation in room temperatures

floated between the comfortable temperature of the living room and the outdoor temperature. Hall temperatures were similar to bedroom temperatures.

The second finding was that the temperature distribution was also a function of the house type. While living room temperatures were similar for all house types, there was a marked difference in bedroom temperatures for the different house types. Mid-terrace houses sheltered by adjacent houses, had the warmest bedrooms. The detached houses with four exposed walls experienced the coldest bedrooms. A short study on loft temperatures showed a similar effect (figure 2).

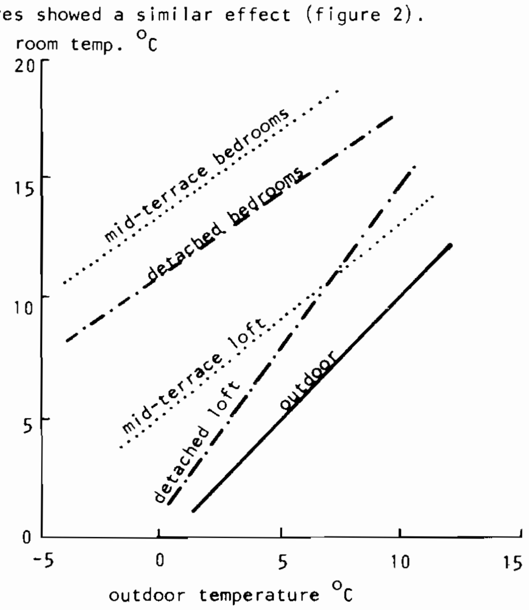

Figure 2 Seasonal variations in loft temperature

The third factor was the diurnal variation in living room temperatures. Maximum temperatures in the living room occurred between 1800 and 2200 hrs. These rooms were fractionally warmer during this period at the weekend. All heating was manually switched off when the occupants retired to bed and the living room temperatures normally fell 3-4°C. The heating was switched on again in the morning and some heating provided during the daytime. Both morning and afternoon temperatures were warmer at the weekends than during weekdays.

The spot check on the thermostat setting in the living room showed surprisingly little relationship with the actual temperatures recorded. This finding was

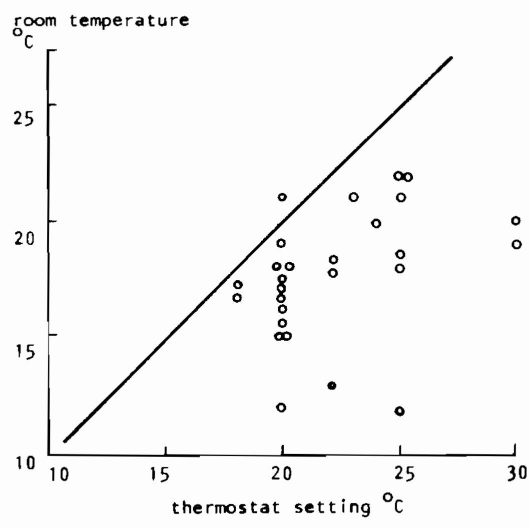

Figure 3 Spot check comparison between actual and thermostat settings in the living room

particularly surprising since this type of control is the most advanced currently manufactured and the heater itself being of very low mass, is very responsive (figure 3).

Energy consumption

On average the space heating energy was very low. However the variation between houses was large. Some of this variation could be attributed to the different temperatures which the occupants choose for their houses. Such a relationship for the detached houses is illustrated in figure 4. Two of the warmest houses having similar mean temperatures, differ by over a factor of 2 in terms of space heating energy. The correlation therefore between space heating energy and average

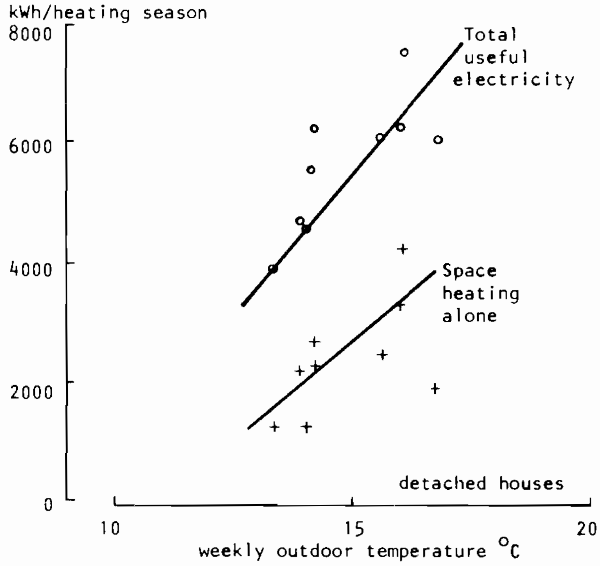

Figure 4 Energy relationship for the detached houses

house temperature is poor (correlation coefficient $r = 0.4$). However, much of the other electrical energy used in the house is also useful for space heating. All the heat from lighting, television and small appliances is considered useful. Only 50% of the energy used in cooking is considered useful. The remaining 50% is associated with moisture and cooking smells and is assumed to be ventilated directly through the kitchen extract fan. Even the domestic hot water system provides some useful heat during winter from the heat losses associated with the piping distribution. Some 30% of the domestic hot water energy is assumed to be released usefully into the house during winter. The total electricity consumption considered useful for winter space heating is therefore taken to be 100% of that used in the heating devices themselves, 30% of that used for water heating during the heating season and 87% of the rest of the electricity used. This improves the relationship between total energy used and the mean house temperature (correlation coefficient $r = 0.58$).

Moisture control

Mould growth is associated with relative humidities greater than 70%. . Averages of relative humidity in the bedrooms increased with diminishing outdoor temperatures (figure 5). Moisture measurements in the loft space showed very high relative humidities leading to condensation on the roof timbers and initial signs of mould growth. Detailed measurements revealed several ventilation routes from the house itself into the loft space. Moisture was migrating and accumulating in the roof during calm weather. Sealing and weatherstripping techniques were applied to all service and trapdoor penetrations of the bedroom ceilings. No further roof condensation troubles have been found.

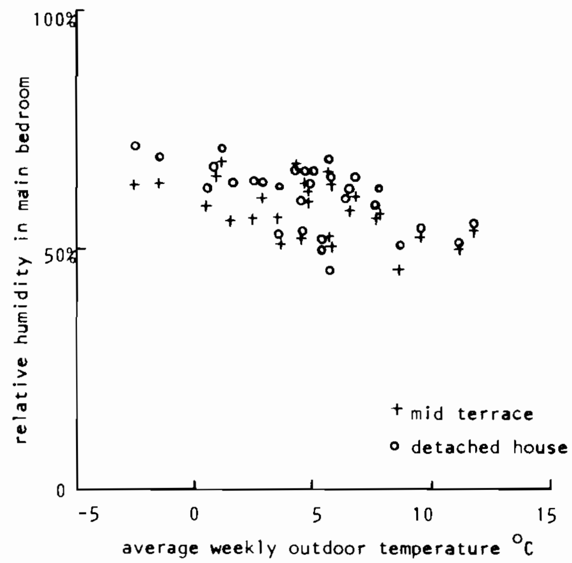

Figure 5 Relative humidity in bedrooms

Conclusions

On average, the space heating energy was very low in these well insulated houses. It is exceeded by the hot water load which now becomes the dominant one. However, there was a large variability between users. This is partly due to the free heat which other activities in the house create. This includes the incidental heat from the occupants themselves, lighting, television, refrigeration, cooking and hot water in its route to the taps. It is also modified to some extent by the ventilation characteristics of the households.

The temperature records illustrate the occupants' desire to maintain one comfortable room within the house. This is the living room and all living rooms were operated at comfort temperatures in the evening. The bedroom and the hall floated between the living room temperature and the outside temperature. The house type itself had a distinct influence upon the hall and bedroom temperature. Mid-terrace houses protected by another dwelling on either side experienced significantly warmer bedrooms than those in the detached houses.

Relative humidities in the bedrooms seldom averaged below 50% R.H. and tended to increase with decreasing outdoor temperatures. Condensation difficulties were experienced in some of the roof spaces. These were attributed to the ventilation paths from the house into the roof space. Weatherstripping and sealing these air paths successfully eliminated the trouble.

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Bioclimatic Design of the Building Envelope in Vernacular Architecture

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Summary

Through out history men has learnt to build in accordance with climatic conditions. In vernacular architecture examples of bioclimatic design are seen but with the elaboration of heating and airc onditioning systems unfortunately designers have started to design buildings that are not compatible with climate.

In the equality of
outdoor conditions + Building envelope + Energy = Comfortable indoor climate

Comfortable indoor climate was tried to be achieved only with increasing the energy input whereas, in this epoch of energy crisis,building envelope has to be designed so that it will use a minimum amount of energy to achieve bioclimatic comfort.

In this study examples of vernacular architecture in Turkey showing how all the building components, walls,windows, shutters, balconies, verandohs, courtyards, roofs were used as design elements that provide comfort will be presented. The theory behind design decision, coordination with life styles, plan types is analysed. Design recommendations for the energy conserving building envelope is derived from the presented examples.

Sommaire

Les hommes ont su batir selon de climat pendant la durée de l'histoire, Les dessinateurs ont oublié, malheuresement, le dessin bioclimatologique à course d'evollopment des systems de chauffage et d'air condition.Les conditions climatologiques, l'envelope du batiment et l'energie, sont les facteurs qui produit le confor d'endroit d'interieur. Les hommes ont été essayé d'avoir un climat confortable d'endroit d'interieur en aggrandissent l'entré d'energie mais dans cette époque de crise d'energie,if faut dessiner l'envelope de batiment pour minimiser l'emploie d'energie qu'il faut.

Cette travaille est presenté des examples des murs, des fenétres, des balcons, des verandas, des cours, des toits, des panjours dans l'architecture traditionelle de Turquie. Dans ce travail, ont analyse le theorie quiest au font des decisions de dessin , la condition de vie et les plans.

On sort des exemples qui on présente les recommandations du dessin pour une batiment qui conserve l'energie.

Introduction

Man has forgotten what he had learnt to conserve energy with the sophisticated heating and cooling systems. Whereas vernacular architecture is full of examples of cases in which buildings are successfully kept within comfort conditions only through the design of the building shell. Bioclimatic comfort is the product of the physical factors such as ambient air temperature, mean radiant temperature, air movement, humidity, the activity level and the clothing of users. The comfort temperature is within the range of 18°C to 26°C for human beings but in order to maintain these temperatures very sophisticated heating and cooling systems are devised and huge amounts of fuel energy that would have been useful for production are burnt away.

With the energy crisis men are trying once more to decrease the amount of fuel consumed to achieve comfort; this can be done by a careful design of the building shell. A building design which is sensitive to the user requirements whether these are the bioclimatic, antropome tric, economic or visual ones as well as the outdoor conditions and sources is capable to maximise the comfort conditions while minimising the cost for doing it.

Comfort conditions can be symbolised by the following equation. Outdoor conditions + Building shell = Actual indoor conditions. User activity + User Clothing = Comfort conditions indoors. Actual indoor conditions can be equated to comfort conditions by alternating the design of the building shell which is a variable and the heating and cooling systems. In vernacular architecture the emphasis is on the design of the building shell. No attention is payed to heating or cooling systems as they are either non existent or kept very simple. The effective use of building design to achieve bioclimatic comfort will be explained through examples of vernacular architecture in Turkey.

Climatic Conditions

The socio economic, cultural and climatic factors have effected the form of buildings in Turkey which is between 36-42° N hattitudes. The climate is temperate, having maritime characteristics mainly on the Black Sea Coast and Marmara Sea Coast, Mediterenean characteristics on the Mediterenean coast. At the Black Sea and Marmara regions, there is much rain. The summers are cool and rainy, winters are warm (For Sinop, in this region, annual mean temperature is 14°C, monthly mean maximum temperature is 9.6°C in January and 25.6°C in July, monthly mean minimum is 43°C in January and 19.4°C in July).

At the Mediterenean and Aegean Coast, usually winters are short and warm, summers are arrid ond hot. The rainy seasons are spring and autumn. (For Antalya, annual mean temperature is 18.7°C, monthly mean maximum is 14.9°C in January and 33.7°C in July, monthly mean minimum is 6.2°C in January and 22.7°C in July.)

The mainland Anatolia has temperate climate with cold winters and hot, arrid summers, rainy autumn and spring. As one goes to the east, winters get longer and colder and summers get shorter and cooler. The South Eastern part of Anatolia gets very hot and arrid in the summers. (Central Anatolian example Ankara, an annual mean temperature of 11.7°C, Monthly mean max. of 4.1°C in January and 30.1°C in July, monthly mean minimum of -3.7°C in January and 15.2°C in July. Eastern Anatolian example Erzurum has an annual mean temperature of 5.9°C, monthly mean max of -4°C in January, 25.8°C in July, montly mean min of -12.9°C in January and 11.8°C in July. South Eastern example Diyarbakır has an annual mean temperature of 15.8°C, monthly mean max of 6.5°C in January, 38.2°C in July, monthly mean min. of -2.6°C in January and 21.5°C in July.)

Interaction of Climatic Conditions and the Design of Buildings

In vernacular architecture the bioclimatic comfort was mainly kept in buildings through the design and usage of buildings. The mechanical heating and cooling systems were either very simple or non existent. For that reason special attention was size of opennings, plan layout and the usage of buildings so in a way all buildings were heated and cooled passively. The thermal capacity and even the colour of materials became very important elements in providing comfort. Another very important factor was the amount of effort put by the users to provide comfort or in other words usage of the buildings. Usually in contemporary buildings, users expect to have the bioclimatic comfort conditions only through the setting of the thermostats. Whereas handling of the curtains, shutters, using certain parts of the house at certain seasons are very important means of usage in providing comfort. Today with the increase of passive solar heating systems men are relearning such patterns of use of buildings.

Use of Seasonal Living Spaces

Especially in the Central Anatolia, and inland regions houses had 2 or 3 storeys overlooking a small countyard. The courtyards were shut off from the street by high walls. A narrow door lead into the courtyard. The second floor was reached by a flight of steps. From the courtyard. The ground floor usually has thestorage areas if the building had 3 floors. The ground floor or the 2nd floor was used for winter living and the top floor was used during summers. In the design of these 2 floors there were distinct differences. The space for winter living had thick walls, very small windows protected by timber shutters. The walls were made of stone or heavy mud brick in the winter living area. The walls were covered with built in timber shelves, wardrobes indoors that protect the walls from the cold outside. (Fig. I)

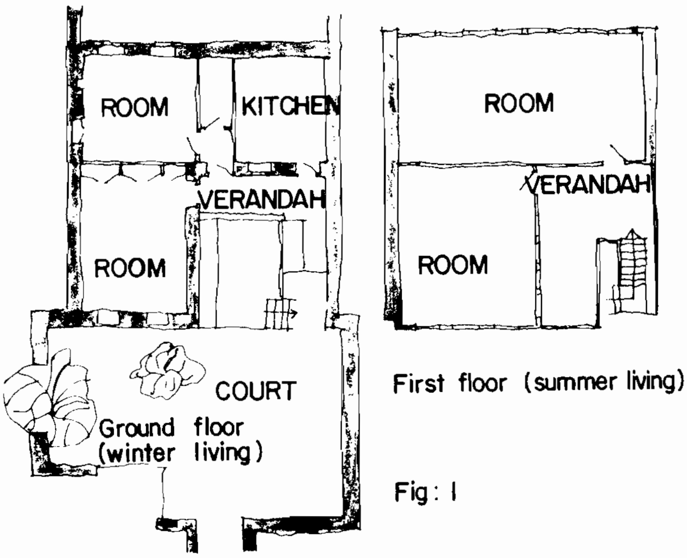


Fig: I

The top floor became the summer residence with its light timber construction, huge openable windows and the verandah. The winter living area could have heavy, mudbrick walls as well as stone walls. Special attendion was payed to the north elevations and the elevations facing the winds so that they had either no opennings or very small ones. The hight of the rooms in that part was less than the rooms in the summer living areas. With the decrease of the volume of air in the room it was easier to heat the space. The shutters were placed indoors so that they could be operated without openning the windows. The door jamb had a special design to prevent air flow. The floors and ceiling were insulated in winter rooms. Over the timber floor, a special kind of earth that had a good insulation value was placed (Thickness 10 cm) and this was covered by timber or brick. Over this floor, wall to wall corpeting was used. The rooms were heated with built-in stoves. The summer living areas had high ceilings, and big windows. The walls were made of timber. The windows had shutters on the outside so that they could be used to prevent the penetration of the sun's rays. A second row of top windows were seen in many houses. These windows were used to take in light and to ventilate the room taking away the hot air that rises.

Use of two distinct living spaces for summer and winter was a means of achieving bioclimatic comfort throughout the year and this method was especially seen in the mainland, in regions where winters are cold and summers are hot. (Fig 2.)

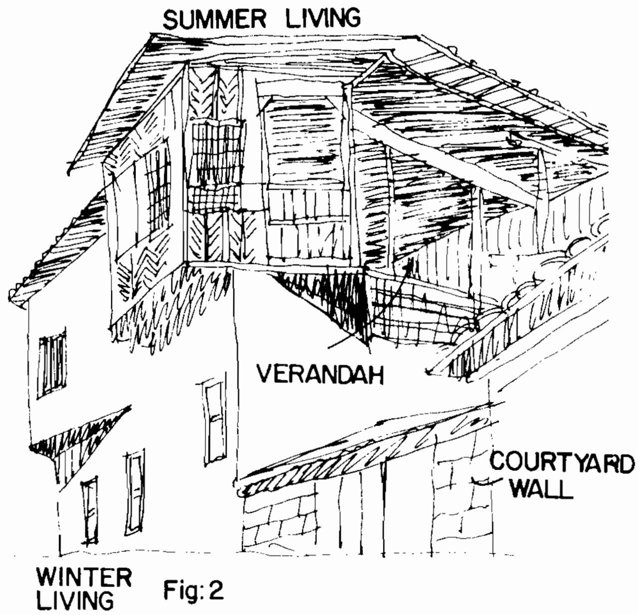


Fig:2

Use of Verandahs and plan types

Outdoor living was very important all over Turkey. In Spring, summer, and autumn much time was spent outdoors. Outdoor living was a means of providing bioclimatic comfort to the users. In the most common plan types the main element of the house was the verandah. It was reached by a flight of stairs from the court. In winter usually the verandah was closed off by glass doors, to protect the house from the cold and to provide an outdoor living area whose climate was moderated.

The most common plan types which were used in the west and central parts of the country were shaped around a verandah which was called "Life" or "Hayat".

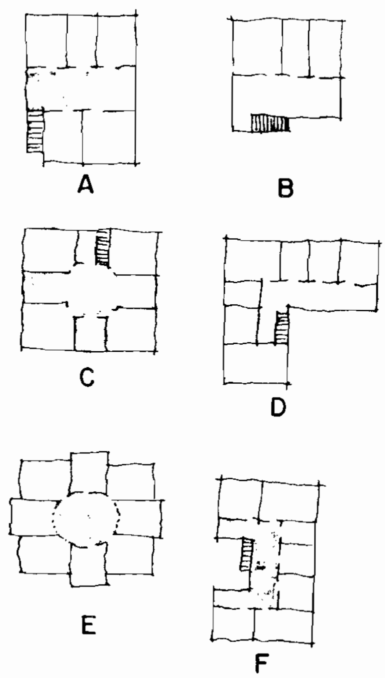


Fig: 3 - Plan types

The rooms might be on one or both sides of the verandah. (Fig. 3, A,B) The house might take an L or a N shape (Fig 3, D F) In Istanbul and its near surroundings the house became a square around the verandah (Fig. C. E)This type of plan was on efficient tool to achieve bioclimatic comfort. It consisted of a central living space (sofa or hall) which was open on 2 or 4 sides. (Fig. 3 C) The family's main activities took place in this semi open area. In the cold reason the ends of this semi open area were closed by glass partitions. The glass partitions when opened in summer resulted in a great cross ventilation which cooled the main living area. In winter the stove was placed at the center and heated the rooms through its central location. The glass partitions heated the main space through the green house effect in sunny winter autumn days. At nights these windows were closed off by heavy curtains. The overhangs over the verandah protected the living space from the sun in summer.

Use of Eaves, Cantilevered Closed balconies.

A cantilevered, closed balcony was an important feature of houses in vernacular architecture. Such a closed balcony was usually placed overlooking the street or the best view. There were plan types in which this contilever became just a continuation of the living room. (Fig. 3 E) Its protrusion extended over the street or the sea to have a better view and use the breezer coming from different directions. These places were very popular living spaces in the house, for dining, accepting visitors or resting. These cantilevered balconies or "CIKMA"s almost touched each other on both sides of a narrow street. (Fig. 4) Together with the eaves, they protected the sidewalks of the streets from rain and provided shade in summer. (Fig 4) Widely used eaves were another important design tool to protect the walls and windows from the rain and high sun's rays in summer.

The windows on the cıkmas were protected from the cold winters or sunny summers by timber shutters or a delicate tember latticeworh that provided privacy to the users. The shutters and the latticework decreased the heat loss from or heat gain to the building.

Courtyards Design in Hat Arrid Climates

In hot arrid zones of Turkey, especially South Eastern Anatolia, buildings were shaped directly in accordance with the climatic requirements. In this climate the courtyard verandah combination was replaced by the courtyard, collonaded living area, "EYVAN" combination. The courty and became the most important design feature as all the rooms were aligned around it. The part of the house that was used for summer (eyvan) faces north. (Fig. 5) By facing north the, collonaded living area never received direct sun's rays. The rooms were oriented and the windows were designed so that othey should not face sun's rays. Some rooms did not have any windows facing north. These rooms were used mainly in winter (Fig 5). Some rooms did not have any windows facing south and these were used mainly in summer.

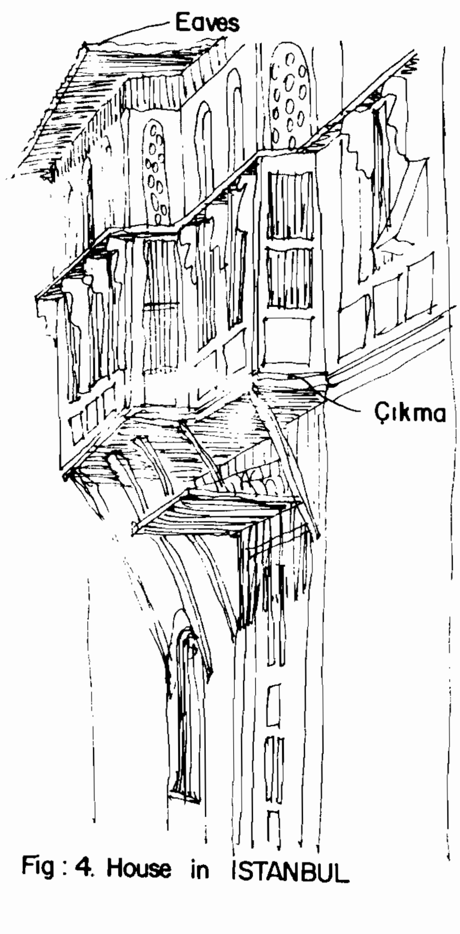
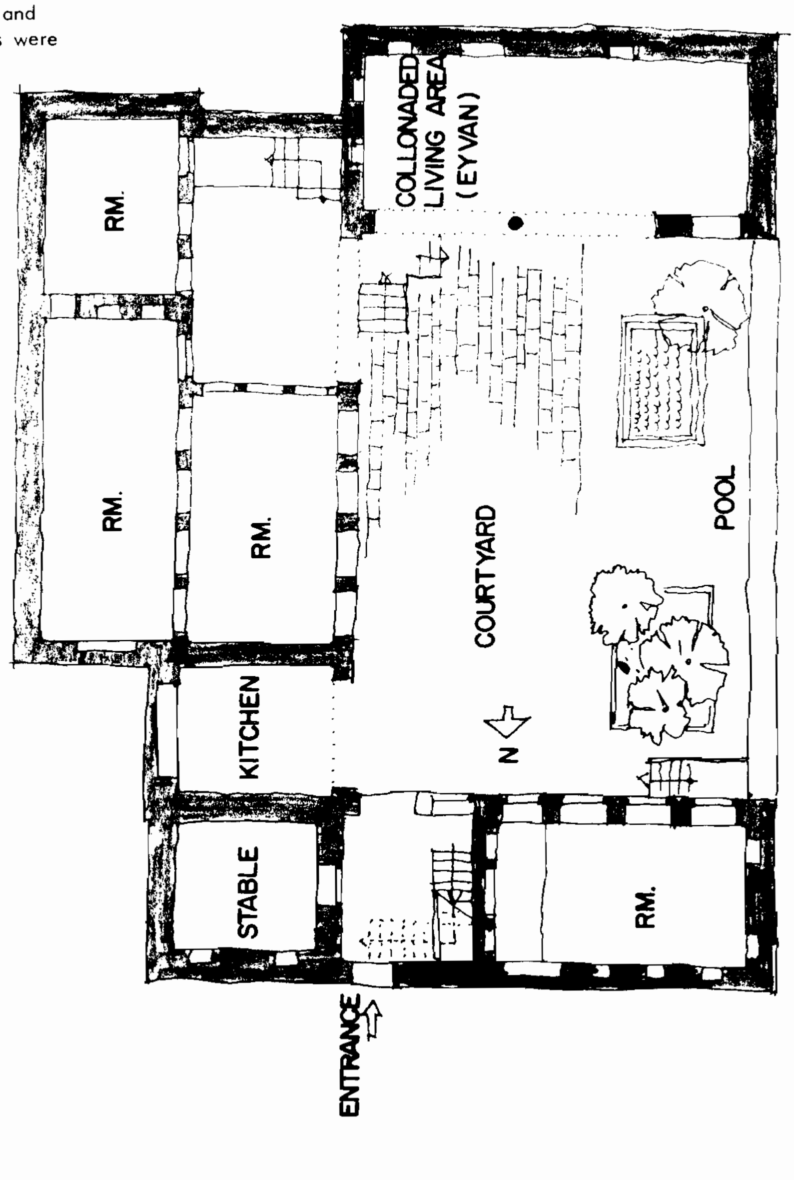


Fig: 4. House in ISTANBUL

Fig: 5- House in DIYARBAKIR south eastern ANATOLIA



All the windows faced the courtyard. There were no windows on the street for privacy reason's. The houses were built close together so that they would benefit from the shades of each other. The narrow streets were thus almost always shaded. The only openning to the street was a small low door. The design principles were completely different from those in temperate areas where the house opened up toward the street by means of cıkmas.

At one side of the courtyard, there was a collonaded living area (eyvan) which was a few steps higher than the courtyard. The eyvan was used continuously during summer. Sometimes there was a pool in the eyvan as well as in the courtyard.

There were usually basements which were used for storage as well as living during summer. The rooms had 2 rows of windows. The top windows provided a very efficient means of natural cooling of the space. The courtyards were used as a means for efficient evaporative cooling. The floor of the courtyards were covered with cobblestones. In every 2 or 3 hours water was poured from the pond, all over the courtyard and the filled the spaces between the cobblestones. The evaporative cooling effect of this water is enormous. Sometimes a continuous water movement is hept in which the water overflowing in the pond go along the sides of the cobblestones to the other parts of the courtyard.

The floor of the houses was finished with stones or soil. The floor was covered by carpets during winter. The roof was made by putting soil over a timber construction. During the hot summer nights beds were put either on the top of the flat roofs or in the courtyard in order to provide comfort. The houses in the Meditterenean coast (Fig 6) had similarities to the south Eastern houses in terms of the use of the courtyards, evaporative cooling through the pool use of massive thick adobe or stone walls, smallness and ramity of windows. The thermal capacity of the building mass was very successfully used in the hot, arrid regions.

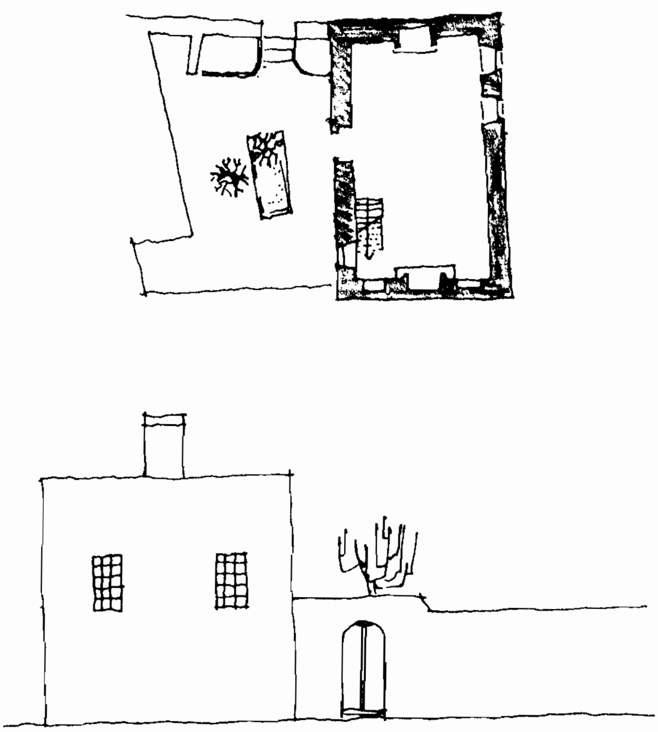


Fig: 6
House in BODRUM - MEDITTERENEAN COAST

Conclusion

Vernacular architecture is a rich source in which building design is used to achieve bioclimatic comfort with minimum use of energy. The examples of vernacular architecture in Turkey show that through the handling thermal mass and insulation capacity of materials, oventations evaporative cooling prevending heat goins heat losses, by means of shades, shutters, curtains, eaves, design of opennings other and building elements, incorporotion of indoor and outdoor spaces bioclimatic comfort could be achieved throughout the year. The same principles in terms of understanding the thermophysical aspects can be applied to to days buildings with great success. The main comfort.

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The main measures of improvement of enclosing structures in mass construction of the USSR

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In the report there were formulated the requirements to external enclosing structures of completely prefabricated residential buildings: walls, roofs and windows. The evaluation was given to the stressed state of one-layer and three-layer walls with flexible ties and effective insulation. The advantages of three-layer walls were demonstrated including their high thermal efficiency and the possibility of their watertight properties improvement owing to open joints between panels. The assessment was given to light curtain panels with effective insulation. The structure of a roof with "warm garret" is described. The advantages of this structure in arrangement and in operating were shown. There were determined the ways of improvement for roofs with "warm garret". It was pointed out that the improvement of window structures is connected first of all with a higher level of their thermal insulating properties. There were described measures taken for a more wide application of triple glazing in different regions.

* * *

Dans le rapport sont exposées les exigences en matière des structures de protection des immeubles d'habitation préfabriqués - murs, toitures et fenêtres.

On précit l'état de contrainte des murs à une seule couche et multicouches avec les liaisons flexibles et les couches thermiques effectifs. On montre l'avantage des murs multicouches, y compris leur efficacité thermique et la possibilité de l'augmentation des propriétés imperméables au moyen d'installation des joints ouverts entre les panneaux. On précit des murs-rideaux légers avec une couche thermique effective. Il s'agit aussi de la structure de toiture avec le "grenier chauffé"; on montre l'avantage de cette structure dans l'exploitation et l'installation. On a déterminé les voies du perfectionnement des toitures avec le grenier chauffé.

On dit que le perfectionnement des structures des fenêtres est lié tout d'abord avec l'élévation des propriétés thermoisolantes.

Dans le présent exposé sont décrites les mesures d'application des fenêtres triple-vitrerie dans les différentes régions.

* * *

External enclosing structures (walls, roofs, windows) of fully prefabricated residential buildings in mass construction are to meet high requirements. Enclosing structures are to be of necessary strength, to be rather technological in manufacturing and erection, to ensure weather tightness of buildings, to guarantee a minimum of total expenditure on structures with due regard for expenditure on firing to support thermal comfort in buildings.

The creation of industrial enclosing structures meeting all necessary requirements is connected with considerable difficulties.

As the investigations have shown season changes in temperature, external air humidity and intensity of solar radiation occurring in external walls of residential buildings entail a complex stressed-deformative state. In the areas where stresses are concentrated there can appear cracks which are more probable in one-layer panel walls made out of cellular concretes or porous aggregate concretes. Only the application of three-layer and reinforced concrete panels with separate metal ties between external layers and with the thermal insulation having little rigidity under shear allows to a considerable degree to reduce stresses in panels due to climatic effects.

The application of three-layer panels with flexible ties permits to ensure high thermal properties of walls owing to effective thermal insulation and the elimination of thermally conductive cold bridges as well as the necessary watertight properties of walls due to open joints.

It is a serious task to preserve external wall panels from excessive humidity. The structure can be considered to be acceptable if a negative balance of moisture is ensured in an annual cycle of panel wetting (air and vapour moisture) and drying.

The technology of manufacturing and assembling for three-layer panels is mastered to a considerable extent. In the USSR there have been adopted a principal orientation towards the application of three-layer panels in fully prefabricated housing construction as well as panels with external layers being of light concretes.

For regions with extreme influences of rain and wind wall structures with screens are under development.

The weakest point in the system of external enclosing structures of residential buildings is windows. They, in particular, possess low thermal insulating properties and, to a certain degree, they are air penetrating (heat losses through windows with due regard for heat expenditure on warming up filtrating external air reach 50 per cent of the total heat losses in a building). Windows are relatively expensive. In the USSR their production is connected with essential consumption of wood.

In the USSR the improvement of windows in residential buildings is obtained owing to the increase in the number of glazing, the optimization of distance between glass, the perfection of tightness between window elements, the improvement of watertight properties and minimization of wood consumption. Simultaneously, the betterment of window technological properties is under consideration.

In view of actuality of energy problem the new norms in heat engineering adopted in 1979 envisage a wider scope of application for windows with triple glazing as well as the reduction of permissible window air penetration. The new state standard for windows with triple glazing specifies less distances between glazing compared with the previous ones.

It is expected that big yields can be obtained due to mass application of heat reflecting glass in windows. As the result of investigations it has been proved that in windows with double glazing the replacement of one usual glass with heat reflecting one with a stannic oxide film being put on the side of "between-glass" space increases the resistance of the glazed part of the window to heat transfer almost by 1.5 times.

In order to save wood in window manufacturing investigations are carried out in the Soviet Union with the view to find the possibility of using windows without wooden sashes in housing construction.

The experience gained in the field of application of combined roofs in the USSR testifies their comparatively low reliability in operating. At present fully prefabricated roofs with garrets have come into mass building practice. A roof with "warm" garret is the most efficient structure which is a precast vent chamber of static pressure: air from all vent ducts penetrates into garret space and is removed from there through a common exhaust shaft. As a rule, a roof consists of a flat light concrete panel and rolling.

The application of a roof with "warm" garret in residential buildings results in the improvement of exhaust ventilation and the reduction of heat losses, thus, raising a level of comfort in premises of an upper storey. The minimum of vent shafts in roof structure preconditions the reliability of its hydroinsulation.

At present in the USSR the work is under way to create roofs with "warm" garret and with the application of warmer panels without rolling. In this structure roof panels have "raised" joints and are manufactured using watertight and frost resistant concrete. For watertight course mastic and painting coating are practised which are applied under factory conditions. This roof structure allows to carry out assembling practically under any weather conditions. A roof with "warm" garret is regarded as rather perspective.

It is necessary to underline that while improving walls, windows and roofs of fully prefabricated buildings in the USSR a special attention is being paid to thermal insulating properties of the structures.

New building norms envisage higher requirements on thermal insulation of enclosing structures of residential buildings. However, the probability of their faultless work related to thermal technical characteristics is not rated. The specialists stick to the opinion that in future while designing walls, windows and roofs a rating probability of faultless work related to thermal technical characteristics should be introduced. It will allow to balance all thermal calculations of buildings and to regulate the planning of energy expenditure with a view to ensure thermal comfort in buildings.

In accordance with new tasks there are elaborated new methods of thermal technical calculations for structures of residential buildings with the given probability based on sufficiently correct mathematic models of climatic influences upon buildings and heat exchange processes as well as upon the range of values of all calculation indices related to climate and enclosing structures.

It goes without saying that the level of thermal insulation for walls, windows, and roofs in residential buildings determined by thermal technical calculations will be regarded as a minimum necessary level. In case when thermal insulation of structures is to meet higher requirements due to economic considerations, the level of their thermal insulation will be established by economic calculations.

Improvement of the heat insulation of multipane window glazing in residential buildings

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Summary

To improve the thermal resistance of uncoated multipane window glazing the parameters: number of panes, distance between panes and the kind of filling gas can be varied. In the result of experimental investigations in a climatic chamber with specimens in the dimensions 940 x 1290 mm, proposels for further development of uncoated double and triple window panes were elaborated. On behalf of the bending deformations of large sized panes caused, by air pressure difference and production technology, this influence on the thermal resistance was tested, in detail to describe a suitable method for calculation. The influence of steel and wooden frames on the total heat transfer of the window was studied. A further criterion is the condensation on interior surfaces especially in large sized panes in public buildings.

This influence was tested for storey high single and double panes in a three dimensional model with a scale 1 : 2 and different heat loads. By this way the probability of condensation could be determined.

Résumé

Pour améliorer la résistance thermique des vitres il est possible de varier le nombre des carreaux de verre, les distances entre les carreaux et le type de gaz à remplir. Résultant des essais experimentels aux vitres de dimension 940 x 1290 mm dans une chambre de climatisation des propositions sont données pour double et triple vitres nues et remplies d'air et de gaz ayant une meilleure résistance thermique. Etant donné que ce sont surtout les multiples vitres à grande dimension qui révèlent des bombements dûs aux différences de la pression et aux influences de la fabrication, on étudie surtout cette influence sur le transfert de la chaleur et une méthode de calcul appropriée est déduite.

De plus, on a déterminé l'influence des encadrements en bois et en acier sur la transmission de la chaleur des fenêtres. Un autre critère est la condensation sur les faces intérieures des vitres, en particulier dans les vitrages à grand format aux édifices publiques. Cette influence a été étudiée sur vitres simple et double à hauteur d'étage avec intensité de chauffage différente sur maquette tridimensionelle à l'échelle 1 : 2 et la probabilité de condensation a pu être déterminée.

Introduction

The heat insulation qualities of windows can be improved by:
- the improvement of window glazing
- the improvement of frame construction
- the improvement of the built in joints.

A further criterion is the control of ventilation through functional joints of windows to limit ventilation heat loss. This problem is not object of presented paper.

Due to increase productivity and reduce consumption of frame material the double glazed pane is now common in use. This pane has a rather bad heat transfer value (k = 3,1 W/m^2K). Therefore we look for improvement the window panes as a main contribution to reduce heat losses in buildings.

To improve thermal qualities of window panes following methods are applied:
- to arrange optimal distances between panes
- to multiply the number of panes
- to use a special filling gas instead of air
- to provide a metalic coating.

On table 1 thermal properties of normal and coated multiple panes are compiled.

number of panes	distance betw. panes	filling gas	coating	rate of emission ε	permeability of light	k
	mm				%	W/m^2K
2	10	air	-	0,856	70	3,1
2	16	air	-	0,856	70	2,9
2	16	Ar	-	0,856	70	2,7
3	2 x 10	air	-	0,856	65	2,1
3	2 x 10	Ar	-	0,856	65	1,85
2	12	air	gold	0,06	40	1,85
2	16	Ar	gold	0,06	40	1,25
2	16	Ar	gold	0,04	30	1,20

Table 1. Thermal properties of window panes.

Heat transfer in spaces between panes

The different mechanism of heat transfer are characterized by different values of thermal conductivity.

λ_L : only conduction

λ_{LK}: apparent value of conductivity in consequence of conduction and convection

λ_{St}: apparent value of conductivity in consequence of radiation.

For some filling gases the values have been calculated (Fig. 1).

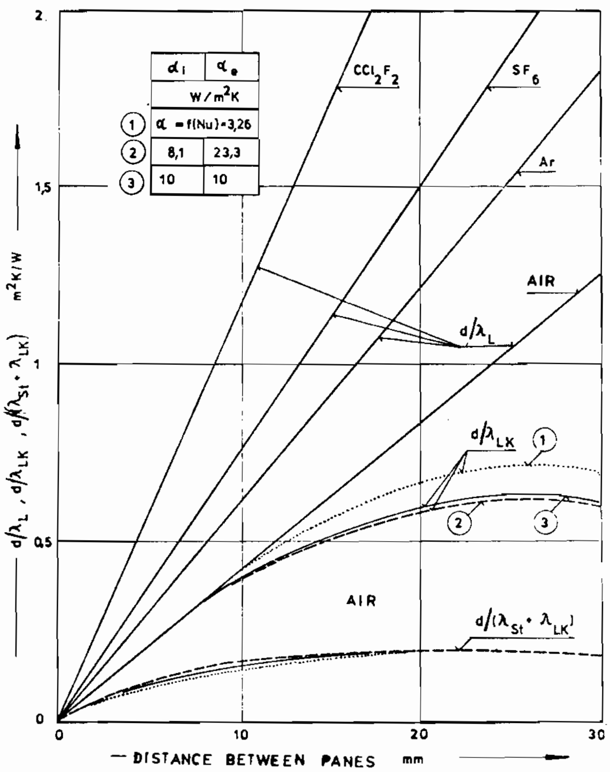

Figure 1. Heat transmission resistance between double panes, thickness: $s_1 = s_2 = 3$ mm $\Delta t = 30$ K, $t_i = 25$ °C.

Considered values of heat transition resistance:

1 as a function of Nusselt value

2 according to regulations

3 according to the conditions in the climate chamber

Following results can be noticed:

- heavy gases like SF_6 or CCl_2F_2 have a considerable higher thermal resistance owing to conduction than air
- the partial resistance d/λ_{LK} depends on the exterior and interior heat transition resistances α as well as on the tendency of gases for convection
- the determinating influence on the thermal resistance is the radiation exchange between surfaces of panes. The course of $d/(\lambda_{St} + \lambda_{LK})$ shows, that is no influence of heat transition on heat transmission in the space
- Considering air spaces, the maximum value of $d/(\lambda_{St} + \lambda_{LK})$ occurs at a distance of 25 mm. Because the maximum is not marked distinctly a distance of panes of 16 mm can be excepted for good thermal properties.

Influence of radiation

Long wawy temperature radiation by heating (wavelength 2,5...80 µm) cannot permeate the glass. It is absorbed and warms up the pane which emits again secundary radiation. The thermal conductivity by radiation λ_{St} can be calculated as follows for double panes:

$$\lambda_{ST} = \frac{10^{-8} \cdot d}{\frac{2}{C} - \frac{1}{C_s}} = \frac{T_1^4 - T_2^4}{T_1 - T_2} \qquad (1)$$

for triple panes

$$\lambda_{ST} = \frac{1}{2} \frac{10^{-8} \cdot d}{\frac{2}{C} - \frac{1}{C_s}} \cdot \frac{T_1^4 - T_2^4}{T_1 - T_2} \qquad (2)$$

d = thickness of lgass

T_1, T_2 = temperature of mutual radiating surfaces

C = radiation capacity of glass

C_s = radiation capacity of a black substance ($C_s = 5{,}77$ W/m²K⁴).

By the carried out experiments the value C was determined to $C = 5{,}06$ W/m²K⁴.

Other authors found values of C in the limits 4,49...5,25 W/m²K⁴. The emission power $\varepsilon = C/S_s$ of normal glass amounts thus: $\varepsilon = 0{,}876$. By goldcating this value can be reduced to $\varepsilon = 0{,}065$.

Influence of convection

The typs of convection are shown in fig. 2. It must be noticed, that the panes can be bended too on behalf on pressure differences.

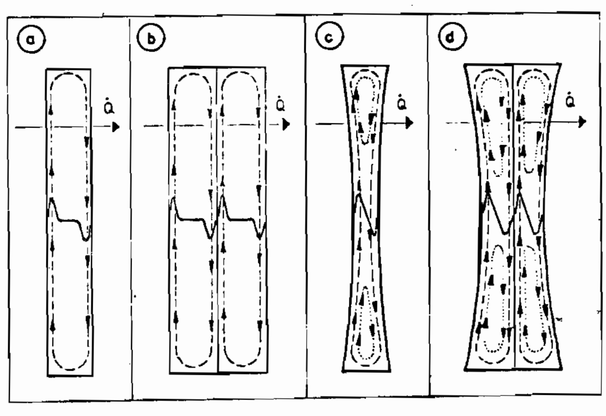

Figure 2. Convection in spaces of parallel and bended window panes.

The carried out experiments confirmed the following relations, elaborated by MULL and REIHER as most suitable /1/.

$$\frac{\lambda_{LK}}{\lambda_L} = 0{,}18\ Gr_d^{1/4} \left(\frac{d}{h}\right)^{1/9} \qquad (3)$$

for $2 \cdot 10^3 < Gr_d < 2 \cdot 10^4$

$$\frac{\lambda_{LK}}{\lambda_L} = 0{,}065\ Gr_d^{1/3} \left(\frac{d}{h}\right)^{1/9} \qquad (4)$$

for $2 \cdot 10^4 < Gr_d < 2 \cdot 10^6$

Gr_d = Grashof- value
d = space distance
h = height of space.

The convection properties of filling gases are different from those of air. In spite of their good heat conduction qualities the maximum of total heat transfer resistance occurs at a smaller distance of panes. Resulting to this effect only small spaces should be filled with gases.

Experimental investigations

The experiments have been carried out on a climatic chamber shown in fig. 3. On the hot side is a heating box to determine the heat capacity. Between the cold and hot side is arranged a partition wall of polystyrene foam.

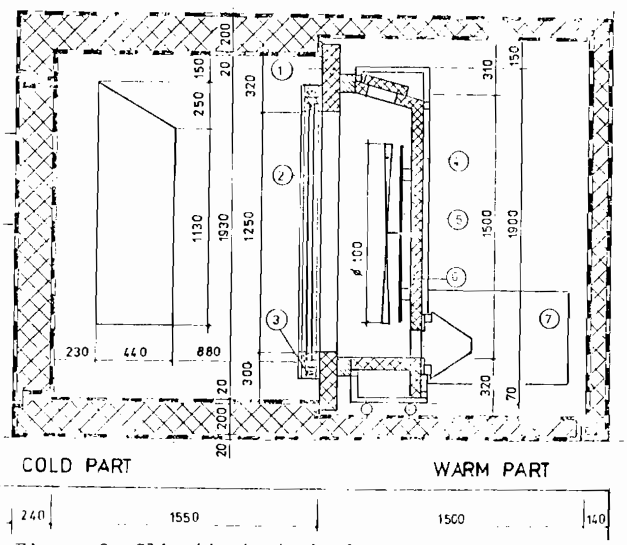

Figure 3. Climatic test chamber

1 partition wall from polystyrene d = 100 mm
2 test object
3 auxiliary frame
4 ventilator
5 heating device
6 heating box
7 air conditioning

The total heat current $\dot{Q}$ consists of three parts:

$$\dot{Q} = \dot{Q}_1 + \dot{Q}_2 + \dot{Q}_3 \qquad (5)$$

$\dot{Q}_1$ = current through the glass
$\dot{Q}_2$ = current through the frame, resp. auxiliary frame
$\dot{Q}_3$ = current through the partition wall

The total heat current can be calculated as:

$$\dot{Q} = \frac{\Delta\vartheta_1 \cdot A_1}{R_1} + \frac{\Delta\vartheta_2 \cdot A_2}{R_2} + \frac{\Delta\vartheta_3 \cdot A_3}{R_3} \qquad (6)$$

$\Delta\vartheta_i$ = difference of surface temperatures K
A_i = relating area m^2
R_i = heat transmission resistance m^2K/W

From this the demanded value R_1 can be calculated.

Following objects have been tested

1. window panes with auxiliary frame
2. window panes within a steel frame
3. window panes within a wooden frame.

The different shares of size are:

	sharing area for pane A_1		frame A_2		partition A_3	
	m^2	%	m^2	%	m^2	%
pane only	1,125	39,06	-	-	1,755	60,94
pane within steel frame	1,08	37,5	0,327	11,35	1,473	51,15
pane within wooden frame	1,049	36,42	0,358	12,43	1,473	51,15

The different installation conditions are shown in fig. 4.

The dimensions of test panes for the variant: pane only were 940 x 1290 mm. The difference of air temperatures in the chamber was 30 K.

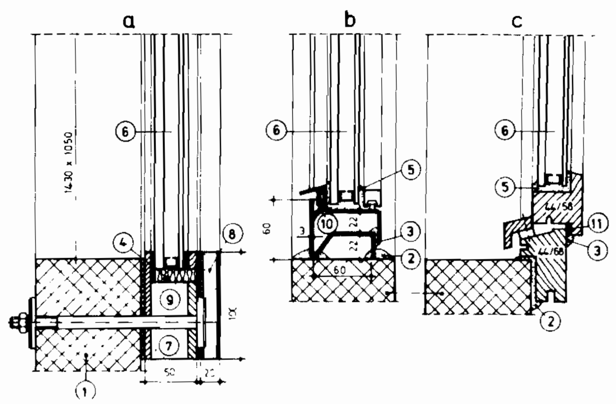

Figure 4. Arrangement of test objects in the partition wall of the climatic chamber

a) pane within auxiliary frame
b) steel frame
c) wooden frame

1 polystyrene foam 100 mm thick
2, 3, 5 plastic sealing
4 mineral wool
6 double pane 5,5/16/3 mm
7 polyurethane foam 50 mm thick
8 fibre plate
9 PVC-bolt M/2 x 160
10 neoprene sealing
11 rubber foam

Influence of deformations of panes

The bending of panes results from pressure differences and from the dead load of the panes if they are assembled in horizontal position.
The bending effect is shown in fig. 5.
The bending can be calculated by aid of the membrane value α, which for symmetrical double panes can be calculated as:

$$\alpha = \frac{E\,s^3}{2\,K_f \cdot b^4} \qquad (7)$$

α = membrane value Pa/mm
$K_f = \beta \cdot 12(1-\mu^2)$ factor of shape
E = modul of elasticity Pa
b = length of the short side mm
s = thickness of glass mm

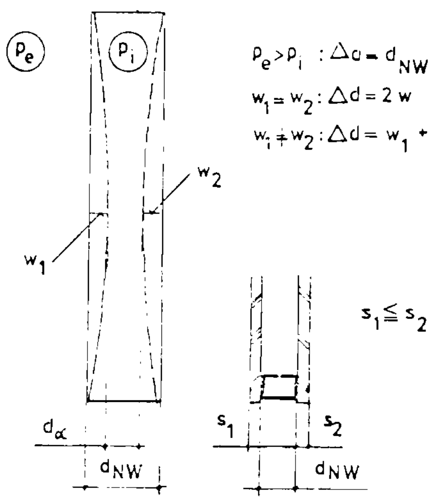

Figure 5. Bending of double panes

The total bending can be determined as follows:

$$\Delta d = d + \frac{p_o}{2\alpha} - \sqrt{d^2 + \frac{2p_o}{\alpha}\left[\frac{p_o}{8\alpha} + (d+0{,}5\Delta d)\left(1-\frac{p_w}{p_o}\right)\frac{T}{T_o} - \frac{d}{2}\right]} \qquad (8)$$

α = membrane value
$p_o = 9{,}81 \cdot 10^4$ Pa (air pressure)
$p_w = 1500$ Pa (partial vapour pressure)
d = nominal width of space
d_o = deformation resulting from production
T_o = temperature during production K ($\sim$ 295 K)
T = real temperature during usage.

If geometrical and mechanical properties are constant, the total bending depends on the distance between panes, the temperature of usage and the pressure differences. For some selected double panes the total bending has been under following conditions calculated:
h = 1290 mm, b = 940 mm, h/b = 1,37, K_f = 0,0771
$E = 7 \cdot 10^{10}$ Pa, p_w = 1500 Pa, $p_o = 9{,}81 \cdot 10^4$ Pa,
d_o = - 1 mm.

type of pane	membrane value α Pa/mm	total bending Δd mm		
		T		
		283 K	278 K	273 K
3/6/3	15,70	1,60	1,79	1,97
3/10/3	15,70	2,05	2,36	2,68
6/10/3	27,91	2,04	2,36	2,67
3/16/3	15,70	2,70	3,21	3,73
6/16/3	27,91	2,69	3,21	3,72
6/24/3	27,91	3,56	4,33	5,29

The bending effect results a reduction of heat transfer resistance of 5...10 %.

Influence of window frame

The relations, shown in fig. 6, are experimental results with a window size 1430 x 1050 mm.

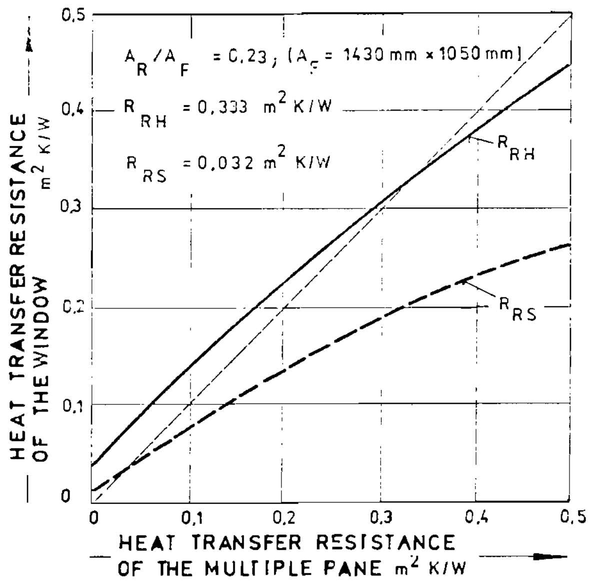

Figure 6. Heat transfer resistance of windows with different frame materials.

R_{RH} = heat transfer resistance of a wooden frame
R_{RS} = heat transfer resistance of a steel frame.

Windows with steel frames in the mentioned dimensions have a reduced resistance of 30 % in average in relation to those with wooden frames. If are applied panes with higher heat transfer resistance it is necessary to use frames with higher thermal qualities too.

Conclusions and development of window panes

The results of accomplished experiments are shown in fig. 7.

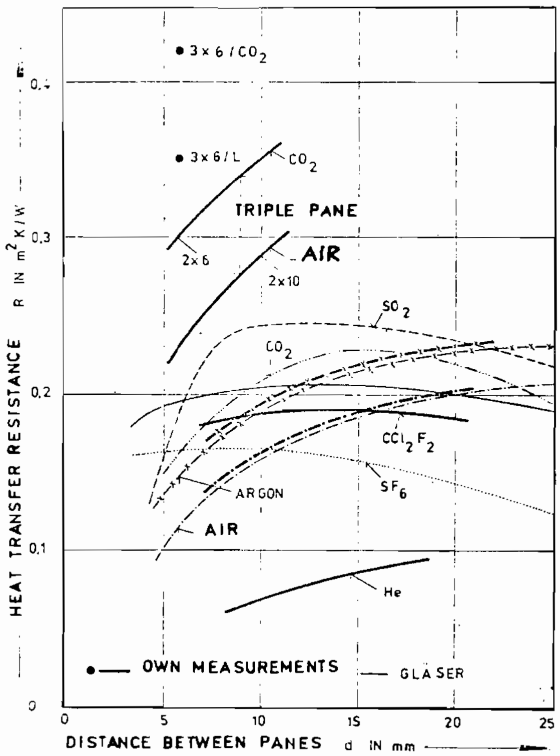

Figure 7. Heat transfer resistance of air and gas filled multiple window panes.

It can be seen, that some filling gases, for instance SF_6, CCl_2F_2, SO_2 have a maximum near to 6...8 mm space width. Therefore they are used fortunately for triple panes with small distances of panes.

Argon and CO_2 have a similar behavior like air. They are suitable for spaces to 15...20 mm.

Lightweight gases like Helium or hydrogen have worse thermal properties than air, but they can be favourably applied for improvement of sound insulation.

In the following table are scheduled some results of the investigations. It is evident that the Argon filled triple pane 3/10/3/10/3 has the best thermal quality. Production and usage are not connected with special problems. Measured and calculated values show a good coincidence. The measured values are due to the bending effect 10 % lower in average than hitherto ascertained. In respect of this effect the equations (3)(4) have been corrected:

$$\frac{\lambda_{LK}}{\lambda_L} = 0{,}192\,(Gr_{d_m} \cdot Pr)^{1/4} \left(\frac{d_m}{h}\right)^{1/9} \qquad (9)$$

for $1{,}5 \cdot 10^3 < (Gr_{d_m} \cdot Pr) < 1{,}5 \cdot 10^4$

$$\frac{\lambda_{LK}}{\lambda_L} = 0{,}071\,(Gr_{d_m} \cdot Pr)^{1/3} \left(\frac{d_m}{h}\right)^{1/9} \qquad (10)$$

for $1{,}5 \cdot 10^4 < (Gr_{d_m} \cdot Pr) < 1{,}5 \cdot 10^6$

structure of panes	filling gas	heat transfer resistance R • m²K/W		
		MULL REIHER /1/	calculated values	measured values
3/10/3	air	0,165	0,162	0,161
3/10/3	Ar	0,189	0,181	0,179
3/10/3	He	0,059	0,063	0,069
3/10/3	CCl_2F_2	0,191	0,186	0,174
3/6/3/6/3	air	0,261	0,235	0,229
3/6/3/6/3	CO_2	0,329	0,307	0,296
3/10/3/10/3	air	0,327	0,294	0,287
3/10/3/10/3	CO_2	0,389	0,356	0,351
3/10/3/10/3	Ar	0,373	0,367	0,362

$$d_m = d - \frac{\Delta d}{2}$$

d_m = mean width of space

Gr = Grashof value

Pr = Prandl value.

Condensation on window panes

Condensation on panes depends on the interior climatic conditions and the temperature of surfaces. The room climate is characterized by temperature a humidity of air and the current conditions of heating and ventilation. Condensation must be mainly avoided at large sized window panes in public facilities like gastronomies. In respect of this condition, experiments have been carried out with a spatial test modal in the scale 1 : 2, in which the thermal properties of 3300 mm high single and double glass panes were studied. In the area of parapet was arranged a heating equipment which could effect the necessary impulse to deviate the cold falling stream in a height of 1300 mm. This criterion was fixed to avoid discomfort conditions near to the interior pane surfaces. This mechanism shows that condensation and ventilation current conditions at the surfaces of window panes are in a narrow correlation. The results of experiments are shown in fig. 8.

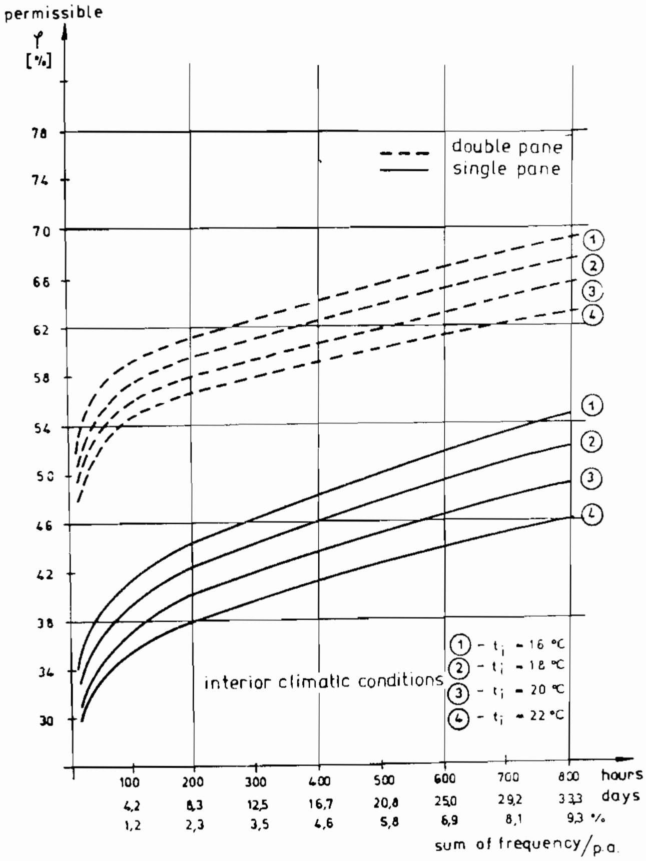

Figure 8. Occurence of condensation on 3300 mm high undisturbed panes /4/.
single pane: 6 mm thick
double pane: 6/12/6 mm thick

It can be seen that the permissible air humidity may be 16..18 % higher, if double panes are used, the same probability of condensation occurence supposed.

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Energy savings by means of improved thermal insulation of the building envelope

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Summary

In view of rising energy prices, improvements of the thermal insulation of the building envelope seem to be an economic problem rather than a technical one. The economy of certain measures is much different in existing buildings and new buildings. An important contribution to energy economy in buildings is the passive utilization of solar energy as well as ventilation only when required.

Résumé

Economies d'énergie au moyen d'une isolation thermique améliorée de l'enveloppe de bâtiment

Etant donné que les prix d'énergie augmentent de plus en plus, les améliorations de l'enveloppe de bâtiment semblent être plutôt un problème économique qu'un problème technique. La rentabilité de certaines mesures est différente en bâtiments existants et nouveaux. Pour faire des économies d'énergie, l'utilisation passive de l'énergie solaire et une ventilation suivant les besoins y contribuent beaucoup.

The loss of energy due to transmission through the components of the building envelope is an important factor in the total energy balance of a building. The heat transmission losses through the building envelope are about 80 % of the total heat loss in old buildings (with less thermal insulation) and about 60 to 70 % of the total heat loss in new buildings (with better thermal insulation).

Thus it pays to improve thermal insulation of the building envelope. The extent of improvement depends on the costs accruing and on the possibility of amortization of the improvement measures. Apart from a few special problems*, it can be stated on principle that the thermal improvement of components of the building envelope is no technical problem but an economic one. Quite a number of investigations [1] show that the improvement of thermal insulation of new buildings can more easily be financed than subsequent improvement of old buildings. This means that in case of old buildings measures of different kinds, i.e. improvements of heating equipment and heating control device, should be given preference over structural improvements of the building envelope. In detail, the following points are to be stated:

1. Existing buildings

For reasons of cost and as a matter of principle, there should first of all be taken measures regarding the heating equipment. If, however, measures are taken to improve the building envelope - amortization of which should be examined very carefully - priorities should be established in the following order:

Priority 1. Replacement of single-glazing by double-glazing, utilization of the old window frame as a blank frame.

Priority 2. Improvement of thermal insulation of the cellar ceiling by means of thermal insulating layers to be fixed from below.

Priority 3. Improvement of thermal insulation of the roof by means of heat insulating layers to be fixed from the loft or between the rafters.

Priority 4. Improvement of thermal insulation of the outside walls; for quite a number of reasons, the following structures can be recommended:

outside insulation	(with and without ventilation)
inside insulation	(with attention to water vapour diffusion, sound and fire protection)
core insulation	(with loose fillings or insulating foams)

2. New buildings

Quite a number of investigations on economy [2] [3] [4] [5] have shown that up to now building owners have only taken account of the investment costs incurred at the time of construction, disregarding the operating costs incurred subsequently during decades. By calculation of an economically optimal thermal insulation including investment and operating costs, the building owners' mind will have to be changed.

The economically optimal thermal insulation of components of the building envelope is no "constant factor" but a changing one, according to the rising energy price. This would mean that

-with energy price rising, either the components of the building envelope would have to be improved continuously, making any new building an "old building" requiring steady modernization;

-alternatively, calculations for new buildings to be built should be based on the (higher) energy price to be expected in future.

* Such special problems, which require further research and development work, are e.g.:
-Foam sealing and infilling technics of cavity walls (core insulation, i.e. insulation in the space of cavity walls)
-Questions of fire protection for organic insulating materials
-Protection of outside insulating layers against driving rain
-Gas fillings of insulating glass etc.

Starting from an energy price of 15 DM/GJ, the following values of specific heat resistance of the building envelope are economically optimal in Central European climate conditions:

outside wall: 2 to 3 m^2K/W
cellar ceiling: 3 to 4 m^2K/W
roof: 4 to 5 m^2K/W
windows: double-glazing

For territories with cooler climate, the values should be higher; for territories with milder climate, the values should be lower.

Further, in new buildings, south orientation of windows should be preferred. In Central Europe, due to the low position of the sun in winter, south orientated windows gain high radiation intensities, thus being excellent "solar collectors" [6] [7] [8] working gratuitously because south orientated windows are available at any rate for other reasons. This kind of "passive solar technology" should be given stronger support in future. Solar energy research so far has paid attention only to active systems.

Besides, the ventilation of buildings, strictly speaking the uncontrollable infiltration of buildings through window joints, as well as the users' behaviour (which may be influenced!) with regard to ventilation play an important part, as far as energy economy is concerned. The construction of the building envelope, especially of the window joints, should be so tight that ventilation takes place only when required [9] [10], either by natural, yet better controllable ventilation [11] or by mechanical ventilating equipments; in case of users being absent, the building envelope should be practically tight.

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Reduction of heat losses in dwelling buildings by the application of new research knowledge

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Summary

In the paper it is shown, by which method an approch towards heat-losses reduction was made with the aim to reduce the thermal energy consumption.

The system for peripheral precast units quality control is given as well as the knowledge obtained at the application of the thermovision metod in the quality control of the thermal insulating layer of peripheral precast units.

Résumé

Dans l'article est referé sur manière d'inhibition de disparaitre du chaux des batiments pour diminuer l'energie.

Il est encore referé sur le systéme de la contrôle, surveilleance de la qualitée des mures préfabriqués. Et sûrtout sur la contrôle dans la domaine chaux-technique. Il sont constatées les connaisants pratiques avec la metode de la thermovision sur la qualité des mures exterieures.

Introduction

It is assumed that approx. 30 % of the entire produced energy is consumed for dwelling buildings heating. To reach an economy in this region means a high effect from the social viewpoint. Therefore in Czechoslovakia an approach was made towards an increased care of the peripheral envelope of buildings as an important means for ensuring heat economy.

Ensuring Heat Losses Reduction in Buildings

Practical measurements in the dwelling construction showed that the actual heat consumption for heating flats usually exceeds the 1.5-multiple of the projected consumption. The quality of the peripheral envelope of buildings participates significantly in these heat losses.

To ensure a reduction of heat losses of buildings the efforts is concentrated mainly to the following activities:

- quality increase of the produced peripheral precast units,
- quality increase of mounted peripheral envelopes,
- requirements increase towards the thermal resistance of peripheral constructions,
- all of the new type projects are approved by central organs, only after this approval they can be currently applied.

In the interest of peripheral precast units quality increase in the end of the sixties the obligatory evaluation of peripheral precast units was introduced that will be described in the subsequent chapter.

First, for a more efficient control of mounted peripheral envelopes, an effective, and mainly non-destructive control method is missing. This shortcoming was removed by the introduction of the thermographic method of quality control to the peripheral envelopes of buildings. Even if this method can not be used in a large scale, it still gives the possibility of a random quality control of performed works at least. Some data on the method's application are presented in a separarate chapter.

The requirement to reduce the heat consumption for heating flats lead to the determination of a limited heat consumption for the so-called normal flat with the enclosed space of 200 m^3 in the amount of 9.3 MWh yearly. In the intentions of this requirement, immediately an increase of requirements to the thermal resistance of peripheral envelopes was demanded from 1979 on and simultaneously considerably higher values of the thermal resistance were determined that must be met by the peripheral envelopes of all the buildings being exploited after December 31st. A survey of these values is presented in Table 1.

	Type of peripheral structure	Smallest permitted thermal resistance R_N /m^2kW^{-1}/ at the temperature of environmental air t_e /°C/ -15	-18	-21
vertical	wall structure	0,95 /0,55/	1,0 /0,61/	1,10 /0,67/
horizontal	plane roof structure	1,80 /0,91/	1,95 /1,00/	2,15 /1,10/
horizontal	roof structure above an open passage and on freely standing pillars	1,80	1,95	2,15

Tab.1. The smallest permitted thermal resistance of peripheral structures.

In parantheses reduced values are given that are permitted maximum for one outer wall of the room and it is possible to use such peripheral envelopes /or ceiling constructions/ until December 31st, 1983 and for brick walls produced in the traditional way until December 31st, 1985.

The given period of several years gives the possibility to reconstruct the entire production basis for the production of precast units for peripheral envelopes with satisfying thermal insulation properties. It is necessary to state that even presently peripheral envelopes of several construction systems satisfy the increased requirements valid from 1984.

It appears that the most advantageous are reinforced concrete peripheral envelopes of the sandwich type that have a thermal insulating layer with the thickness of 8 cm. Amongst unilayer peripheral envelopes, cellular concrete precast units with the thickness of 30 cm are suitable. If ceramic peripheral precast units have to be of an acceptable thickness, they must be combined with an insulating layer with a thickness of approx. 5-6 cm. The new requirements exclude the application of unilayer peripheral precast units from slag-pumice, expandite and also from keramzit /provided that its volume mass will not be reduced substantially/.

To prevent the repeated occurence of defects in the constructions of dwelling buildings, all of the new type projects are subjected to an approval. In this approval the knowledge is applied, obtained during quality control of peripheral envelopes on experimental objects as well as the knowledge obtained during the obligatory evaluation of peripheral precast units of similar construction systems that are currently produced.

System of Quality Control for Peripheral Precast Units

An increased interest towards the quality of peripheral precast units appeared already in the late sixties, even if it is necessary to state that this interest was not induced by the effort of thermal energy economy, but rather by the necessity to remove several undesirable phenomena /such as peripheral envelope leakage, mildew occurence/ in the dwelling construction.

For ensuring the quality of peripheral precast units, already in those days valid regulations existed that included the necessity to perform a conclusive test at the production inception of new peripheral precast units by a specialized institute, and further a systematic quality control of produced precast units, performed by the producer himself. Sufficient demands towards the quality of the accepted products were also supposed to be present from the part of the purchaser. However, it appeared in practice that all these measures were insufficient to ensure the demanded quality of precast units. Therefore in the early 1970-ties the obligatory evaluation of peripheral precast units was introduced in the framework of State Testing.

The Process of Precast Units Obligatory Evaluation

The obligatory evaluation is a special type of testing, performed by an objective authority - a State Testing Institution. Those products that are advertised /appointed/ for obligatory evaluation, must be booked for obligatory evaluation by the producer, from each precast units factory, in the State Testing Institution /in the case of omitting the booking, the producer is charged by a high financial penalty/.

The following types of peripheral precast units were appointed for obligatory evaluation:

- reinforced concrete peripheral precast units - laminated sandwich precast units,
- cellular concrete peripheral precast units,
- ceramic moulded blocks peripheral precast units,
- light-weight aggregates concrete peripheral precast units.

The producer is obliged to book only those of the products that are produced in an amount of 400 m^3 of precast units per year at least.

In the process of obligatory evaluation, the employees of the State Testing Institution /for the territory of Slovakia and the construction branch the State Testing Institution is the Construction Engineering and Testing Institute/ check first the completeness of the production documentation and of the data in it, the works standards on the peripheral precast units, the technological equipment for the production of precast units as well as the level of the products quality control, performed by the production enterprise.

Usually in one enterprise peripheral precast units are produced on one material basis only, or of one type only, for example, sandwich-type peripheral precast units, or peripheral precast units from cellular concrete for one construction system of dwelling objects or civic amenties. For the purposes of obligatory evaluation and for assessing their quality they represent one group of products /consisting of several dozens of various separate types of peripheral precast units/.

A further phase of the obligatory evaluation that passes in the space of time from 3 to 6 months, is the performance of tests to determine the properties of peripheral precast units. On the despatch store, precast units that are subjected to the tests are chosen at random. An example of the investigated properties for peripheral precast units is given in the Table 2.

Property group		Property	Permitted % of non-conforming products
Main	A	Thermal-engineering properties	0
		Bearing capacity	0
		Security of suspending elements	0
	B	Appearance	10
		Weight	5
		Concrete strength on the products	5
		Steel properties	5
		Surface layer hold on the substrate	5
Secondary	A	Dimensions	10
		Product designation	10
		Shape	10
		Surface suitability for final treatment	10
		Concrete strength on testing samples	5
		Location of mounting facilities of the precast units	10
		Location of throughs in the precast units	10
	B	Precast unit resistance at the transport	Is evaluated on the basis of determined knowledge
		Level of production technology and production control	
		Precast unit resistance against weather influences	
		Inpermeability for water vapours	

Table 2. Investigated properties at the evaluation of peripheral precast units and the permitted per cent of non-conforming products.

The properties enumerated in this table are completed for the separate types of peripheral precast units by the properties, which characterize the basic materials, used in the production of the respective precast units.

For reinforced concrete laminated peripheral precast units the complementary properties are:

- the thickness of the thermal insulating layer,
- the volume weight of the thermal insulating material;

for cellular concrete peripheral precast units:

- the compressive strength of the cellular concrete /in the dried state/,
- the volume weight of the cellular concrete /in the dried state/,
- the heat conductance,
- the tensile strength at bending of the cellular concrete /in the dried state/,
- the protective layer against corrosion;

for peripheral precast units made from concrete with light-weight aggregates:

- the compressive strength of the light-weight concrete tested on cubes,
- the compressive strength of the light-weight concrete tested on cylinders,
- the volume weight of the light-weight concrete /in the dried state/,
- the protection layer against corrosion;

for peripheral precast units from ceramic moulded blocks:

- the compressive strength of the ceramic moulded blocks /in the dried state/,
- the volume weight of the ceramic moulded blocks /in the dried state/,
- the compressive strength of mortar on test cubes.

It is necessary to state that some of the properties comprise a number of evaluated parameters. For example, the property "shape" comprises also the observation of the shape of the draining slots, the formation of joining profiles etc.

All of the tests are performed on 20 precast units at least /except loading tests and thermal-engineering properties that are tested on 3 samples at least/. Every investigated property is compared with the requirements of the respective standards, project documentation or other binding regulations.

According to their significance for the resulting quality of the product, the properties are divided into four groups:

- main properties - group a,
- main properties - group b,
- secondary properties - group a,
- secondary properties - group b.

On the basis of test results the per cent of not complying products in the given testing assortment is determined for each of the properties. From the number of not complying products in the random sample experimentally determined in such a way, the rejection coefficient in the entire standard population of the products is deduced under the assumption that the statement: "The property is not complying in the standard population" is stressed by the error risk ω_2, and the statement: "The property is complying in the standard population" is stressed by the error risk ω_1. The values of ω_1 and ω_2 are changing in dependence on the group of properties, for example, for the main properties, group a there is $\omega_1 = 10$ % and $\omega_2 = 5$ %.

Some of the properties are evaluated conventionally, for example, the thermal-engineering properties and the carrying capacity; at the tests all of the tested samples must comply.

For each property /apart from those ones that are evaluated conventionally/ the permissible per cent of the not complying products is given for the more rigorous, the basic, as well as the softer level of quality /in Table 1 the per cent values are given for the basis level of quality/.

The entire evaluation process is concluded by a report, where all test results are given, as well as determinations of the production technology level and production control level, further all of the other data completing the image of the products quality level /for example, the volume of claims, complaints towards the quality of products received by the State Testing Institute etc./. The report is submitted to the producer for giving his viewpoint and, in the same time, it is submitted to the all-state evaluation comission for an examination and compiling a proposal for granting the respective quality grade.

The products can be incorporated into the following quality grades:

- the 1st quality grade - the product corresponds to the quality requirements even of a more severe quality level and it is comparable with the best products of foreign origin;
- the 2nd quality grade - the product corresponds to the quality requirements of the basic quality level and fulfills the requirements of the relevant Czechoslovak standards;
- the 3rd quality grade - the product corresponds to the quality requirements of a reduced quality level, not all of its properties comply with the requirements of the relevant Czechoslovak standards, but by its use no threat of its functional properties in the finished construction arises /its reduced quality can, however, cause the need of supplementary work on the construction etc./.

If the product does not comply even with the quality requirements on the reduced quality level, the granting of a quality grade is denied, this means practically an interdiction of the production for such a product.

The given quality grades are valid for a period of time that is determined at the granting of the quality grade, however, for 3 years maximum. After quality grade validity elapsing the entire process of evaluation is repeated, either in full extension, or certain properties that during the initial evaluation were found to be highly complying /for example the bearing capacity of reinforced concrete sandwich type precast units/ are verified only by complementary tests /for example the bearing capacity of precast units by the aid of strength and homogeneity of concrete reinforced concrete sandwich type precast units/; emphasis is given to properties that were not complying during the initial evaluation as well as to those ones that could have become worser after a certain period of time.

The granted quality grades are also connected with specific financial preferences /in the case of the 1st quality grade/ and with a financial penalty /when granting the 3rd quality grade/. The producer is interested in achieving the best quality grade also for the purposes of fulfilling the requirements of the plan. In the Czechoslovak Socialist Republic a verification takes place of the complex system of quality control in the framework of which for each of the producers the contingent of products is appointed, which must have such a quality as to fulfill the requirements of granting the 1st quality grade from the entire volume of issued products.

To ensure that no quality decrease of the products arises in the period between two evaluations, the State Testing Institute performs random quality control tests 1-2-times throughout the year. If a quality decrease is detected, the State Testing Institute administers a decrease in the granted quality grade.

Experiences from the Obligatory Evaluation of Products

Hitherto knowledge from the evaluation shows that while at the first evaluation usually worser results are obtained in the products quality, a considerable improvement takes place in the quality of the evaluated products at the further evaluation. A very important phenomenon is the fact that in the case of granting the 3rd quality grade the producer performs immediate corrective measures to remove the shortcomings of the products, and he tries hard to obtain at least the 2nd quality grade in the shortest possible time. Under the influence of the obligatory evaluation the producers increased also their care for the production equipment, its maintenance and renowal; the technological discipline in precast units production increased as well. Gradually the production of single layer peripheral precast units from concretes with lightweight aggregates /for example from slag concrete, pumice concrete, keramzit concrete/ was reduced, as these ones reached a lower quality level most frequently. The contingent of reinforced concrete sandwich type peripheral precast units and cellular concrete completed peripheral precast units was increased.

Application of the Thermographic Method for the Control of Peripheral Precast Units Quality

The widest distribution among the peripheral precast unit types obtained in the last 70 years the sandwich precast unit composed from 2 layers of concrete and a thermal insulating layer from polystyrene with a thickness of 6-8 cm. First, for the quality control of these precast units, it was possible to use only random destructive test methods by drilling a series of control cylinders. The disadvantages of this control consisted in the high laboriousness and in the low probability to detect failures in the product. Therefore the second half of the seventies was the beginning of an approach towards applying the thermographic method /based on the investigation of surface temperatures of the tested bodies/ for the quality control of the peripheral precast units. Measurements were made partly on finished objects /as a rule in the heating period to obtain a better temperature difference/, and partly on seperate peripheral precast units directly in the precast units production enterprise. These tests helped to detect the places of thermal bridges arising in sandwich type precast units /for example, the gap of 3-5 mm width between the separate polystyrene plates, which is filled with concrete during concreting/ that were afterwards proved also by destructive tests. Based on these statements a considerable increase was obtained in the technologic discipline in the course of inserting the thermal insulating layers. As for the realization of test by the use of the thermographic method it is necessary to produce a temperature difference between the inner surface of the precast unit and the outer one, all of the production works must provide a control chamber. Such a chamber contains heating elements and one side of it is open - onto this side the tested peripheral precast unit is attached, in such a way the chamber is closed. It is assumed that in the eighties this thermographic method will be used for obligatory evaluation tests of peripheral precast units as well - as a defectoscopic method. In the same time efforts are made to apply the thermographic method for a quantitative judgment of the determined failures on the basis of obtained thermograms also.

Conclusions

It is assumed that the increase of requirements towards the thermal resistance of peripheral envelopes of buildings will result in a reduction of energy consumption for heating by approx. 10-20 %. The execution of the obligatory evaluation of peripheral precast units will provide their permanent quality for ensuring the required quality of the peripheral envelope from the thermal engineering aspect mainly, however, for fulfilling the other requirements towards the peripheral envelope as well.

The use of the new control method - the thermographic quality control of the peripheral envelope - provides the possibility to reveal defects in their production and to ensure promptly their removal.

L'expérience belge en matière d'isolation thermique par injection de mousses isolantes dans les murs creux

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Résumé

Cette communication traitera de l'expérience belge en matière d'isolation thermique par injection de mousse d'urée-formaldéhyde dans la lame d'air des murs creux.

Elle décrira les recherches qui ont été menées, en Belgique, pour étudier le comportement aux conditions climatiques des maçonneries dont l'espace creux est rempli d'isolant. Il sera donné les caractéristiques des murs aptes à recevoir cette injection.

Bénéficiant d'une prime lors des premières mesures gouvernementales prises en vue de l'amélioration de la qualité thermique des habitations, et étant constituée de produits et procédés nouveaux, il était obligatoire pour cette forme d'isolation d'obtenir l'agrément technique dans la construction. Par cet agrément, délivré par l'Institut national du logement, les utilisateurs s'entourent de certaines garanties.

Il sera fait état des conditions de délivrance de cet agrément technique et de la procédure de contrôle qui s'y rattache.

Les résultats des mesures faites sur des échantillons prélevés durant l'exécution des travaux d'isolation thermique des murs creux seront analysés statistiquement.

Enfin, l'importance et l'organisation du marché seront examinées.

Summary

This paper will deal with the Belgian experience on the thermal cavity wall insulation by injection of ufoam urea formaldehyde in the sheet of air.

It will describe the researches which have been done, in Belgium, in order of studying how the maconries of cavity walls filled with a thermal insulant behave towards climatic conditions. It will also give the characteristics of the cavity walls fit to receive the filling by injection.

The technical agrément in the building was binding on this form of insulation profiting by subsidy on the first measures of the government to encourage the thermal insulation of dwellings and consisting of new products and proceedings. By this agrément, delivered by the National Institute of Housing, the users obtain safeguards.

It will note the conditions of delivery for this technical agrément as for the control which is attached to it.

It will statistically analyze the results of the measures of the sampling during the ufoam U.F. cavity wall insulation.

Finally, the importance and the organization of the market will be examined.

1. Historique

En Belgique, le remplissage de la lame d'air des murs creux avec des matériaux isolants a été un sujet fort controversé.

En règle générale, la conclusion, dans le passé, était que l'amélioration de l'isolation thermique, obtenue avec un tel procédé, ne compenserait pas les risques supplémentaires de pénétration d'humidité dans l'isolant et dans le mur intérieur. Cependant vers 1973, suite à l'évolution de certains procédés de remplissage, au relèvement des exigences en matière d'isolation thermique, la question a été réexaminée.

En août 1975, paraissait un arrêté royal concernant l'octroi d'une prime en vue de l'amélioration thermique des habitations et de leurs équipements qui retenait cette forme d'isolation dans sa nomenclature des procédés réduisant la consommation d'énergie.

Au sein de l'Union belge pour l'agrément technique (U.B.A.t.c.), l'Institut national du logement et ses partenaires (Bureau Seco et le C.S.T.C. - Centre scientifique et technique de la construction) se trouvaient confrontés à la difficulté de formuler rapidement un avis relatif à la qualité des matériaux et des techniques d'injection avant de pouvoir délivrer un agrément technique définitif qui permette à cette branche d'activité de se développer.

2. Recherches

De 1975 à 1979, deux biennales de recherches furent entreprises par le CSTC.

2.1. Objectifs

- établir les exigences de qualité que doivent présenter les isolants thermiques et les murs extérieurs en maçonnerie dans l'espace creux desquels ces isolants sont introduits;
- établir des critères de comportement du complexe mur-isolant vis-à-vis des facteurs climatiques tels que pluie, vent et gel.

2.2. Essais

Ils ont porté sur les matériaux et sur des murs d'une demi brique, d'une surface de 1.20 m2, comprenant les paramètres de base suivants :

-3 briques de porosité différente

Briques (origine)	Dimensions (mm)	Masse volumique (kg/dm3)	Porosité totale exprimée en masse d'eau % absorbée sous vide (pression résiduelle 20 mm Hg)
Campine	180 x 85 x 50	1,994	12,19
Littoral	190 x 90 x 65	1,615	25,22
Campagne	190 x 90 x 57	1,664	21,95

- 1 peinture destinée au mur construit au moyen de la brique la plus poreuse
- des isolants thermiques. Jusqu'à présent, on ne connait les résultats du remplissage du creux du dispositif expérimental que pour les isolants injectables à base de mousse d'urée-formaldéhyde.

2.3. Interprétation des résultats

A partir des résultats obtenus et des observations effectuées, on peut déjà émettre certaines conclusions concernant l'opportunité de remplir la coulisse des murs creux au moyen d'un isolant thermique injectable.

2.3.1. La mousse d'urée-formaldéhyde présente le risque de formation de lacunes de remplissage ou poches dans lesquelles l'eau ayant traversé la maçonnerie peut s'accumuler. Si ces poches intéressent toute l'épaisseur de l'isolant, elles créent un "pont-d'eau" entre le mur extérieur et le mur intérieur, avec comme conséquence une humidification du mur intérieur.

L'existence de ces poches est due à des accidents d'injection que la connaissance et le respect des conditions de mise en oeuvre de ces isolants doivent permettre d'éviter.

2.3.2. Après imprégnation d'eau du mur extérieur, celui-ci sèche beaucoup plus lentement lorsqu'il est isolé par la mousse U.F.

2.3.3. La mousse U.F. peut présenter un retrait de séchage assez important (8%), qui dépend des conditions dans lesquelles s'effectue le séchage. Plus celui-ci est rapide, plus le retrait est important, entraînant parfois la fissuration de la mousse.

Il est donc nécessaire de rechercher des formulations peu sensibles au retrait et d'effectuer les injections dans des conditions favorables de température et d'humidité.

Le retrait entraînant même, des fissurations n'influence que d'une façon négligeable le coefficient de conductivité thermique(λ variant de 0,034 à 0,037 W/m.K).

2.3.4. Quel est le risque de pénétration d'eau dans l'isolant avec humidification de celui-ci ?

La mousse U.F. est légèrement capillaire, en général d'une capillarité très inférieure à celle de la majorité des matériaux.

En outre, l'eau liquide ne reste éventuellement à son contact que pendant un temps limité - celui de la pluie - pendant lequel l'eau ruisselle sur la face intérieure du mur extérieur.

La proportion d'eau absorbée, dans ces conditions reste encore à déterminer.

Toutefois, le retrait a l'avantage de décoller la mousse des parois maçonnées. Cependant, des plages d'ahérence peuvent subsister entraînant des risques d'humidification qui pourraient encore s'aggraver si la mousse présente une cavité à cet endroit.

2.4. Recommandations d'application

2.4.1. Le mur creux injecté d'isolant voit ses performances modifiées en ce qui concerne l'élimination de l'humidité par la suppression du creux du mur.

Etant donné que la pénétration de l'eau dépend d'une série de paramètres tels que la direction et la force du vent, la pluviosité, le relief du terrain, la hauteur du bâtiment, l'orientation du mur, la porosité des briques de parement, la qualité de la maçonnerie, etc... il faut éviter de réaliser l'injection dans les cas suivants :

-murs dont l'état est tel que des rentrées notables d'eau sont probables;

-immeubles ou parties d'immeuble où le risque d'une forte pénétration d'eau existe par suite de leur exposition, sauf si une protection extérieure supplémentaire peut être prévue;

-murs creux dont la paroi intérieure est humide à cause de l'humidité ascensionnelle, en raison d'une mauvaise protection de la partie supérieure des murs ou d'une mauvaise conception du mur.

Toutefois, au cas où cette humidité résulte de condensation superficielle temporaire, l'injection peut être admise après élimination des risques de condensation grâce à l'augmentation des températures de surface découlant de l'accroissement de la résistance thermique du mur.

2.4.2. La fragilité au gel des briques de parement risque d'être augmentée par l'apport d'un isolant à peu de distance du parement. Il est recommandé d'éviter l'injection dans les murs creux dont le parement a donné lieu à réparation suite à des dégâts dus au gel.

2.4.3. Enfin, comme une rentrée d'eau accidentelle dans le creux est toujours possible, il faut éviter l'injection dans les murs creux dont le parement empêcherait l'évacuation de la vapeur d'eau comme par exemple, ceux qui sont pourvus de parement en briques émaillées.

2.4.4. Cependant, si des mesures particulières sont prévues dans le mur de parement pour empêcher l'accumulation de l'humidité ou pour favoriser son assèchement, l'injection peut être exécutée. Dans le même ordre d'idées, il est recommandé de veiller à ce que les orifices prévus pour la ventilation à la base des murs soient bien dégagés.

3. Agrément technique

3.1. Définition

L'agrément technique est une appréciation favorable de l'aptitude à l'emploi dans la construction des procédés, matériaux, éléments ou équipements non traditionnels :

- Non traditionnels, c'est-à-dire ceux qui n'ont pas reçu la sanction de l'expérience et du temps et, partant, ne sont pas définis par des normes;
- Aptitude à l'emploi dans la construction signifie que l'appréciation s'effectue en fonction d'un emploi bien défini et que non seulement la qualité intrinsèque d'un produit est examinée mais aussi la validité des indications d'emploi et les performances réelles;
- Appréciation favorable : l'agrément est une présomption favorable qui ne dégage pas les utilisateurs de leurs responsabilités légales ou contractuelles.

Cependant, tout est mis en oeuvre pour que l'agrément technique constitue au moment de sa délivrance le meilleur avis possible compte tenu de l'état d'avancement de la science. Il assure une qualité minimale.

Pour cette forme d'isolation, l'agrément technique porte sur le principe, le produit, l'équipement et la méthode d'injection.

3.2. Description sommaire du procédé d'injection de mousse

3.2.1. Processus chimique

Les mousses solides sont le résultat d'une polymérisation d'urée et de formaldéhyde sur un agent moussant et avec l'aide d'un durcisseur. L'agent moussant est nécessaire pour obtenir la structure aérée de ce condensat et le durcisseur a pour effet de donner à la mousse une résistance suffisante.

Les résines urée-formol étant fournies en solutions concentrées, elles doivent être diluées dans de l'eau dont la dureté doit être strictement contrôlée pour ne pas entraver la formation de la mousse.

3.2.2. Caractéristiques de la mousse d'urée-formaldéhyde

C'est une mousse rigide mais fragile, de couleur blanche, imputrescible, présentant une structure homogène de cellules ouvertes.

Ces caractéristiques physiques sont les suivantes :

- masse volumique, après séchage, comprise entre 9 et 12 kg/m3;
- conductivité thermique : λ sec = 0,035 W/m.K. Au moment de l'injection, la valeur de λ est de l'ordre de 0,12 W/m.K.
- perméabilité à la vapeur d'eau : la valeur du facteur de résistance à la diffusion de la vapeur d'eau est de l'ordre de 2 à 5;
- retrait : le retrait mesuré suivant les règles d'agrément ne dépasse pas 8 %;
- absorption d'eau mesurée suivant les règles d'agrément de l'ordre de 2% en volume.

3.2.3. Appareillage (voir schéma)

L'appareillage comporte deux réservoirs : un contenant la résine convenablement diluée et un autre contenant l'agent moussant et le durcisseur.

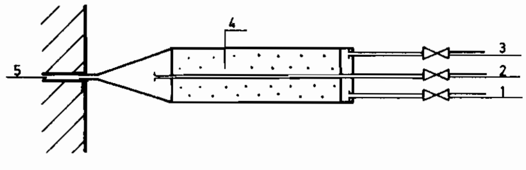
Il y a également un pistolet d'injection dans lequel se forme le mélange à injecter et qui doit être engagé dans un orifice communiquant avec le creux du mur. Le pistolet est alimenté par 3 tubes dont deux sont en provenance des deux réservoirs alors que le troisième apporte l'air comprimé nécessaire à la pénétration du mélange dans le creux du mur.

Les liquides contenus dans les réservoirs peuvent être pompés ou au contraire mis en mouvement par la pression d'air produite par le compresseur .

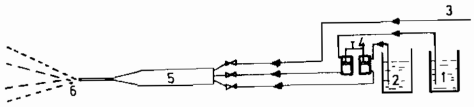
Le corps du pistolet est un réservoir cylindrique dans lequel sont disposées des billes de verre. Le passage du mélange agent-moussant et durcisseur à travers le cylindre encombré de billes se fait de manière turbulente ce qui favorise la formation de la mousse.

Ce n'est que dans l'extrémité conique du pistolet que cette mousse se charge de la résine qui y est directement injectée.

Pistolet d'injection



1. Durcisseur + agent moussant
2. Résine U.F.
3. Air comprimé
4. Billes de verre
5. Orifice d'injection



1. Résine U.F.
2. Durcisseur + agent moussant
3. Air comprimé
4. Pompe doseuse
5. Pistolet d'injection
6. Mousse

3.2.4. Orifices d'injection

Les orifices d'injection ont environ 20 mm de diamètre, et sont forés à la jonction des joints de mortier verticaux et horizontaux.

L'espace à injecter est habituellement continu. Les orifices sont disposés en files horizontales distantes de moins d'un mètre l'une de l'autre. Dans chaque file, l'entredistance des trous est de 45 cm et ils sont placés en quinconce d'une file à l'autre.

3.3. Procédure

3.3.1. Pour les produits de fabrication industrielle, on utilise parfois la procédure de l'agrément suivi. Son principe repose sur un autocontrôle de la qualité de la production, mis en place par le fabricant et vérifié par l'Institut agréeur.

Mais, ce double contrôle ne peut se rapporter qu'à la qualité des produits qui quittent l'usine et pas à la qualité de l'exécution sur chantier. Il a fallu innover pour l'injection de mousse U.F. dans les murs creux puisque tout se passe sur chantier jusqu'à la préparation des produits.

3.3.2. Ici, le bénéficiaire de l'agrément s'engage pour lui-même et ses applicateurs, à respecter les modalités de contrôle fixées dans l'agrément technique.

Il accepte qu'à tout moment, des opérations de contrôle soient effectuées sur chantier. Partant, il s'engage à communiquer ou à faire communiquer par les applicateurs 10 jours à l'avance, toutes les adresses de ces chantiers et les dates précises d'injection.

3.3.3. Ce contrôle par sondages se fait en deux stades:

- le contrôle in situ de l'isolation de l'espace creux des murs afin de vérifier si celle-ci est réalisée conformément aux données techniques du dossier introduit par le demandeur d'agrément
- la vérification des caractéristiques de l'isolant au moyen d'essais effectués sur un échantillon prélevé lors du contrôle in situ.

En laboratoire, on calcule les masses volumiques (g/dm3) de la mousse au moment de l'injection (mousse humide) et de la mousse à l'état sec.

On mesure le retrait dimensionnel de l'échantillon au départ des dimensions internes de la boîte du prélèvement.

Après l'échantillon est découpé à mi-hauteur pour en apprécier l'homogénéité ainsi que la présence et l'importance des cavités.

On mesure également l'absorption d'eau.

Enfin, on effectue une analyse en "réflexion totale atténuée" qui consiste à déterminer le spectre des composants chimiques de la mousse et permet de vérifier la constance des composants.

Les résultats des essais doivent permettre d'une part d'évaluer la constance de la qualité de la mousse et d'autre part de vérifier que ses caractéristiques sont au minimum celles annoncées dans l'agrément.

3.4. Résultats des contrôles

Parmi les mesures sur les échantillons prélevés sur place, on retiendra celles qui concernent le retrait dimensionnel.

3.4.1. L'analyse statistique, pratiquée sur 80 échantillons, a été faite dans le but de déterminer les valeurs limites admissibles pour le retrait des mousses.

Les conclusions de cette analyse apparaissent sur le tableau suivant :

	moyenne arithmétique $\bar{x}$	écart type s	fractile 90%
Retrait en longueur	4,2%	1,3	5,8%
Retrait en hauteur	5,0%	1,4	6,7%
Retrait en épaisseur	4,6%	1,9	7,3%

On constate que les valeurs moyennes du retrait sont assez voisines dans les trois directions considérées. Toutefois, la dispersion des valeurs va en croissant lorsqu'on passe de la longueur à la hauteur et à l'épaisseur.

Il paraît raisonnable de considérer comme limites admissibles les valeurs appelées "fractiles 90%". Ce sont les valeurs du retrait qui ne sont actuellement pas dépassées par 90% des échantillons.

3.4.2. Pour apprécier l'influence du retrait sur l'isolation thermique d'un mur, on a calculé les valeurs k d'un mur double en maçonnerie sans et avec un retrait moyen des mousses de 5% dans toutes les directions.

Le coefficient de transmission thermique k est passé de 1,59 W/m2.K sans isolation, à 0,51 W/m2.K avec mur creux injecté de mousse sans retrait à 0,60 W/m2.K avec creux injecté de mousse et accusant un retrait de 5%.

La transmission calorifique réelle est de 18% supérieure à celle qu'indiquerait le calcul théorique faisant abstraction du retrait.

4. Marché

4.1. Importance

4.1.1. La généralisation de maisons avec murs creux a surtout eu lieu après la deuxième guerre mondiale.

On peut estimer à environ 500.000 le mombre de maisons unifamiliales de 1 à 3 niveaux, construites avec murs creux. Au-delà de 3 niveaux, les cas d'application sont rares.

4.1.2. Les expériences menées sur diverses maisons, ont permis de constaté, une économie de l'ordre minimum de 13%, par le procédé d'injection dans les murs creux.

Comme la consommation moyenne par logement en Belgique est estimée à 4.500 litres de gasoil, cela permettrait d'économiser environ 600 litres par maison , par saison de chauffe.

Si toutes les maisons à murs creux devaient être ainsi isolées, on ferait une économie d'environ 300.000 Tep. Pour le parc immobilier de la Belgique de quelque 3.800.000 logements, cela équivaudrait à une économie de chauffage de près de 2%.

4.2. Organisation

Cette branche d'activité semble avoir connu son âge d'or en 1975/76, lors de l'instauration de la prime d'Etat à l'isolation thermique.

D'octobre 1976 à décembre 1977, le nombre d'applicateurs, dans le cadre de l'agrément technique, à la fois pour la laine de roche et pour la mousse d'urée-formaldéhyde était de 33. Fin 1978, on en dénombrait 7 et fin septembre 1979, 4 seulement.

Ces 4 firmes possèdent 9 machines à injection de mousse U.F. (vers 1975, 15 de ces machines existaient sur le marché).

Le potentiel de telles firmes est de 1 maison par jour, par machine, pendant environ 200 jours par an soit environ 2000 maisons à isoler annuellement. Le coût d'une telle opération est de l'ordre de 25 à 30.000 F.B.

Parallèlement, le nombre d'applications signalées pour le prélèvements d'échantillons sur le site, dans le cadre du contrôle, a chuté de manière identique, passant de 1571 fin 1977 à 261 fin 1978 pour arriver à 149 fin septembre 1979.

Ici, il est vraisemblable que les règles du contrôle ne sont plus respectées, sans doute pour de simples raisons financières : éviter le paiement des prélèvements et des analyses des échantillons.

De plus, il existe très certainement des applicateurs indépendants qui effectuent leurs travaux dans des conditions non précisées de garanties.

Il semble donc évident qu'en ce domaine la procédure du contrôle est à revoir.

Le type de maison ainsi traité est surtout celui de la maison indépendante à combles habités, construite depuis 1960. Une tendance se constate toutefois d'injection des murs des maisons en cours de construction.

5. CONCLUSIONS

Le remplissage des murs creux par injection peut apporter une solution satisfaisante au problème de l'isolation des logements existants.

Cependant, il est évident qu'il s'agit d'une opération qui exige de réelles connaissances professionnelles et techniques.

L'expérience belge en matière d'isolation a néanmoins montré que la réussite des campagnes de sensibilisation du public à ce problème ne peut aller de pair qu'avec l'octroi d'aides par l'Etat.

C'est pourquoi, il est particulièrement important de pouvoir évaluer les résultats obtenus par les diverses mesures d'économie d'énergie, d'établir un bilan à la fois économique et thermique des dispositifs et procédés mis en place, afin d'orienter les aides de l'Etat vers les solutions présentant le meilleur rapport coût-rendement.

Une politique d'aides est d'ailleurs à nouveau appliquée, avec toutefois des modalités d'octroi différentes de celles de 1975. Mais, il faudra encore attendre pour en évaluer les retombées.

The natural ventilation of groups of low rise buildings and the implications for energy conservation.

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Summary

Whilst the assessment of the natural ventilation rates of low rise buildings is an area of growing concern in the continued search for greater interior comfort standards, this concern is perhaps reflected more in our awareness of the energy impact which this source of heat loss has in the present financial climate. It is surprising therefore that so little is known about air infiltration in the low rise buildings, which continue to comprise the majority of our housing stock. The relatively small amount of data which exists relates only to isolated buildings despite the fact that other spheres of fluid mechanics have for some time recognised the importance of proximity effects in the prediction of fluid flow phenomena.

It is the intention of this paper to describe a series of wind tunnel investigations which have led to the development of a procedure by which it is possible to estimate the wind pressure forces which act on a low rise building which itself is part of a large group of similar buildings. The use of this technique makes it possible to allow for the building form, the parameters which describe the array in which it is situated, the upstream building conditions and the orientation of the wind.

Résumé

Pendant que l'évaluation des taux d'aération naturelle dans les bâtiments peu élevés concerne de plus en plus de monde - ceci dans le cadre de la perpétuelle recherche d'un niveau de confort interieur plus élevé - cet intérêt se reflète peut-être plus dans notre prise de conscience de l'impact sur la consommation d'énergie, dû à cette source de déperdition de chaleur, dans le climat financier actuel. Il est donc surprenant que si peu soit connu au sujet de l'infiltration de l'air dans ces bâtiments peu élevés qui continuent à former la majorité de nos habitations. La quantité relativement faible de données qui existe ne porte que sur des bâtiments isolés, en dépit du fait que d'autres sphères d'études de la mécanique des fluides aient reconnu, depuis quelque temps déjà, l'importance des effets de proximité dans la prédiction des phénomènes de courants de fluides.

Le but de cet article est de décrire une série d'enquêtes sur les tunnels aérodynamiques qui ont abouti au développement d'un procédé par lequel il est possible d'estimer les forces de pression de vent qui agissent sur un bâtiment peu élevé, celui-ci faisant partie d'un large groupe de bâtiments similaires. L'utilisation de cette technique permet de tenir compte de la forme du bâtiment, des paramètres qui décrivent les rangs dans lesquels il est situé, des conditions créées par les bâtiments en amont, et de l'orientation du vent.

1. Introduction

Building design is a procedure which must be accomplished within both economic and environmental constraints. As part of this design process very often natural ventilation is found to be the only means available to the designer for supplying fresh outside air into building interiors where the external climatic impacts are not too severe. Therefore a proper estimate of the natural ventilation rates in buildings is necessary if buildings are to meet both their environmental and economic requirements.

The crack method for natural ventilation rate calculation, described in the ASHRAE Guide (1) is based in principle on the following equation which relates the ventilation rate, Q, to the pressure difference, Δp_o, acting across any opening,

$$Q = C_i \cdot L_c (\Delta p_o)^{1/n} \qquad (1)$$

For a particular building, the infiltration coefficient, C_i, the exponent n, and the crack length L_c, are dependent on the type and the area of the openings. Therefore, it remains to determine Δp_o in the equation in order to obtain the ventilation rate, Q. From the work on air flow round building models an estimate of the mean pressure difference across the building Δp, may be obtained, half of which is assumed to act across each of the windward and the leeward faces of the building, giving Δp_o. It appears that the main assumption made in the guides for the estimation of Δp may result in considerable error since a number of important factors affecting its magnitude are neglected, where these factors include definitions of the building form and the properties of the oncoming flow.

The pressures which govern the value of Δp are determined by the process of separation and reattachment of air flow round the body. Although the factors affecting separation are not necessarily the same as those affecting reattachment, it seems logical to classify all the factors involved into the following two groups:

(a) factors related to the building form, and
(b) factors related to the properties of the wind.

In the case of low building density where buildings are wide apart, i.e. in open country, the individual building form is the only form that the wind can 'see'. As the density increases, i.e. in suburban and urban areas, buildings are close to each other so that each building form becomes a detail in the group form as a whole. In this case the group form becomes more important than the individual building form in influencing the drag forces experienced by each building.

2. The present investigation

In the discussion so far, the problem of making a reliable estimate of the value of the wind pressure forces for natural ventilation calculations is shown to depend on two main groups of factors, i.e. form-related factors and flow-related factors. Thus, in urban areas where buildings are mostly in groups, it is expected that the three main factors affecting Δp are (i) the building geometry, (ii) the group form and (iii) the properties of the natural wind.

If the properties of the wind structure in the atmospheric boundary layer flow over sub-urban terrain are assumed to be known on the basis of previous full scale measurements, and if these properties can be adequately modelled in a wind tunnel, it should then be possible to conduct a series of detailed measurements to establish the existence of a set of relationships between the wind-induced pressure forces on a building and the form factors which describe the building and its immediate surroundings. It is the intention of this paper to demonstrate that such a set of relationships may be determined.

3. The experimental procedure

The series of experimental tests, to be described here, were conducted in the Sheffield University 1.2 x 1.2 m boundary layer wind tunnel. The wind tunnel has a working section 7.2 m long whose cross section measures 1.2 x 1.2 m, incorporating a 1.1 m diameter turntable and whose centre lies 5.4 m downstream of the entry position.

The method used for the simulation of the suburban terrain atmospheric boundary layer utilises an approach based on a combination of fences, spires and floor roughness elements. The use of this method has been shown to give an adequate representation of both the mean velocity and turbulence characteristics appropriate to flow over suburban terrain conditions, Lee (2).

Throughout the test programme pressures were measured on a range of instrumented model buildings fitted with wall pressure tappings, and which were positioned at the centre of arrays of identical models.

The overall investigation was conducted in 3 phases as follows:

Phase 1 Cuboid models
- Dimensions: 20mm cubes and 36 mm cubes, H
- Array patterns: Normal (gridiron)
  - Staggered (checkerboard)
  - Random
- Array plan area density : 3.1% to 50% (13 values)
- Wind directions : $0^0 < \theta < 90^0$

Phase 2 Frontal aspect ratio models, A_f
- Dimensions: Front face 36mm x l_1, side face 36 x 36 mm where l_1 = 18, 36, 54, 72 and 144mm
- Array pattern : Normal (gridiron)
- Array plan area density : 2.5% to 60% (15 values)
- Wind direction: $\theta = 0^0$, wind normal to front face

Phase 3 Side aspect ratio models, A_s
- Dimensions : Side face 36mm x l_2, front face 36 x 36mm where l_2 = 18, 36, 54 and 72mm
- Array pattern : Normal (gridiron)
- Array plan area density : 2.5% to 60% (15 values)
- Wind direction : $\theta = 0^0$ wind normal to front face

In the tests included in phase 1 of the investigation a study was made of the influence of the size of the array and the influence of upstream fetch, the results of which were then applied to phases 2 and 3. The results are presented in the form of pressure coefficients, normalised by means of a free stream or gradient wind velocity.

4. The results and discussion

4.1 The influence of the array form on model surface pressures

When turbulent flow occurs over a rough surface composed of discrete roughness elements it is possible to describe the existence of a number of flow regimes which are governed by the way in which the layout of elements occurs. These flow regimes, which were suggested by Morris (3) and whose existence for some types of three-dimensional roughness element has been confirmed by Lee and Soliman (4) are denoted as isolated roughness flow, wake interference flow and skimming flow.

In the isolated roughness flow regime, Fig 1(a), the roughness elements are sufficiently far apart that each element acts in isolation and behind which the wake and separation bubble develop completely, flow reattachment to the surface occurring before the next element is reached. Here the clear spacing in the flow direction between adjacent elements, Sc, is greater than E_t, the sum of the upstream separation distance, Eu, and the downstream distance, Ed. In the third category, the skimming flow regime, Figure 1(c), the roughness elements are now sufficiently close together that a stable vortex can form in the space between the elements and the flow appears to skim on their crests. Here the separation distance between elements is less than E_v, the maximum gap size for the existence of such a stable vortex. The wake interference regime, Figure 1(b), then exists between these other regimes where the separation bubble does not have sufficient space to develop fully but where the distance is too large for a stable vortex to remain. Here the clear spacing lies between E_t and E_v.

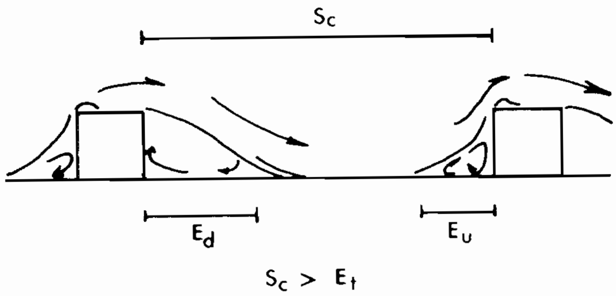

Figure 1a Isolated roughness flow regime.

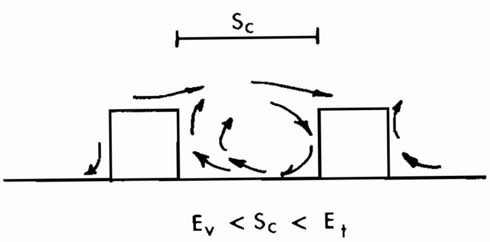

Figure 1b Wake interference flow regime.

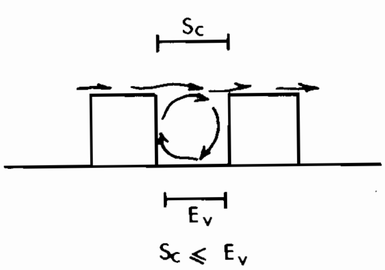

Figure 1c Skimming flow regime.

The cuboid model tests

The measurements of the mean surface pressure forces were first carried out on the cuboid models. Figure 2, which presents these results, shows the variation of ΔC_{pl} with element clear spacing ratio S_c/H, and plan area density λp, for both the normal and staggered patterns, where ΔC_{pl} is the coefficient of Δp as defined in section 3. These results are shown to be represented by broken straight line relationships for both layout patterns considered, where break points are considered to reflect a change from one flow regime to the next.

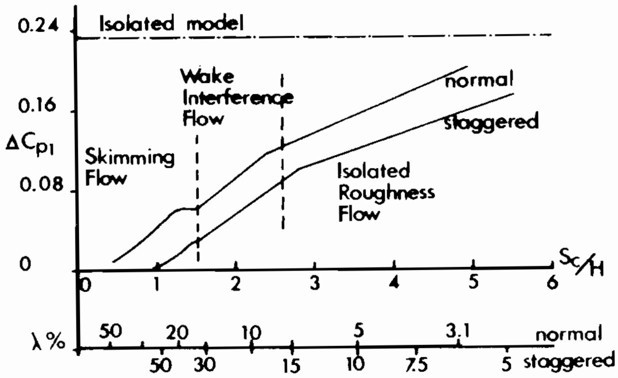

Figure 2 The variation of pressure difference coefficient with array spacing and plan area density. Cuboid models.

From this figure the following conclusions are suggested:

(a) The isolated roughness flow regime exists for values of $S_c/H > 2.6$ for both layout patterns.

(b) The wake interference flow regime exists for values of $1.4 < Sc/H < 2.6$.

(c) The skimming flow regime exists for values of $S_c/H < 1.4$ for both layout patterns.

Figure 2 also shows the value of ΔC_{pl} for an isolated cuboid model building in the simulated atmospheric flow. A comparison of this value with those for the pressure drop across grouped buildings clearly illustrates the importance of building proximity effects in the determination of wind pressure forces and hence wind induced ventilation rates.

The frontal aspect ratio variation tests

The variation of the central model pressure drop coefficient, ΔC_{pl}, with variations in array model clear spacing for the range of frontal aspect ratio models from $A_f = 0.5$ to $A_f = 4.0$ were studied in phase 2 of the investigation.

The inflection points in the relationship between the model pressure drop and the clear spacing ratio, were similar to those found for the cuboid models, but suggested that the values of S_c/H at which the flow regime changes occur depends not only on the model spacing but also on the value of the model's frontal aspect ratio. Across the range of frontal aspect ratio from 0.5 to 4.0 it was found that the change of flow regime from isolated roughness flow to wake interference flow occurs at values of S_c/H which progress from 2.25 to 3.0 respectively. Similarly, the values of S_c/H at which the second change occurs also increases from 1.30 to 1.55 across the same range of frontal aspect ratio models.

The side aspect ratio variation tests

Phase 3 of the investigation then studied the variation of the model pressure drop coefficient, ΔC_{p1}, with the model clear spacing, Sc, for values of the side aspect ratio models of A_s = 0.5, 1.0, 1.5 and 2.0. The inflection points in the rate of reduction of model pressure drop with spacing were again used to identify the changes of flow regimes. The first change from the isolated roughness to wake interference flow regimes occurred at values of S_c/H varying from 2.1 to 2.6 as the side aspect ratio was increased from 0.5 to 2.0. The second change from the wake interference to the skimming flow regime occurred at a constant value of S_c/H of 1.4 for all model side aspect ratio array values.

4.2 The fetch length correction

The influence of upstream fetch on the surface pressures acting on the central model, for arrays of cubes, was studied in Phase 1 of the investigation. Here it was found that the model group fetch size required for the surface pressures to stabilise at their minimum value varied from 10H to 25H and was dependent also on the group plan area density, for groups of buildings situated within a suburban terrain atmospheric boundary layer. From these tests it was found that if the fetch length was too short for the conditions of pressure stabilisation to occur then this would result in an increase in the surface pressure forces. It was possible then, using the results of all the tests on the influence of upstream fetch length, to produce a family of curves for each of the flow regimes indicating the increase in surface pressure difference which is consequent upon the existence of short fetch lengths.

4.3 The influence of wind direction on the side wall pressures

The data on the influence of wind direction on the surface pressures acting on groups of low rise buildings stem from a series of tests on groups of cuboid models in normal, staggered and random layout patterns.

The variation of ΔC_{p1} with the model orientation, θ, is shown in Figure 3, where the values for all layout patterns were averaged for three values of the group plan area density corresponding to the three flow regimes. A comparison with the corresponding data for an isolated cuboid model is also presented.

In the first example the building form parameters have the values A_f = 1.5 and A_s = 1.0, the clear space ratio S_c/H = 3.0, the fetch length is greater than 25H and the wind is blowing at an angle of 60^0 to the nominally defined front face; this results in a value of ΔC_{p1} = 0.104. The pressure difference between the adjacent faces may be similarly determined by exchanging front and side aspect ratios.

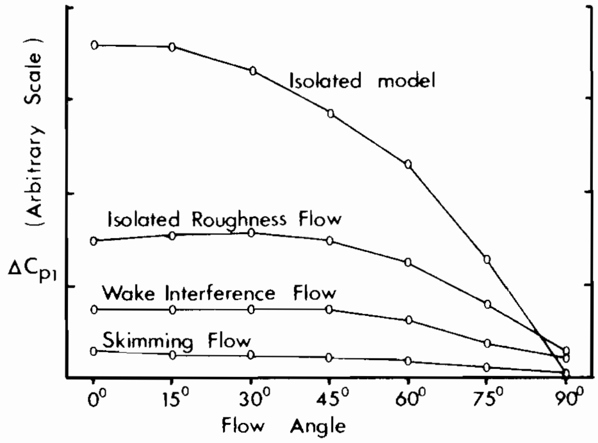

Figure 3 The variation of pressure difference coefficient with wind direction. Cuboid models.

The effect of model orientation on the value of ΔC_{p1} in the range of $0^0 < \theta < 45^0$ is shown to be negligible for the values of density considered.

5. The prediction method

Having seen the effect of the important parameters which influence the value of the side wall pressure difference coefficient, ΔC_{p1}, a prediction procedure for low rise buildings is now possible. Assuming the buildings to be of similar heights in a group, a chart can be constructed by placing the parametric data sets side by side, as shown in Figure 4. Parts (a) and (b) of Figure 4 indicate the variation of ΔC_{p1} for models of various frontal or side aspect ratio, determined in a similar manner to that for the cuboid model data shown in Figure 2. Part (c) of Figure 4 is the upstream fetch length correction, which enables an increased value of ΔC_{p1} to be used for short upstream distances. Part (d) of Figure 4 enables a correction to be made which allows for the reduced values of ΔC_{p1} which occur when the wind is not normal to the front face, and has been derived from Figure 3. Two examples showing the sequence of these steps are indicated, for different frontal and side aspect ratio buildings.

In the second example A_f = 1.0, A_s = 0.5, S_c/H = 3.5, R = 15H and $\theta = 0^0$ and results in a value of ΔC_{p1} = 0.228. Since ΔC_{p1} is defined as

$$\Delta C_{p1} = \frac{\Delta p}{\frac{1}{2}\rho V_G^2} \qquad (2)$$

it requires only a knowledge of V_G, the gradient wind speed, in order to determine Δp. A significant advantage of this procedure is that it is not necessary to involve an estimate of the wind velocity at the building roof height, an especially difficult procedure where the average roof height of an array of low rise buildings is below the standard meteorological reference height. However, this independence of the roof height velocity is an assumption which is only valid if the ratio of building height to boundary layer thickness is small.

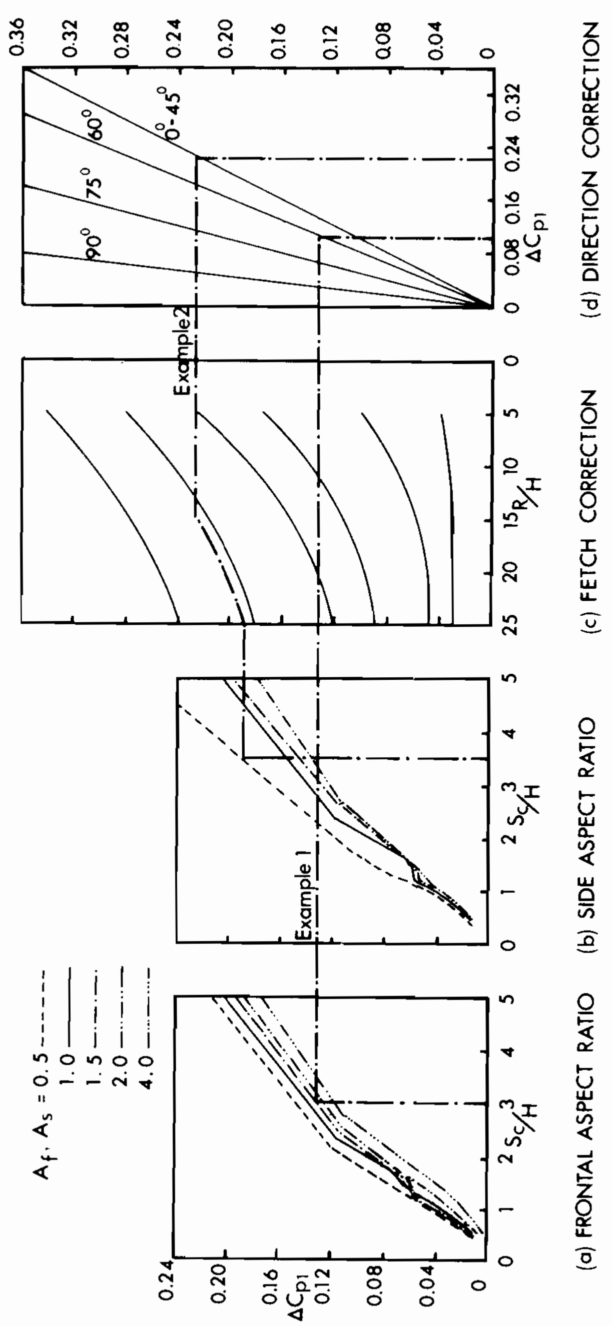

Figure 4 The prediction method for pressure difference coefficients.

A more complete explanation of this prediction method is available by Lee, Hussain and Soliman (5).

6. Conclusions

A prediction technique has been presented which enables the surface pressures acting on a particular building, situated within an array of similar low rise buildings, to be estimated. The procedure takes account of both the geometrical form of the building and the spacing parameters which describe the array as well as the direction of the wind and the upstream fetch conditions. The estimated value is in the form of a pressure coefficient, non dimensionalised with respect to a gradient wind speed, and may be determined by means of a graphical method.

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A hybrid simulation technique for predictions of seasonal energy consumption

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Summary

A brief description is given of an apparatus for simulating the thermal behaviour of buildings. An analogue circuit of electrical resistors and capacitors is used to represent the thermal characteristics of building elements. Meteorological data are stored in the central memory of a digital computer. The solar heat gain is calculated each hour, taking account of the latitude, declination and solar position, and the orientation, shading and size of windows. The dynamic thermal characteristics of a room thermostat are simulated and used to control a room heater during chosen periods of the day. The energy consumed during the heating season is automatically monitored and integrated and displayed at the end of each run. A time scaling factor of 18 000:1 is used, so that a whole year's simulation takes less than 3 minutes. The hourly values of room temperature are stored in the digital memory for analysis and printout.

A study of a simple prediction method for seasonal energy consumption is described. Results for various room conditions and structures are presented and are compared with simple predictions. Improvements to the simple prediction procedure, resulting from this study, are suggested.

Sommaire

Une technique de simulation hybride concernant les prévisions de consommation saisonnière d'énergie.

Il est donné une brève description d'un dispositif simulant le comportement thermique d'immeubles. Un circuit analogue de résistors et de condensateurs électriques est utilisé pour représenter les caractéristiques thermiques des matériaux de construction. Les données météorologiques sont conservées dans la mémoire centrale d'un ordinateur. Le gain en chaleur solaire est calculé toutes les heures, en tenant compte de la latitutde, de la déclinaison et de la position solaire, de l'orientation, de l'exposition et de la taille des fenêtres. Les caractéristiques, dynamiques thermiques d'un thermostat ambiant sont simulées et utilisées pour contrôler un radiateur durant des périodes données de la journée. L'énergie consommée pendant la période de chauffage est automatiquement controlée, intégrée et représentée à la fin de chaque cycle de fonctionnement. Une échelle de graduation temporelle de 1/180 000 ème est utilisée: c'est ainsi que la simulation d'une année entière dure moins de 3 minutes. Les estimations faites chaque heure de la température ambiante sont conservées dansla mémoire arithmétique pour analyse et présentation.

L'étude d'une méthode simple de prévision concernant la consommation saisonnière d'énergie est exposée. Les résultats des différentes conditions et structures ambiantes sont présentés et comparés avec de simples prévisions. Des améliorations du procédé de prévision simple, résultant de cette étude, sont suggérées.

1. Introduction and brief description of apparatus

An apparatus for simulating the dynamic thermal performance of buildings, developed at the Department of Building, UMIST, has been reported elsewhere {1}. It involves a combination of analogue and digital methods to form a hybrid machine. A passive electrical analogue circuit, formed of resistance and capacitance components, is used to represent the radiation and convection heat flows within the room and the conduction heat transfer within the structural materials. Meteorological data consisting of hourly values of external air temperature and of solar radiation intensity are stored in the central memory of a computer in digital form. The solar heat gain into the room is computed each hour, taking account of the latitude, declination and solar position, together with the orientation, shading and size of windows. The static and dynamic characteristics of a room thermostat are simulated and used to control an electric current representing a heat emitter. The heating can be made available only during predetermined times of day. It can be arranged that heating may be shut off during the weekends, Saturday and Sunday, to simulate an Office working on five days of the week, or the heating can be continued at weekends for simulation of domestic operation.

A time scaling factor is used whereby one hour of building operation is simulated in 20 ms, a speed increase of 180 000:1, so that a whole years operation takes less than 3 minutes.

2. Prediction of seasonal energy consumption

The energy requirement for heating a building during a winter heating season can be expressed as

$$H = T\,\{(\bar{t}_i - \bar{t}_o).(0.33\,\bar{N}V + \Sigma UA) - \bar{S}\,\} \qquad (1)$$

where T = duration of heating season, s

$(\bar{t}_i-\bar{t}_o)$ = difference between mean internal and external temperatures, ^oC

$\bar{N}$ = mean ventilation rate, h^{-1}

V = volume of building, m^3

ΣUA = fabric heat loss rate, $W/^oC$

$\bar{S}$ = mean solar heat gain rate, W

The dynamic effects of the fabric due to intermittent heating can be neglected because the heating season is of very long duration compared with the thermal time constants of the building. An efficiency factor can then be applied to H to determine fuel consumption.

This prediction method was published by the British BRE in 1976 in their Digest 190: Heat Losses from Dwellings {2} , in which some guidance is given on suitable values to be assumed for $(\bar{t}_i - \bar{t}_o)$ and for $\bar{S}$. The actual value of ventilation rate $\bar{N}$ in a given building is very difficult to predict or to determine experimentally, without extensive testing. This factor has a very large effect on heat requirement, and recent measures to conserve energy in new and existing housing have tended to reduce ventilation rates. The effects of casual heat gains due to lighting, occupants, etc, are included by a modified choice of the temperature difference $(\bar{t}_i - \bar{t}_o)$. The hybrid computer method permits an accurate assessment to be made of the energy requirement for winter heating, so that the assumptions and results of Digest 190 may be studied.

3. Computer predictions

A computer simulation was carried out of a building, details of which are given in Table I. A heating season of 33 weeks (5544 hours) was adopted, and the meteorological data used was that for the first 33 weeks of the CIBS Example Weather Year for Kew UK {3}, starting 1 October 1964. A range of ventilation rates from zero to 10 air changes per hour was used, and the energy consumption for each case was found. Figure 1 shows the variation in energy consumption with ventilation rate, the calculated consumption, based on a value of $7^{o}C$ for $(\bar{t}_i - \bar{t}_o)$ as recommended in the Digest {2}, also based on a value of $12^{o}C$, which was in fact the observed $(\bar{t}_i - \bar{t}_o)$ taken from the hybrid computer results.

Because the number of different variables is rather large: ventilation, orientation, window area, construction type etc, it would be unreasonable to investigate every combination of all variables. One possibility is to take a typical 'central' case and to observe the effect on energy consumption of modulating each variable in turn. This effect has been presented in Figure 1 with regard to ventilation rate. Taking a ventilation rate of 1 ac/h as central, Table II shows the results for simulations with 20%, 40% and 80% glazing area, expressed as a proportion of total outside wall area. It is interesting to note that reducing the window area from 40% to 20% makes hardly any change in the energy consumption, the decrease in fabric loss being almost exactly matched by the decrease in solar heat gain. Increasing the glazed area from 40% to 80% produces a net reduction in energy consumption of about 25% and gives some overheating on certain days, even in winter. All these results are with South-facing windows.

The results for a range of orientations are presented in Table III and are compared with predictions using the BRE Diget method. It is seen that the energy consumption increases by about 40% as the orientation is changed from South to North. The predictions are reasonably good for South and South-West orientations but for other directions the errors increase to 20 to 30%. This is largely because a single overall value is suggested in the Digest, regardless of orientation. Table IV gives a set of suggested values for the solar gain per m^2 of window, based on orientation.

Finally, a number of simulations were carried out with various regimes of intermittent heating, using the central case of 40% glazing, 1 air change/hour ventilation, and South-facing windows. The heating was available for durations from 3 hours per day to 24 hours per day. The simulation results are shown in Table V and are compared with predictions using the method published by Harrington-Lyn {4}. It can be seen that there is excellent agreement for durations of heating longer than about 5 hours per day. The percentage errors for shorter heating duration become progressively larger.

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Window	:	6 m^2 (40% of total external wall, single glazed, U-value 5.7 $W/m^{2o}C$)
Solid external wall	:	9 m^2 (Brickwork outer leaf, 50 mm cavity, Lightweight concrete block inner leaf, U-value 0.96 $W/m^{2o}C$)
Floor/ceiling	:	20 m^2 (Concrete slab + PVC tiles/ plasterboard ceiling, U-value 0.4 $W/m^{2o}C$)
Internal partitions	:	39 m^2 (Lightweight concrete blockwork)
Ventilation	:	2 air changes/hour
Orientation	:	South-facing
Room thermostat setting	:	$20^{o}C$ throughout

Table I - Details of simulation test building, basic central case.

	Prediction of Energy Consumption, GJ		
	Glazed Area		
	20%	40%	80%
Hybrid computer prediction	10.9	10.9	8.2
BRE Digest prediction, temp.diff.= 7°C	7.9	9.9	13.8
BRE Digest prediction, temp.diff.=12°C	10.7	11.1	12.5

Table II - Comparison of predictions of seasonal energy consumtpion, for the basic case detailed in Table I.

Orientation	Predicted Consumption, GJ a	b
N	14.1	16.8
NE	14.1	16.5
E	13.5	14.9
SE	12.3	13.0
S	10.8	11.1
SW	10.7	11.1
W	12.3	13.4
NW	13.8	15.8

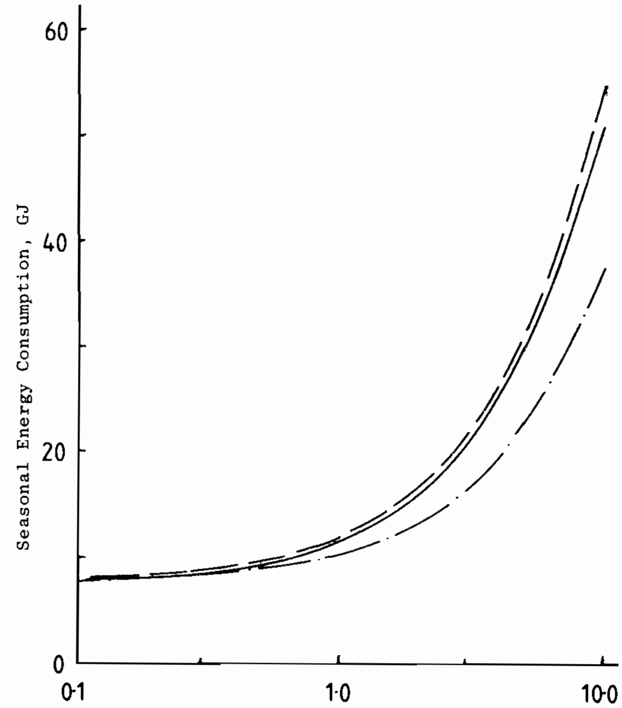
Table III - Comparison of predictions of seasonal consumption, GJ (a): Hybrid computer predictions, (b): BRE Digest method prediction, using 12°C temperature difference and solar gain values listed in Table IV.

Orientation	Seasonal solar gain, GJ/m^2
N	0.01
NE	0.06
E	0.33
SE	0.65
S	0.97
SW	0.97
W	0.59
NW	0.19

Table IV - Effect of orientation on seasonal solar gain through windows.

Heating duration, hr/day	(a) GJ	(b) GJ
24	10.9	10.9
21	10.5	10.5
17	9.8	9.8
13	8.9	8.9
9	7.6	7.5
5	5.7	5.4
3	4.1	3.8

Table V - Comparison of consumption predictions for intermittent heating. (a) Hybrid computer predictions, (b) Consumption predicted from ref 4 .



Ventilation Rate, air changes/hr

Figure 1 - The effect of ventilation rate on seasonal energy consumption.

Hybrid computer prediction

BRE Digest method prediction $(\bar{t}_i - \bar{t}_o) = 12°C)$

BRE Digest method prediction $(\bar{t}_i - \bar{t}_o) = 7°C)$

The geometric form of buildings - qualities and energy consequences. Four office-buildings analyzed.

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Summary

It is often said that low-energy buildings in cold climates should be compact, and it is true that compactness reduces heat-loss through the building envelope.

However, when geometric form of a large building is changed, this affects both environment qualities and many other energy factors besides transmission,for example:

- ventilation, mechanical and natural
- electric lighting
- electricity for lifts and fans
- solar heat gain

Four office-buildings of very different shape were selected and analyzed regarding effects on the aspects mentioned of differences in:

- height and width of buildings
- fenestration
- division into separate units and visual division
- court-yards and arcades

It was found that the energy factors counteract each other completely in very compact and large buildings but in other cases energy requirements are reduced to some extent with more compact form. This is done however, at the cost of important qualities such as usefulness, daylight, views, orientation and ease of access to other parts of the building. Therefore energy comparisons should not be based only on volume, but also take into account the proportion of floor-area with daylight and other quality aspects.

Résumé

On dit souvent que dans les climats froids les bâtiments devraient être compacts pour consommer moins d'energie, et il est vrai qu'une forme compacte réduit les pertes de chaleur par l'enveloppe extérieure du bâtiment. Pourtant, en cas d'immeubles de bureaux, beaucoup d´autres aspects de l´energie entrent en jeu lorsqu'on modifie les formes géométriques, par exemple: la ventilation, mécanique et naturelle, l'éclairage électrique, l'energie requise pour les ascenseurs, le parti à tirer de la chaleur solaire.

Quatre immeubles de bureaux de formes très diverses ont été analysés quant aux effets que peuvent avoir des différences dans: la hauteur et la largeur des bâtiments, le fenêtrage, la division en unités séparées ou l´articulation des volumes, les cours et les arcades.

Il a été ainsi constaté que, bien que les facteurs énergétiques puissent parfois être en complète opposition les uns avec les autres, il est vrai que, d'une façon générale, les besoins en énergie sont réduits lorsqu'on recourt à des formes plus compactes. Mais cela se fait au détriment de qualités importantes telles que utilité, lumière du jour, vues, orientation, facilité d'accès aux autres parties du bâtiment. C'est pourquoi des comparaisons en matière d'energie devraient être basées, non pas uniquement sur le volume, mais aussi tenir compte de la proportion de la surface de plancher éclairée par lu lumière du jour, ainsi que d'autres aspects qualitatifs.

Scope of the study

This study deals with four existing, rather normal office-buildings in the South of Sweden. The aim of the study was to answer the following questions:

- In what ways are energy requirements affected by the geometric form of the buildings?
- What is the magnitude of those influences?
- How were environmental qualities affected by the different forms chosen?

Description of the buildings studied

The buildings chosen were designed and built in Southern Sweden during the period 1970-78 and they are typical examples of different geometric form and lay-out.

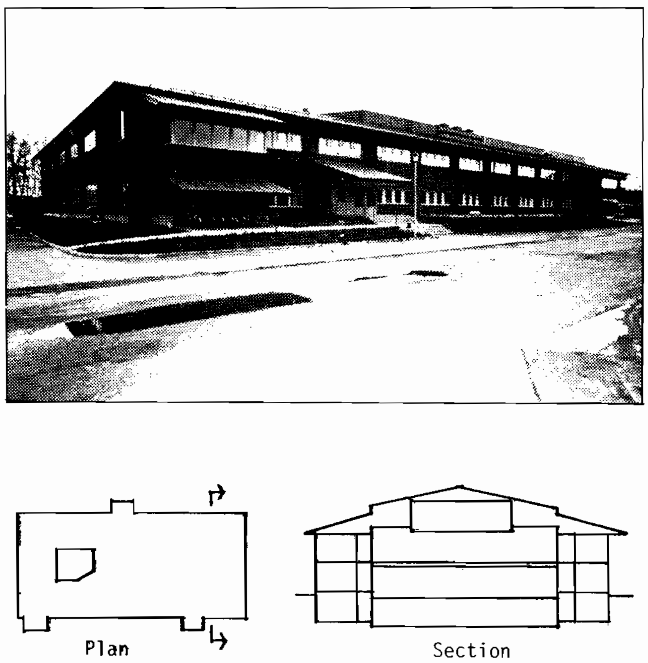


Figure 1. Tele Data is the smallest and most massive of the buildings. It was designed for telecommunication services with a large computer unit. There is working-space for about 150 persons. A considerable part of it without natural lighting. The site is next to a park in the town of Kalmar.

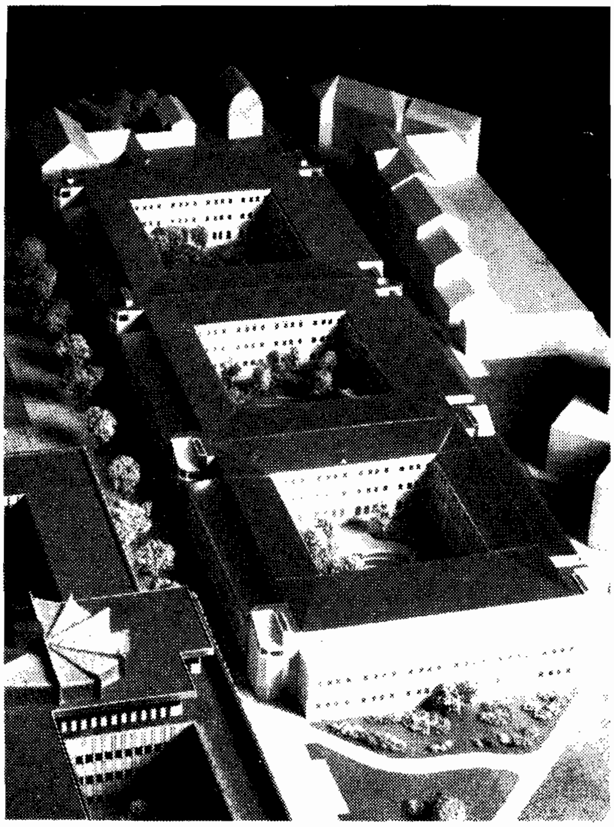


Figure 2. Malmen houses 380 people working for the county administration in central Kalmar. The configuration is fairly elaborate to meet the small-scale surrounding by a visual division of the building.

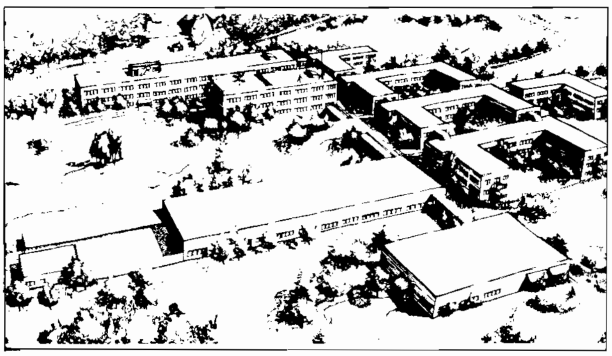


Figure 3. SMHI is the Swedish Meteorological and Hydrological Institute. There are laboratories and offices for a staff of 425 people. The institute is situated in the outskirts of Norrköping and is divided into a number of separate buildings, a large part of which are only 1 or 2 storeys. The most frequent type of window is larger than average, with a glass area of 0.96 m^2.

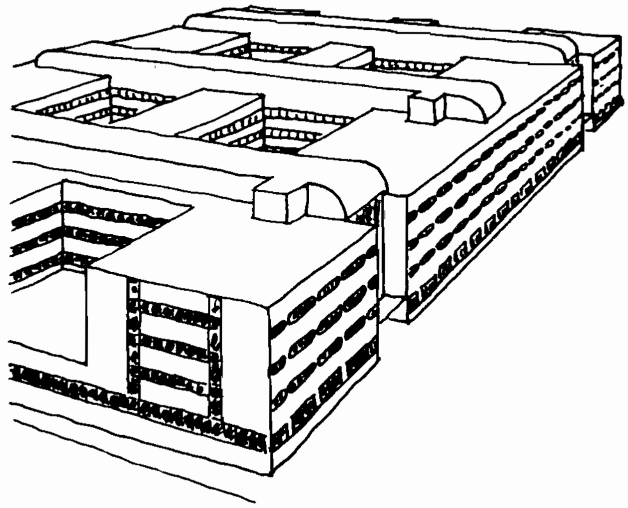


Figure 4. Saltängen is a 4-storey block in central Norrköping, where nearly 1000 people work for civil service departments and local administration. It forms a grid as compact as the massive body of Tele Data. Three arcades make a passage through the block and to the central entrances. The standard windows are smaller than average with 0.58 m^2 of glass area each. There is no basement storey.

	Tele Data	Malmen	SMHI	Saltängen
Volume, m^3	34.490	57.380	65.730	138.040
Floor area (a), m^2	8.690	17.240	19.140	39.261
Floor area (b) with daylight, m^2	2.430	9.330	13.225	18.100
Ratio of (b) to (a)	0.28	0.54	0.69	0.46
Area of shell, m^2	10.380	19.780	31.030	39.630
Energy used 78/79				
Electricity, MWh	2.300	900	1.160	2.280
Heat, MWh	915	2.300	3.430	4.820

Table 1. Basic data for the buildings studied. All of them are connected to district heating systems. Part of the electricity becomes useful heat. In Tele Data most of the heating of ventilation air is provided by heat recovered from the cooling plant of the computer unit.

Variations in geometric measurements

There are marked steps in the variations of the width of the buildings. This is because the depth of the plan must match a combination of useful rooms.

Widths

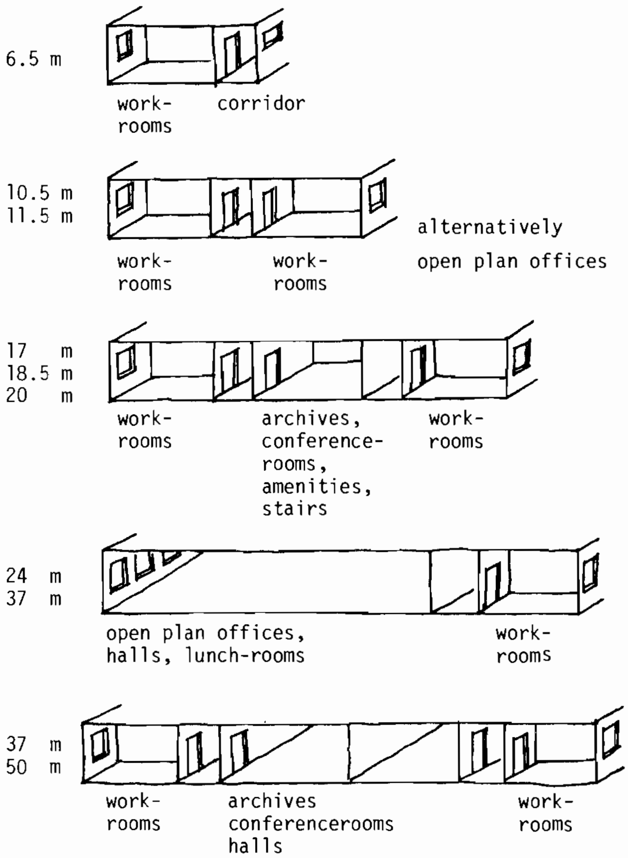


Figure 5. Widths that are found in the four buildings and the corresponding typical combinations of rooms. Space near the facade and the interior of a wide building are not equivalent.
The storey usually has to be higher when the interior of a deep plan is to be used as work-rooms and more electric lighting will be needed, but still it will never have the same qualities as rooms with views and natural lighting.

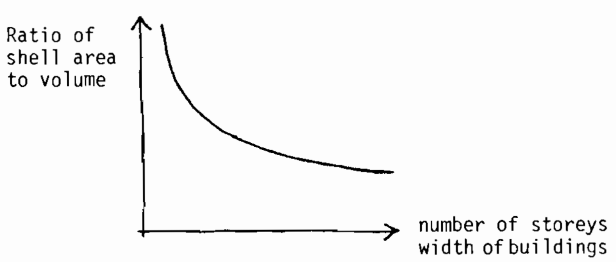


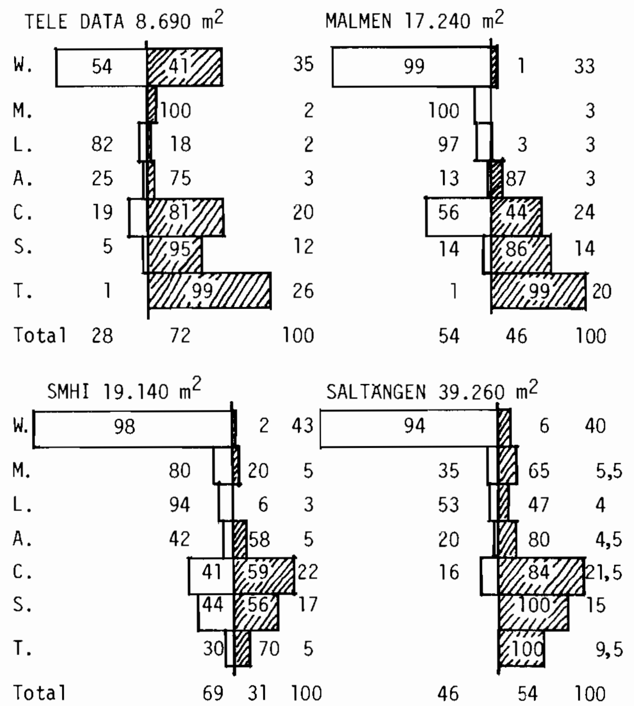
Figure 6. With extremely narrow plans or low buildings a change of dimensions has a strong effect on the area of the envelope. With increasing compactness the effect of a change becomes very much smaller.

The compactness is indicated by the relation between the area of the building envelope and the volume.

	Tele Data	Malmen	SMHI	Saltängen
Roof	0.10	0.09	0.14	0.08
Walls above ground level	0.07	0.10	0.12	0.10
Windows	0.015	0.03	0.05	0.02
Walls below ground level	0.03	0.03	0.03	0.004
Lowest floor	0.10	0.09	0.14	0.08
Total	0.31	0.34	0.47	0.29

Table 2. Ratio of shell area to volume, m^2/m^3.
The ratios found are of the same magnitudes as those found in blocks of flats. Small detached houses however may have a ratio as high as 0.6-0.9 m^2/m^3.

The variation in window area is most significant and the total floor area per window is 15, 10, 8,6 and 13 m^2 respectively for the buildings studied.



= floor area with and without daylight

W = work-rooms M = meeting rooms L = lunchroom

A = amenties C = communication S = storage

T = technical rooms, including garages.

Figure 7. The relations between areas with and without daylight have clearly been affected by the chosen geometric forms. Still the proportions between different types of rooms are rather similar. Inside the diagrams floor areas with and without daylight are given in percent of each category of rooms. To the right the areas of each category are given in percent of total floor area.

Since windows render essential qualities to rooms used by human beings it seems that Tele Data and Saltängen preferably should have been less compact. SMHI on the other hand could have been slightly more compact without loosing essential qualities.

Views from corridors and stairs are an aid to orientation. 41% of communication area with daylight in SMHI and its division into separate buildings makes it easy to find one´s way there - easier than in Malmen.

In Saltängen the corridors are a maze with few views to help in orientation.

Views of the surroundings generally seemed to be more appreciated than the view of a court-yard, where you see mainly other parts of the same building and a bit of the sky. Tele Data's windows are few but 80% face the surroundings. For Malmen, SMHI and Saltängen the figure is around 50%. In SMHI most court-yards are open, but in Saltängen a third of the few and small windows face closed court-yards.

How energy requirements are influenced by the geometric form of the buildings

Both inflows and outflows of energy are affected by the shape of a building. A schematic balance of inflows and outflows over a period of heating may clarify the relationships.

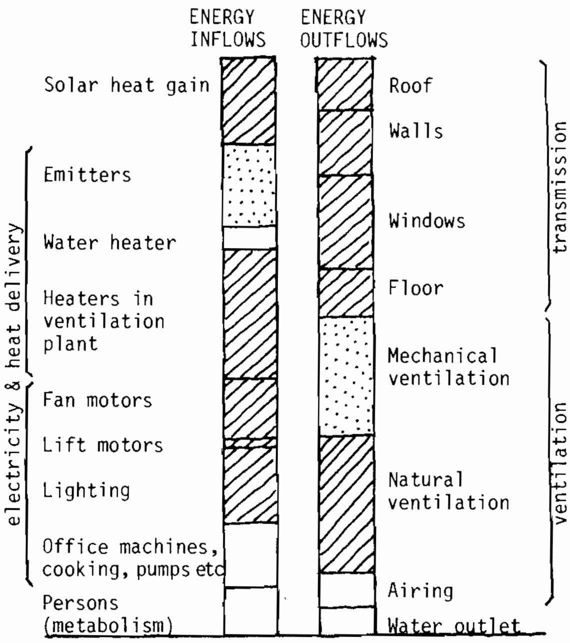


Figure 8. All energy flows in a building branch and unite and thus form a complicated pattern where no inflow exactly corresponds to any outflow. Streaks indicate a direct influence by the building's shape and dots mark flows that are indirectly affected.
For instance the amount of heat that has to be delivered by emitters depends on many other flows such as heat transmission through the shell, natural ventilation, solar heat gain, and heat from persons and electrical equipment used in the building.

Solar heat gain is increased by a shape with a larger shell area, particularly window area, exposed to the sun. Grouping buildings around court-yards tends to reduce useful as well as surplus solar heat gain by shading.

Periods of overheating will call for increased ventilation which means a higher demand for electricity for ventilation motors. Houses with windowless working-rooms and conference rooms need more ventilation air that has to be heated in the ventilation plant.

Electricity for lift machinery naturally is increased with higher buildings.

The need for electric lighting is determined by the natural light conditions in the building which in turn is influenced by its shape and fenestration.

Geometrical form determines the area of the building envelope and thus the amount of heat transmitted through it. A complicated form also tends to give a greater number of weak spots in the insulation.

Natural ventilation is increased with the height of buildings for two reasons. The chimney effect becomes stronger and the building gets more exposed to the stronger winds at high levels. The chimney effect is increased with open vertical communications such as lift shafts and in particular those for cable-lifts - usually chosen for high buildings - where the mechanical room links the shaft with the open air. Also a larger shell area is likely to have a larger number of air-leaks.

Other factors, especially the types of roof, walls and windows determine whether the effect on natural ventilation caused by variations in geometric form will be big or small.

Building - materials and construction represent an inflow of energy and variations in shell area indicate thag geometric form makes a difference here. The study has not gone further into this matter, but a rough estimate shows that the energy used for materials and construction is in the region of 10 - 40.000 MWh for the buildings studied. Energy conservation has made this a significant part of the total energy use in buildings. To some extent building costs reflect these investments of energy.

Calculated energy requirements

	Tele Data	Malmen	SMHI	Saltängen
Heat requirements				
Transmission	370	730	1.285	1.470
Mechanical ventilation	550	380	210	540
Natural ventilation (stereotyped)	400	640	710	1.490
Hot water	60	150	200	340
Electricity requirements				
Lighting	130	165	215	475
Lifts	0,6	-	-	6
Ventilation plants	100	125	175	400

Table 3. Calculated heat requirements and electricity requirements related to building form. Values in MWh/year, except for transmission which was calculated for the normal heating period, September 15th to May 15th. To demonstrate the magnitude of influence from building form the insulation was assumed to be according to the current Swedish building codes (SBN-75) in all cases. Actually Malmen, SMHI and Saltängen have about 30% higher heat transmission since they were designed to earlier standards.

A comparison of transmission figures per volume unit will show the influence of differences in geometric form and fenestration.

Part of shell	U-value required	Tele Data	Malmen	SMHI	Saltängen
Roof	0.2	1.7	1.7	2.8	1.6
Walls above ground level	0.3	2.0	3.0	3.6	3.0
Windows	2.0	3.2	6.2	10.1	4.4
Walls below ground level	0.3	0.9	0.8	0.7	0.1
Lowest floor	0.3	1.5	1.0	2.4	1.4
Total		9.3	12.7	19.6	10.5

Table 4. Specific heat transmission during a normal heating season, kWh/m^3. The compact form and small window area in Tele Data and Saltängen cuts down transmission to about half of that for SMHI. Window areas have a strong influence on these figures but it should be remembered that windows also contribute to heating by solar heat gain.

Reducing window size in SMHI to average would lessen transmission by about 10% (120 MWh). If parts of the narrow plans of SMHI were made deeper, like in Malmen, transmission would be reduced by another 15% (180 MWh), because of less wall and window area. And for the same reason, pushing SMHI´s separate buildings together would give nearly 10% (100 MWh) lower transmission. However, making SMHI more compact in these ways would also mean lower qualities regarding daylight, views and orientation as well as increases in other energy requirements - electricity for lighting would be nearly doubled. Most of this increase takes place in the summertime and would even create energy requirements for cooling.

The effect of reducing roof and floor area by increased building height is more limited. If, for instance, SMHI had in average 4 storeys instead of 2 the transmission through roof and floor would each be reduced by about 5% (65 MWh) of the total transmission.

It should be observed that about 20% of the transmission through parts of the shell below ground level takes place in July - September, and also that the U-value used for windows disregards solar heat gain.

In Malmen parts of the volume have been cut away next to the stairs to give a visual division. Compared to a flat facade this means 30 MWh/year of extra transmission. The roof and ceiling also slope slightly towards the facade. This reduces wall area and transmission is diminished by 6 MWh/year.

In Saltängen there are three arcades. Without these transmission would be only 7,5 MWh less per year since there is no basement storey. With a basement under the arcade the difference would have been 40 MWh/year.

These examples show that the effects of various design features differ widely.

However, the transmission figures per volume unit offer purely technical comparisons. All volumes are not equivalent, so to evaluate alternative designs one should also take quality aspects into account. A simple way is to base comparisons on floor area with daylight.

	Tele Data	Malmen	SMHI	Saltängen
kWh/m^3	9,3	12,7	19,6	10,5
kWh/m^2 floor area with daylight	132	79	97	81

Table 5. Heat transmission per volume and per floor area with daylight during a normal heating season. These two aspects give very different ideas of energy efficiency in the buildings.

The electricity needed for lift machinery is twice as much, in Saltängen (0,15 kWh/year, m^2 floor area) cimpared to Tele Data (0,07). But since the total amounts are small the difference is insignificant. With an eight storey building however, this electricity requirement would have been nearly twenty times as high (1.3).

The loss of useful solar heat because the buildings have been grouped around court-yards was also calculated. Models and sundials were used to find shading. To determine when shading takes away useful or surplus heat available solar heat with clear sky for an unshaded room was compared to its net heating requirements.

SMHI have two-storey court-yards, 22x25 m, and Malmens are three storeys, 23x23 m. In both case the loss of useful solar heat was found to be about 15 MWh/year for one court-yard. In Saltängen there are 4-storey court-yards, 19x36 m, and in one such about 33 MWh/year is lost. The total losses of useful solar heat because of court-yards may be estimated to 45, 50 and 120 MWh/year respectively for Malmen, SMHI and Saltängen.

Conclusions

The geometric form has had a significant influence on both energy requirements and qualities of working environment in the case of the office-buildings studied. This is likely to be true also of many other types of buildings like schools, hospitals and laboratories where conditions are similar.

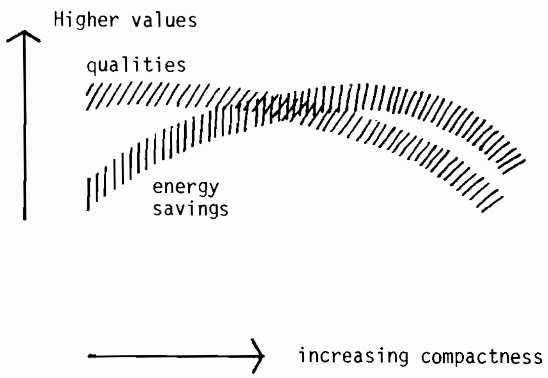


Figure 9. Graphic description of the main trends found. In offices working environment suffers with increasing compactness and extremely slender and transparent as well as extremely compact buildings are unfavourable regarding energy requirements. There is also a shift towards less heat and more electricity needed when plans become deeper which means a higher energy unit-cost.

This study emphasizes the fact that a building and its installations are a whole and the importance that all specialists involved in the design process have a comprehensive understanding of this totality.

Theoretical and Experimental Heat Losses of a Well-Insulated House

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Summary

Insulation was added to a house to give it a theoretical transmission heat loss coefficient of 2.0 kWh/K day. However, a value of 2.6 kWh/K day was obtained from measurements over most of a heating season.

The most important reason for the difference, accounting for about 0.34 kWh/K day, is the disappointing performance of the cavity walls insulated with injected urea-formaldehyde foam. A further 0.14 kWh/K day is accounted for by areas, normally ignored in calculations, which are covered by the edges of internal walls and floors, and the effective areas of edges and corners. A number of minor reasons account for the remaining difference.

Resume

Une maison a ete isolee afin de la donner un coefficient de perte de chaleur par transmission theorique de 2.0 kWh/K jour. Une valeur de 2.6 kWh/K jour a ete realisee experimentalement pendant la plupart d'une saison de chauffage.

On attribue cet ecart a la performance mediocre des murs isoles aux moyens d'injections de urea-formaldehyde (0.34 kWh/K jour), aux pertes de chaleur des surfaces caches par les murs et planchers intereures qui sont normalement ignorees (0.14 kWh/K jour) et d'autres causes subsidaires.

Introduction

The ECRC has six semi-detached test houses representative of much of British housing stock(1). Thermal calibrations showed good agreement between theoretical and experimental transmission heat losses, figure 1. A target was set as shown in the figure of a design transmission heat loss of 1.5 kW, or 2.0 kWh/K day which, for such houses, could be met by having double windows and a U-value of 0.3 W/m^2K elsewhere.

To reach this target theoretically for the already better insulated house (No 16), extra insulation was added as shown in table 1. The wooden framed front and back walls already contained insulation to the full thickness of the studs (90 mm) and could not easily have more insulation applied. To compensate, extra thicknesses were put in the loft, between the joists of the suspended ground floor, and the lower windows were insulated.

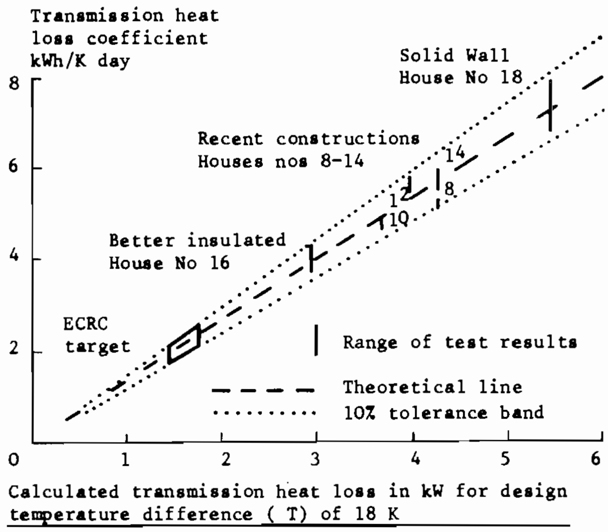

Figure 1: Comparison between experimental and theoretical heat losses for the original ECRC test houses

Table 1: Insulation thicknesses and theoretical thermal transmission values of ECRC House No 16

Component	When Built thickness mm	When Built U-value W/m^2K	Present Tests thickness mm	Present Tests U-value W/m^2K
Gable wall(1)	nil	1.15	75	0.34
Front wall	90	0.43	no change	no change
Back wall	90	0.43	no change	no change
Roof	60	0.48	300	0.13
Floor	nil	0.75	180	0.19
Insulated(2) windows	nil	3.15	50	0.63
Party wall(1)	75	0.33	no change	no change
Normal windows	nil	3.15	no change	no change
Back door and porch	nil	1.04	no change	no change
Front door	nil	2.8	no change	no change

Notes:

(1) Urea-formaldehyde foam injected into the cavities of these brick/block walls. Elsewhere insulation is mineral fibre, between timber joists or studs.

(2) The lower parts of windows were insulated with mineral fibre, amounting to about 4 m^2 of a total of 15 m^2.

This paper gives a summary of the detailed thermal calibration of this house after adding the extra insulation, and puts forward explanations to bring agreement between the theoretical and experimental heat loss coefficients.

Whole House Calibration

Experimentation

The method of calibration was an improved form of that already used to obtain the results in figure 1. As before tests were made with continuous electric heating in each room controlled to give a uniform and constant internal temperature. The house was furnished but unoccupied. Weather data were recorded on site including dry and wet bulb temperatures, windspeed and direction, and insolation on the horizontal plane.

Ventilation rates were measured continuously during the tests instead of using an experimental calibration based on windspeed and direction as before. Solar heat gain was no longer calculated from an experimental calibration, but deduced by a better method of analysing the results.

Theory

The house energy balance without heat storage is:

electric heating (EEN) + solar heating (SEN) = transmission (TEN) + ventilation (VEN) heat losses (1)

It is convenient to work in terms of average daily values (kWh/day) over periods of a week to make the effects of heat storage in the structure negligible.

The electric heating (EEN) is measured. The ventilation heat loss (VEN) is calculated from measurements and the specific heat of air (1.2 kJ/m^3K), and for the house volume of 200 m^3:

$$VEN = 1.6 V\Delta T$$

where V is the ventilation rate in air changes per hour (ac/h) and ΔT is the internal to external temperature difference (K).

The theoretical value of the transmission heat loss can be calculated from the design heat loss, $AU\Delta T$:

$TEN = AU\Delta T \times \frac{24}{1000}$, where A and U are the areas and thermal transmission values of each component.

Re-arranging equation 1, substituting for VEN and TEN, and dividing by ΔT gives:

$$\frac{EEN}{\Delta T} - 1.6 V = 0.024 AU - \frac{SEN}{\Delta T} \quad (2)$$

This equation forms the basis of the graphical analysis of the experimental results. Values of the left hand side are evaluated from measurements, and when there is no solar heating will equal the experimental heat loss coefficient. In practice, there is always some solar heating, and since $SEN/\Delta T$ itself cannot be obtained directly from measurements, what is needed is a parameter representing it which can be calculated from measurements. The most easily obtainable is $SH/\Delta T$, where SH is the measured insolation on the horizontal plane. But better correlations are obtained using $SENG/\Delta T$ where SENG is the calculated solar heat gain through the glass.

Experimental Results

Tests were made during October 1978 to April 1979. Eighteen data sets were obtained, each set being the daily average generally over one week. The results are plotted in figure 2. A linear and a binomial regression analysis were made giving the two correlations shown. The two intercepts at 2.58 and 2.61 kWh/K day were very similar, but significantly larger than the theoretical value of 2.0 kWh/K day, reasons for which are discussed later.

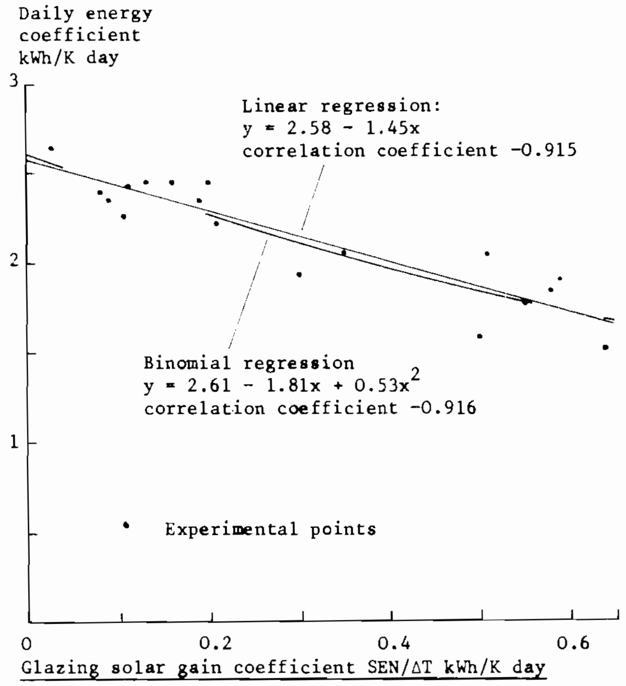

Figure 2: Experimental results and regression lines plotted to obtain transmission heat loss coefficient (the intercept) and solar heating during the tests

Solar Heating

Values of SEN were calculated for all the data sets using the mean intercept value for 0.024AU of 2.595 kWh/K day. For the weekly periods average solar gain varied from about nothing to 12 kWh/day. Daily values would show larger variation than averages over a week.

Over the whole period the average value of SEN was 5.25 kWh/day. The calculated average for SENG was 3.55 kWh/day, a difference of 1.7 kWh/day. This difference can be interpreted as the structural solar heat gain. CIBS[2] procedures were used to calculate SENG taking a solar gain factor of 0.65 for double glazing. The insolation on the vertical surface was obtained from horizontal plane measurements (SH) using curves produced by Basnett[3].

In terms of solar collection efficiency, 5.25 kWh/day is 4.5% of the 117 kWh/day average calculated insolation on the whole exterior of the house. One third or 1.5% is the structural gain which is slightly less than the 2% previously reported[4] based on solar calibration tests.

Component Measurements

Infra-red photography showed considerable non-uniformity of internal surface temperatures, see figure 3, of about 4 or 5 K. Similar photographs in colour showed where to measure heat flows (a) to be representative of a whole component and (b) to help estimate the effects on heat loss of edges and corners between components.

Heat flow measurements were made using transducers consisting of a number of thermocouples in series across a piece of plastic about 0.5 mm thick. Methods of their application and manufacturer's calibration were subjected to laboratory checks.

Experimental U-values were calculated from heat flows and temperature measurements over periods of several days. As far as possible internal, external and structural temperatures were the same at the start and end of each period to eliminate the effects of thermal capcity. The results are summarised in table 2 where they are compared with theoretical values.

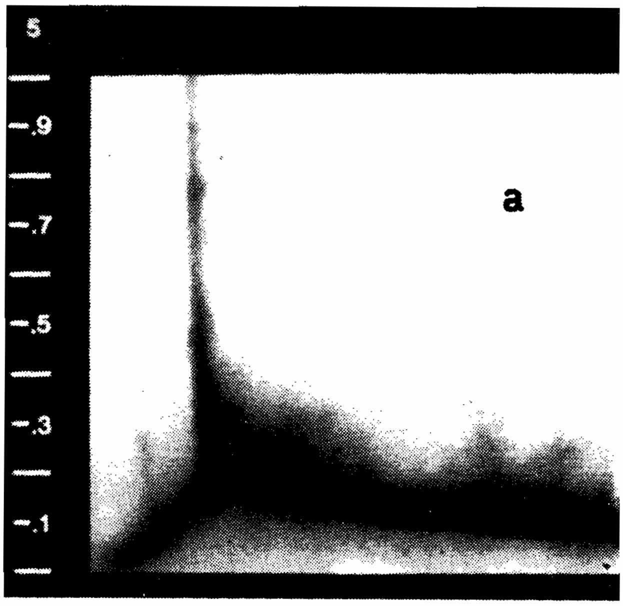

Figure 3: Internal surface temperature non-uniformity shown by the infra-red camera. Also shown is a central (a) and a cold spot (b) position of the heat flow transducers

Table 2: Theoretical and experimental U-values

Component	Thermal Transmission Values (W/m^2K)	
	Theoretical	Average Experimental
Gable wall	0.34	0.57
Front wall	0.43	0.41
Back wall	0.43	0.46
Roof	0.13	0.14
Floor	0.19	0.19
Insulated window	0.63	0.40
Party wall	0.33	0.75
Double glass windows	3.15	3.33
Back door	1.04	1.0
Front door	2.8	not tested

There is good agreement for the uninsulated components and for those insulated with mineral fibre (see table 1). The insulated windows even perform better than predicted. However, the two cavity insulated walls, gable and party, have experimental U-values considerably higher than the theoretical values. The insulation, injected urea-formaldehyde foam, was applied in the party wall when the houses were built in 1970 and that in the gable wall in 1976.

The values given in table 2 are averages of measurements in different positions as well as over several days. Variations in different positions were about ± 20% for the gable wall and ± 35% for the party wall.

Figure 4 shows the state of the foam in the party wall on removing one block measuring 0.45 x 0.22 m. It confirms the existence of extensive cracking in the foam and gaps between foam and wall. The state of the foam in the gable wall has not yet been examined because the wall is to remain undisturbed for further testwork.

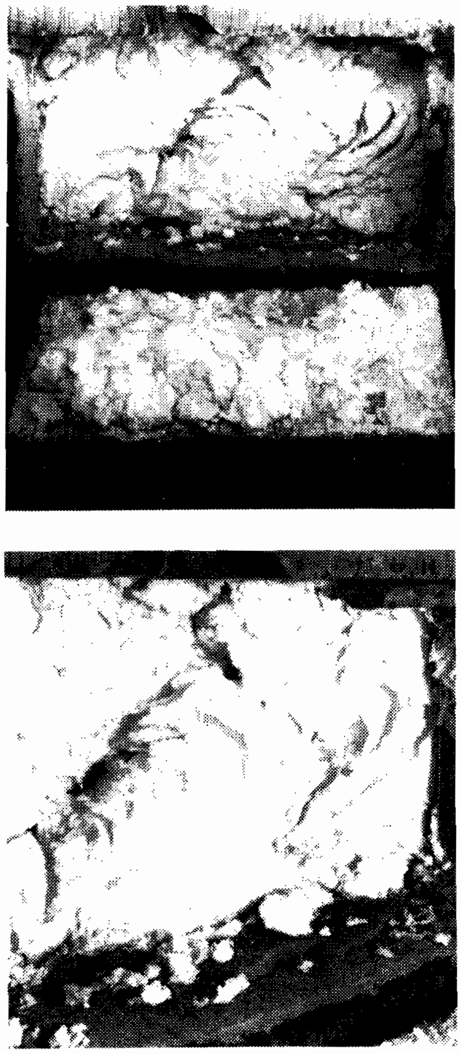

Figure 4: Fissures in urea-formaldehyde cavity wall insulation

It has already been stated[5] that such fissures in foam insulation allow sufficient internal air circulation to affect its insulating properties to give a thermal conductivity of 0.07 W/mK. The CIBS guide book value is 0.038 W/mK and measurements at ECRC confirmed this value for a small piece of foam, without fissures, taken from the gable wall.

If all the differences between the experimental and theoretical U-values is attributed to the foam, then its average in situ thermal conductivity works out to be:

gable wall: 0.095 W/mK

party wall: 0.27 W/mK

The poorer performance of the party wall could be a result of ageing of the foam (installed in 1970) or, alternatively, the relatively better performance of the gable wall (installed in 1976) could be a result of improved materials and techniques. Perhaps other materials in the walls insulate less well than expected to. Results of detailed tests on the gable wall are now being obtained which include measurements of temperature profiles through the wall and are producing values in the range 0.055 - 0.075 W/mK.

Effective Areas

The areas used in conventional heat loss calculations are based on internal room measurements. Extra areas behind the edges of internal walls lose heat, and add between 2% and 10% to the effective areas of the roof, floor and walls.

The extra effective area of the edges and corners can be estimated from the shape factor S:

$$S = 2(ab + bc + ca) + 2.16t(a + b + c) + 1.2t^2$$

where a, b, c, are the internal dimensions and t the wall thickness. The first term is the plane areas, the second is the effective area of the edges and the third that of the corners. For the present tests taking an average thickness of 0.25 m the second and third terms increase the effective area by 3.5%. Experimental values are slightly higher. From infra-red photographs (figure 3) and heat flow measurements gave an increase for the gable wall of around 10%, and about 5% for the front and back walls.

Comparison of Heat Loss Results

Table 3 shows a comparison of heat loss coefficients for each component (a) using theoretical U-values and internal dimensions and (b) experimental U-values and effective areas.

Table 3: Theoretical and experimental component heat loss coefficients

Component	Heat Loss Coefficient (kWh/K day	
	Theoretical	Experimental
Gable wall	0.27	0.53
Front wall	0.17	0.19
Back wall	0.20	0.23
Roof	0.13	0.15
Floor	0.20	0.21
Insulated window	0.06	0.04
Party wall	0.08	0.21
Double glass window	0.81	0.86
Back door	0.05	0.05
Front door	0.12	0.13

The following list summarises the influence of the various factors on the whole house heat loss coefficient:

	kWh/K day
theoretical, conventional calculations	2.0
add areas behind internal walls and floors	2.08
add effect of edges and corners	
(a) theoretical	2.12
(b) experimental	2.14
add experimental window U-value	2.18
add experimental gable wall U-value	2.39
add theoretical loss through party wall	2.47
add experimental party wall U-value	2.60
whole house experimental result	2.59

Conclusions

1. The test house which was insulated to have a transmission heat loss coefficient of 2.0 kWh/K day using normal design methods of calculation was found to have an experimental value of 2.59 kWh/K day from whole house heating tests after allowing experimentally for ventilation and solar heating.

2. Heat flow measurements through all components showed that 0.34 kWh/K day of the difference was due to the disappointing performance of the cavity gable and party walls which were insulated with injected urea-formaldehyde foam. Examination of the foam in one wall showed extensive fissures, and the poor performance is attributed as before[5] to internal air circulation in the foam.

3. A further 0.14 kWh/K day of the difference is accounted for by including in the design calculations the effective areas of the edges and corners and the component areas covered by internal floors and walls.

4. Experimental and theoretical U-values agree where fibrous insulation is applied in the loft, between the joists in the suspended floor and in the timber framed walls.

5. Analysis of the heating test results for net solar heating has produced an average value of 4.5% of the total insolation on the exterior surfaces. Calculation shows 3% to be the heat gain through the glass, leaving 1.5% effective through the opaque parts of the structure.

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Preliminary measurements of the heat losses from an unoccupied house

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Summary

Measurements are being made of the heat losses through the walls, roof and floor of an unoccupied, but regularly heated, house. The floor is insulated with polystyrene boards and the heat fluxes are determined from the temperature gradient across the thickness of the boards. Altogether, nearly five hundred thermocouples are used to measure heat fluxes, air temperatures, surface temperatures and below-ground temperatures. During the preliminary measurements which are described, the house is sealed to prevent the exchange of air between inside and outside and the windows are covered and insulated.

Sommaire

Les mesures s'enregistrent des pertes de la chaleur à travers des murs, du toit et du plancher d'une maison pas habitée mais régulierement échauffée. La maison se calorifuge au moyen des planches de polystyrène, et les flux de la chaleur se déterminent de la gradation de la température mesurée à travers de la grosseur des planchers. En tout, presque 500 thermocouples s'utilisent afin de mesurer les flux de la chaleur et les températures de l'air, des surfaces et des régions souterraines. Pendant les mesures préliminaires, qui se décrivent ici, la maison se cachète pour prévenir l'échange de l'air entre l'intérireur et l'extérieur, et les fenêtres se couvrent et se calorifugent.

Introduction

Estimates are now frequently made of the energy requirements for the space heating of buildings. The purpose is to determine, for example at the design stage, what will be the likely energy requirement of a particular building or, at a national level, to examine the effects upon energy consumption of changes in standards of insulation. Such estimates may be made using simple equations to describe the heat losses from the building fabric or by using sophisticated computer programs which model the non-steady-state nature of the problem. Both approaches require an important but usually imprecisely known allowance for the heat losses due to infiltration and ventilation.

Although the cost implications of these estimates of heat loss may be extremely high there seems little information regarding their accuracy.

This paper is a preliminary report of an experiment designed to correlate measured heat losses from the various structural elements of a house with heat losses calculated using simple procedures or by more complex computer-based methods.

The test house

The test house is probably over 100 years old and has solid walls, some 250 mm thick, made of clay brick. Various extensions had been added over the years and these have been demolished to leave the simple four-room structure as seen in the photograph, Fig.1.

Insulation technique and heat flux measurement

The level of insulation in the house was inadequate by present-day standards and it was decided to insulate the walls, the solid ground floor and the upstairs ceiling using extruded expanded polystyrene board 'Styrofoam'. The walls, chimneys and porch of the house were insulated by fixing insulation boards 50 mm thick to the outside using both mechanical fixing and an adhesive. Pairs of copper-constantan thermocouples were placed, one on either side of the boards, at approximately 1 m

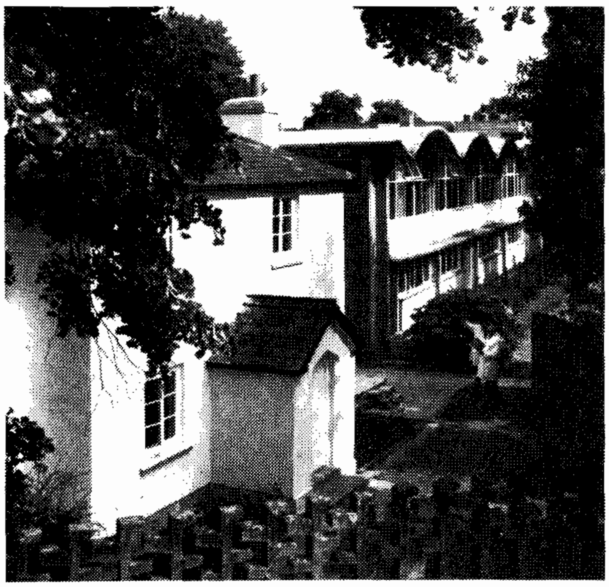

Figure 1. Experimental house.

intervals. The thermal conductivity and thickness of the Styrofoam boards are accurately known and therefore the heat flowing through them at any time can be calculated from the temperature difference between the faces of the boards. Some 320 thermocouples are used to measure the heat flux through the four walls of the house. The insulation board is protected externally by a 6-8 mm thickness of glass-fibre reinforced cement render 'Fibrocem', covered finally by a decorative finish 'High Build'.

The ceiling of the upstairs rooms was insulated with 50 mm of Styrofoam board and about 50 thermocouples used to measure the temperature gradient across these glazing on the inside and 50 mm Styrofoam insulation board fixed behind the windows. The heat flux through these insulated window areas is also measured.

Once a balance is obtained between measured heat input and measured losses then, in later experiments, the heat lost in ventilation can be deduced when doors and windows are allowed to be opened according to some predetermined regime. Similarly the net contribution of the windows will be assessed by removing the aluminium foil and insulation and examining a new heat balance over a long period.

Preliminary test results

Monitoring of the heat losses from the house commenced just before Christmas 1979 but initial problems with the data recording system have meant that no runs of more than 5 days duration have yet been obtained. However, the following results refer to a 5-day period (128 hours) over Christmas where the data were recorded at hourly intervals.

Heat losses through the house fabric

The house is aligned East-West and therefore the various parts of the structure are identified in the following Table 1 according to their orientation.

During this 5-day period, the total energy consumed according to the meter monitoring the electricity supply was 155 kWh. Therefore, there seems to be a deficit on the total measured heat loss of some 22 kWh. This deficit can be reasonably explained by a measured overall increase in temperature of about 1.3°C of the house walls during the 5 days. Calculation shows that the walls (including internal walls) store approximately 18 kWh of heat for 1°C temperature rise. The observed temperature rise of 1.3°C would correspond to an increase in the heat stored in the walls of 23 kWh.

There are indications that the heat losses through the North wall are greater than through the other walls. There seems no immediate explanation for this apart from its orientation. The heat losses from the

Element of house	Area m^2	Heat loss during 5 day period kWh	% of total heat loss	Heat loss kWh/m^2
North wall	36.9	32.9	24.8	0.89
East wall	22.2	17.4	13.1	0.78
South wall	36.2	28.5	21.5	0.79
West wall	24.9	18.7	14.1	0.75
Roof	27.4	25.1	18.9	0.92
Floor (Perimeter*	10.1	4.5	3.4	0.45
Floor (Central	17.1	5.1	3.8	0.30
Chimneys and porch	-	0.5	0.4	-
Total		132.7 kWh	100.0	

* The perimeter area is a strip, 0.5m wide which was measured separately from the rest of the ground floor.

0.5 m wide perimeter strip of the ground floor are 50% higher than from the central area. Perimeter insulation at least would thus seem sensible in a well insulated house.

Early indications are that simple estimates of heat losses based upon assumed U-values may be overestimating actual heat losses. This seems particularly true for the ground floor where the observed losses are only about one third of those based upon I.H.V.E. (2) calculations. It is obviously necessary to monitor for longer periods before firm conclusions can be drawn.

Inside air temperatures - computer modelling

The variation of average inside air temperature in the house during one of the days has been modelled using a computer program which has been described before (3). The program models the heat flow through the house fabric using finite difference techniques but is unable to describe the house construction in much detail. The upper solid line in Figure 4 shows the observed variation of average inside air temperature with time and the lowest solid line shows the outside 'sol-air' temperature. The dotted line is the estimated temperature variation in the house from the computer program. The agreement is reasonably good although the computer method indicates that temperatures fall about 1°C more than they actually do in practice when the heating is off. The computer program indicated an energy consumption of 30 kWh compared with a recorded meter consumption of 27 kWh. However, as has already been indicated, comparisons of energy consumption over short periods are very sensitive to changes in house fabric temperature.

Also shown on Figure 4 is the variation during the day of the total heat flux through the house fabric.

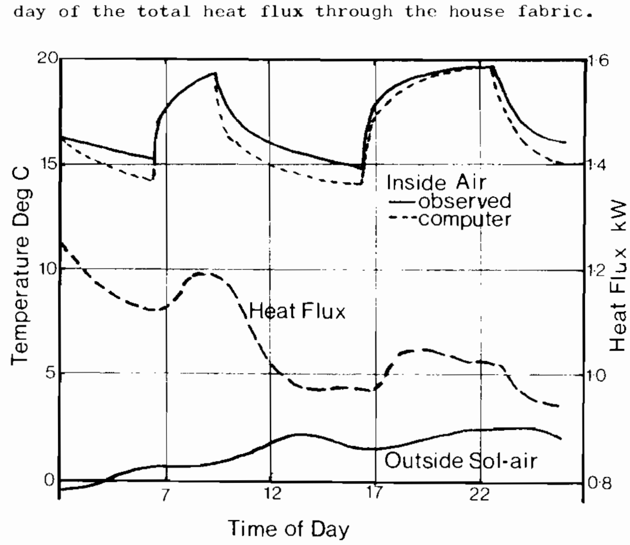

Figure 4. Air temperature and heat flux measurements, together with computed inside air temperatures

Concluding remarks

Measurement of the heat losses from the house by determining the temperature gradient across insulating insulation boards. The solid concrete ground floor was insulated by placing 25 mm thick Styrofoam boards upon it and about 90 thermocouples installed for heat flux measurement. The insulation boards on the floor were protected with a 10 mm thick layer of Fibrocem.

Air, surface and ground temperature measurements

Air temperatures are measured in each room by 8 thermocouples. Four couples measured the air temperature 300 mm above the floor and the other four measure it 300 mm below the ceiling. These thermocouples are radiation shielded. Four measurements are made of outside air temperature using thermocouples and four thermocouples are set in four vertical exposed panels to measure "sol-air" temperature.

The temperature of the ground is measured at five locations at depths of 0.0mm, 250mm, 500mm and 1 m. The five locations lie along a straight line, three locations being inside the house and two outside.

Two measurements of surface temperature are made on each of the six surfaces in each of the four rooms in the house.

Heating regime in the house

Each room in the house is heated by a 750W electric fan-heater controlled by an air temperature thermostat in the room and set at 20°C. Figure 2 shows this arrangement. All the fan heaters are under the overall control of a clock so that they can be switched on or off at set times. The clock is set so that the house is heated from 06.30 until 09.30 and from 16.30 until 22.30. The energy consumed by the fan heater is continuously recorded by a meter reading kWh connected to the incoming electricity supply.

Data collection and analysis

The electrical outputs from a total of 484 thermocouples plus the reading of energy consumed are all passed to a RAPCO data logger and to a micro-computer for initial processing. Because of the large quantity of data and because it is required to obtain readings every half-hour for several months at a time, it is not possible to store all the data for very long. Consequently, some initial data processing is carried out and these data which are stored for later analysis are in summarized form. The initial data processing is done by a Commodore PET micro-computer linked to a floppy disc unit for data storage. Some of this equipment is shown in Figure 3.

Test programme

It was thought necessary, as a first experiment, to establish that the heat fluxes measured did in fact represent, to a reasonable accuracy, all the heat lost through the house fabric. To prove this, it seemed sensible to compare the measured heat input to the house over a long period with the measured heat losses through the fabric. In order to do this experiment it is obviously necessary to make heat losses due to

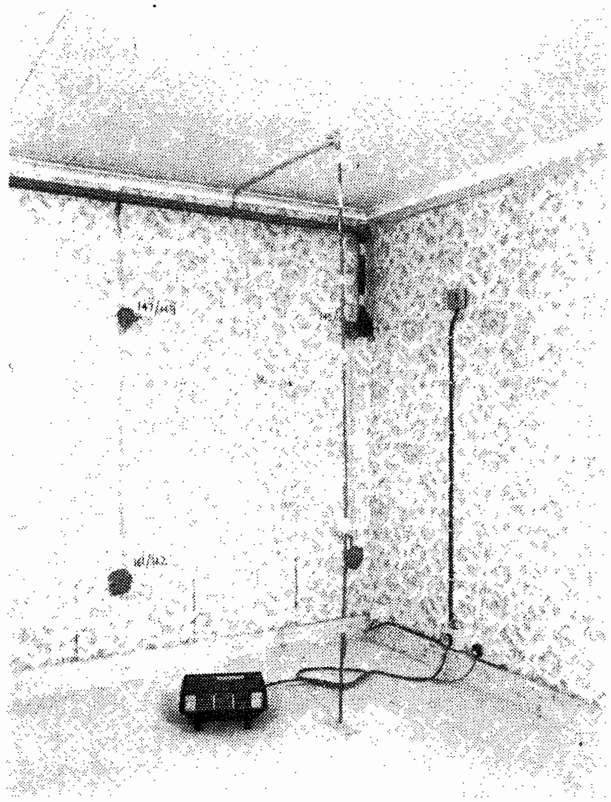

Figure 2 Heating and control arrangement in each room

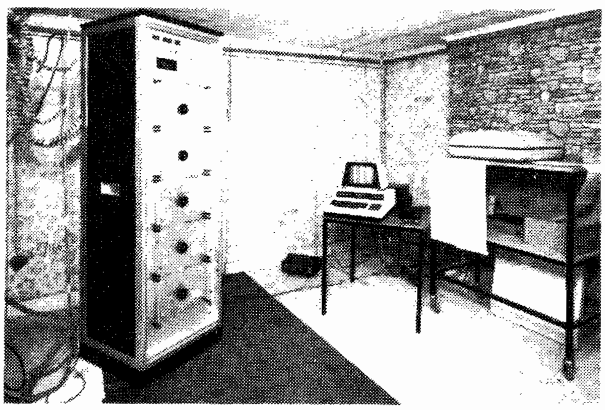

Figure 3. Data collection and processing equipment

air infiltration and ventilation as small as possible and temporarily to eliminate the windows of the house.

Since the house is of solid wall construction with concrete ground floors it is already fairly well sealed against air infiltration but in addition all window frames and door frames, chimney pots, fireplaces etc., have been sealed. Measurements of infiltration rate, by a method developed at BRE (1) which monitors the decay of concentration of nitrous oxide with time, have shown the rate not to exceed 0.1 - 0.2 air changes per hour. Even if this rate prevailed for the whole monitoring period, which is unlikely, the error introduced would not appear large.

Aluminium foil has been used to cover the window

It is noticeable how this is affected by both the inside air temperature and the outside 'sol-air' temperature. The total energy consumed for the day based upon heat-flux measurements is 26 kWh.

board seems to be working well. So far it has only been possible to record continuously for periods of up to 5 days due to initial problems with the data collection system. Despite this, the data seem useful and reliable and are already indicating areas where present calculation methods seem inaccurate. Over the five-day-period covered in this report the measured heat losses were some 22 kWh lower than the heat input to the house. It is thought that this discrepancy is due to an increase in the heat stored in the house during the period.

Estimates of inside temperature variations with time using computer techniques indicate reasonable agreement with the observed behaviour but greater accuracy may be achieved with more sophisticated programs.

It is certain that the data collected from a longer period will prove most useful and, once a heat balance is obtained, enable measurements to be made of heat losses due to ventilation and of the net contribution of the windows.

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Natural Wind Effects on the Infiltration of Low-Rise Buildings

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Summary

Conservation of energy, ventilation need and insulation effectiveness considerations have increased the public awareness of the significance of building infiltration. The present paper examines the effect of wind pressure distribution on the infiltration of low residential and industrial buildings of various geometrical configurations, wall openings and permeability. Internal pressures of scaled building models have been measured in a boundary layer wind tunnel for various wind directions and two roughness conditions representing an open country and a suburban terrain. A computer program has also been developed, which calculates internal pressures and infiltration rates at external building walls, and the results agree with the experimental measurements reasonably well. Air flow rates have also been compared with experimental data from previous studies, and the importance of the use of a correct wind pressure distribution has been shown. Comparisons with the Canadian, American and Swedish Standards have indicated that more parameters have to be incorporated for the determination of infiltration of low-rise buildings.

Resumé

Les considérations sur la conservation de l'énergie, la nécessité de ventilation et l'éfficacité de l'isolation ont accru la conscience du public sur la signification de l'infiltration dans les bâtiments. Cet article étudie l'effet de la distribution de la pression du vent sur l'infiltration dans des bas bâtiments résidentiels et industriels ayant différentes configurations géométriques, ouvertures de murs et perméabilitée. Les pressions intérieures des quelques bâtiments modèles ont été mesurées en soufflerie simulant le vent naturel dans différentes directions de vent et dans deux conditions turbulentes représentant un terrain ouvert et un terrain suburbain. Un programme au calculateur a aussi été développé, qui calcule les pressions intérieurs et les vitesses d'infiltration aux murs extérieurs des bâtiments, et les résultats coincident assez bien avec les expériments. Les vitesses de coulement de l'air ont été aussi comparées avec les données expérimentaux obtenues dans des recherches antérieures et aussi a été demontrée l'importance de l'utilisation d'une distribution correcte de la pression du vent. Les comparaisons avec les standards canadiens, américains et suédois ont indiqué qu'il faut tenir compte de plusieurs paramètres pour déterminer l'infiltration dans les bâtiments de faible hauteur.

1. Introduction

Whereas conservation of energy is the subject of central interest in the world nowadays, not enough information is available regarding heat gains and losses from buildings and wind-generated natural ventilation of housing. In reality, a building may have considerable inherent leakage, as well as the potentiality for large openings due to the presence of doors or windows. As a result, internal pressures and infiltration rates in various building configurations due to wind action may vary drastically.

Although the significance of internal pressures is well recognized, not only for energy considerations but also for structural applications in the wind loading problems, very few studies have dealt with it. Among those that have, only one or two are either full-scale cases or model cases in appropriate atmospheric simulations. A study [1], recently completed, deals with the determination of internal pressures in low residential and industrial buildings with various uniform porosities combined with different wall openings. The present paper compares some of the experimental results of this study with analytically predicted values of internal pressures, and provides data of infiltration rates. Due to the lack of sufficient data on these topics, only limited comparisons with others' findings can be made.

2. Experimental Methodology; Building Models

The experimental measurements have been carried out at the Boundary Layer Wind Tunnel of the University of Western Ontario. The tunnel has a working section about 80 ft long, 8ft wide and 7 ft high. Most of this fetch is required for the natural production of a boundary layer which grows in a manner paralleling the atmospheric process under neutral conditions. The surfaces in the wind tunnel can be changed to represent different terrains. For the tests reported here, two terrain models have been used representing open country and suburban conditions. A picture of the wind tunnel with a model placed at the test section is shown in Fig. 1.

Three basic 1:250 scale models were constructed, all providing variable side-wall and end-wall openings and three background porosities of 0%, 0.5% and 3% of the total surface area. All models are sealed underneath. The two "small" models represent 80 x 125 ft buildings with 1:12 and 4:12 roof slopes. The "large" model, shown in Fig. 2 diagrammatically, represents a building geometrically similar in plan and having 2.5 times the plan dimensions. The small models could be tested at 16, 24 and 32 ft eave heights, whereas the large model could be tested only for a 32 ft eave height. The background porosity or permeability of the envelopes of models was achieved by twelve rows of circular holes of two different sizes. These small and large holes were evenly distributed in three zones (at the middle and both ends of each wall and the roof) and were left open or closed in various symmetrical combinations so that

Fig. 1. The Boundary Layer Wind Tunnel of the University of Western Ontario with the Small Model at the Test Section.

a uniform permeability could be attained. Although this simulates porosity in a manner somewhat different to reality, local effects were found to be small, and hence for pressure measurements at locations, a reasonable distance from the holes, the difference is not likely to be significant. The chosen values of background porosity ratios (0-3%) appear to include most cases of practical interest.

All models are equipped with pressure taps on both the internal and external surfaces. Each tap is connected to a pressure transducer through a length of plastic tubing 1/16" I.D., which contains a restrictor to optimize its frequence response characteristics. Scaling and similarity requirements for wind tunnel determination of external and internal pressures have been discussed in detail in references 1 and 2. Such similarity considerations lead to the determination of velocity and time scales of the order of 3:10 and 1:100 respectively, for typical full-scale design speeds. The

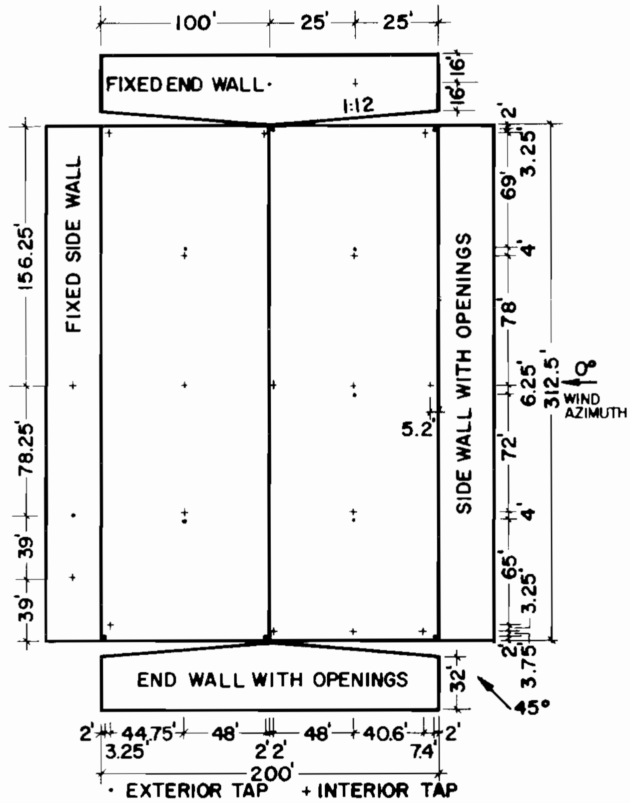

Fig. 2. Exploded Plan View of the Large Model Showing the Position of Pressure Taps.

air speed in the wind-tunnel above the boundary layer is about 45 ft/sec.

3. Analytical Predictions

Under steady conditions of external pressures acting on the building envelope, the air entering a building should balance the air leaving the building. Thus, internal pressures depend on the external pressure distribution and the air-leakage characteristics of a building. Internal pressures for all building configurations of this study have been calculated as follows :

Each of the six faces of the building envelope (four walls, windward roof side and leeward roof side) has been divided into three parts, for each of which the air-leakage equation [3] can be written as :

$$q_j = \pm CA_j(|\bar{P}_{e,j} - \bar{P}_i|)^\eta \qquad (1)$$

in which q_j is the air leakage per unit time for the j^{th} part; C is a constant of proportionality; A_j is the open area of the j^{th} section; $\bar{P}_{e,j}$ is the mean external pressure at the j^{th} part; $\bar{P}_i$ is the mean internal pressure; and η is the flow exponent. The sign in the right-hand side of Eq. 1 indicates the direction of the flow. A positive sign has been used for inward air leakage.

In the fully-developed turbulent flow, a value of 0.6 is commonly used for the proportionality constant C, and a value of 0.5 for the flow exponent. As the flow becomes less turbulent, both C and η increase and approach unity in the case of laminar flow. Full-scale measurements in buildings [4,5] indicate values of η ranging between 0.5 and 0.8. In the present work, three combinations of values for C and η parameters have been used, namely :

C	η
0.6	0.5
0.8	0.667
1.0	1.0

The air balance equation

$$\Sigma_j q_j = 0 \qquad (2)$$

has then been formulated by using external pressure measurement results and has been solved numerically through a computer program to yield the internal pressure $\bar{P}_i$ for each building configuration and terrain roughness.

After this calculation, equation 1 was used to derive the air leakage per unit time for each section. The total building infiltration rate was then found by considering the algebraic sum of all partial air leakages. Results have been expressed in the well-known air change number form by dividing the total air leakage with the building volume for each case.

4. Results and Discussion

Pressure measurement and calculation results have been expressed in coefficient form as :

$$C\bar{p}_e = \frac{\bar{P}_e - P_o}{\frac{1}{2}\rho \bar{V}_E^2}, \quad C\bar{p}_i = \frac{\bar{P}_i - P_o}{\frac{1}{2}\rho \bar{V}_E^2} \qquad (3)$$

in which $\bar{P}_e$ and $\bar{P}_i$ are mean external and internal pressures respectively; P_o is the static pressure of the free stream outside the boundary layer height; $\bar{V}_E$ is the mean wind speed at eave height; and ρ is the air density.

The principal highlights of the experimental measurements and analytical results can be summarized as follows :

i) External pressure coefficients have been found insensitive to both background porosities and wall-opening ratios. It is expected, however, that external pressure distribution will be affected in cases for which the configuration of the openings permits large flows through the building.

ii) Internal pressures fluctuate significantly, but their overall magnitudes are generally less than that of the local external pressures. The overall gust factor - the ratio of peak pressure to the mean - is roughly two in open country exposure.

iii) The fluctuations in internal pressure show little or no spatial variation, except in regions close to dominant openings. This is illustrated in Fig. 3 where typical time traces of pressures from two internal taps located at opposite ends of the large building are shown. The traces are virtually identical. This characteristic is quite general for all various configurations examined and leads to the conclusion that properties of the internal pressure can be given without reference to the particular location within the building.

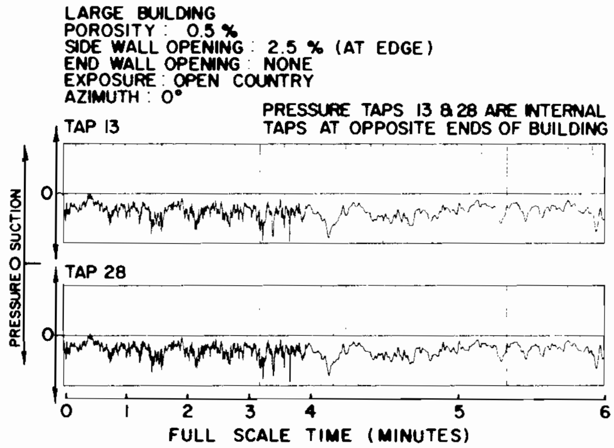

Fig. 3. Simultaneous Time Traces of Internal Pressures for Two Different Taps.

iv) A high correlation between external and internal pressures has been found in all cases.

v) Largest internal pressures occur when the wind direction is perpendicular to the wall with dominant openings.

vi) For windward openings, although internal pressure coefficients are generally positive, cases with high background porosity combined with small openings produce zero, or slightly negative coefficients. Typical results of measured and analytically predicted mean internal pressure coefficients are shown in Fig. 4 for both larger and smaller building models. It can be seen that for wall openings of significant size (more than 50% of the wall area) the internal pressure coefficients become essentially independent of the background porosity. The lower the background porosity, the smaller the necessary size of the wall opening needed to make the internal pressure coefficients insensitive to further increases of the wall opening.

The analytically predicted values of $C\bar{p}_i$, shown also in Fig. 4, agree well with the experimental results. Calculated internal pressure coefficients have been found by using C = 0.8 and η = 0.667. Very similar results, however, have been obtained by using other combinations of C and η values referred to in section 3. For instance, in the case of fully turbulent flow, $C\bar{p}_i$ values were found slightly higher, the largest difference being 0.02; in the case of laminar flow $C\bar{p}_i$ values were a little lower, the largest difference

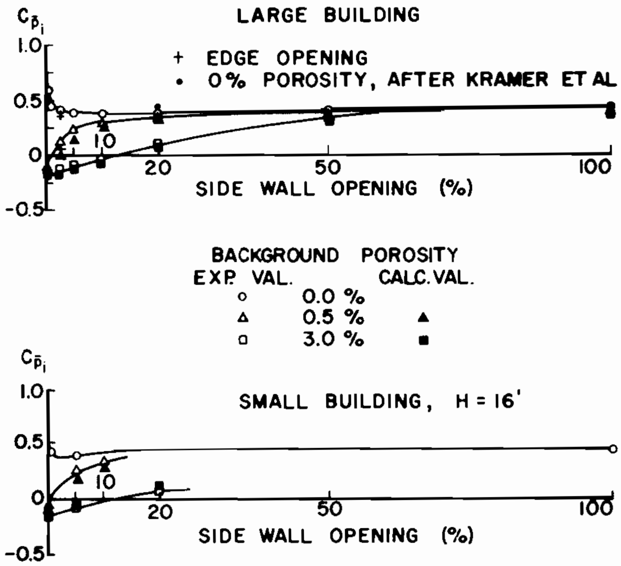

Fig. 4. Measured and Predicted Mean Internal Pressure Coefficients for Various Side Wall Openings and Background Porosities - No End Wall Opening, 1:12 Roof Slope, Open Country Exposure, 0° Azimuth.

found was 0.06. The above comparisons show that model building internal flows have a rather dominant turbulent character.

In the case of 0% background porosity, experimental measurements show that internal pressure coefficients have a constant value, that of external wall pressure coefficient for all different side wall openings. Some increase of $C\bar{p}_i$ values appears for very small wall openings, but this is perhaps due to experimental inaccuracies since the slightest leakage between the model and the outside of the wind tunnel may contaminate the data under conditions approaching nominal building impermeability. Experimental results from a study carried out by Kramer et al [6] for an impermeable model building with 20% side wall opening agree very well with the present data. No significant difference has been noticed as far as the internal pressure coefficients measured or calculated for the larger and smaller buildings.

vii) When the dominant openings are at the rear of the building, and the windward wall is closed (azimuth 180°), the internal pressures are generally negative and are not very sensitive to the size of wall openings or to the background porosity. Typical results are presented in Fig. 5 for measured and calculated $C\bar{p}_i$ values for all configurations of the tested large building. The largest negative $C\bar{p}_i$'s are almost equal to the external pressure coefficients measured on the leeward walls. Again, a good agreement between measured and calculated values is apparent.

viii) Infiltration rates have been found very sensitive

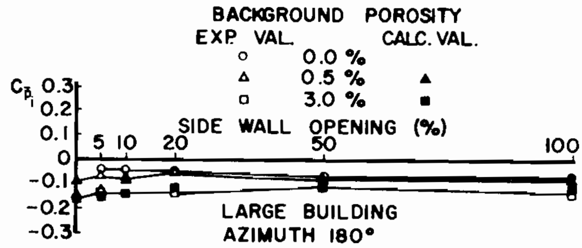

Fig. 5. Measured and Predicted Mean Internal Pressure Coefficients for Various Side Wall Openings and Background Porosities - No End Wall Opening, Open Country Exposure, 180° Azimuth.

to internal pressure variation.. Air change numbers have been calculated by using the internal pressure predicted and the procedure explained in section 3. Results are presented in Fig. 6 for two background porosities and both 0° and 180° azimuths for a mean wind speed of 10 ft/sec at building eave height. In case of windward openings, the higher the background porosity, the higher the necessary opening ratio to make the air change number insensitive to further increase of openings. In contrast, for leeward openings, the air change number remains almost constant for each permeability regardless of the wall opening. The latter has been predicted since internal pressures have values very similar to the external wind pressures on the leeward wall for all opening ratios.

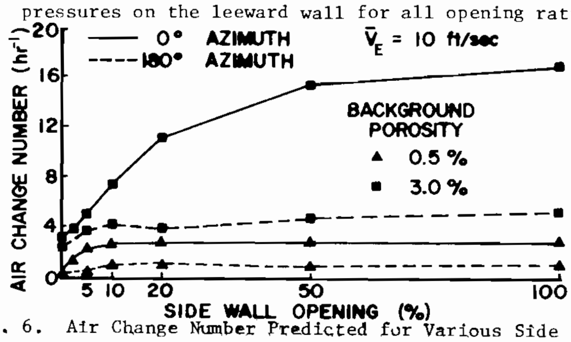

Fig. 6. Air Change Number Predicted for Various Side Wall Openings and Background Porosities - No End Wall Opening, Large Building, Open Country Exposure.

ix) For higher values of background porosity, the air change number varies drastically with wind speed variation, whereas for small building permeabilities air change number remains almost constant. Figure 7 shows the variation of air change number in the case of large building with no wall openings. Data have been calculated for various permeabilities ranging from 0.01% to 0.5% and for wind speeds at eave height up to 40 ft/sec, since these are the cases of main practical interest. For typical permeability values of well-insulated buildings, the air change number is very low.

x) Although internal pressure coefficients have been found significantly higher for the suburban exposure, the actual internal pressures and, consequently, infiltration rates are not very different

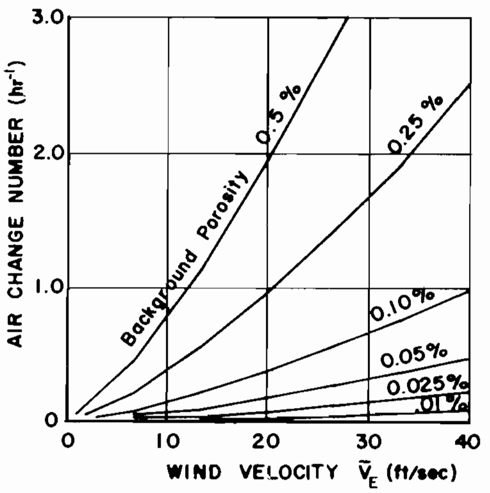

Fig. 7. Background Porosity Effect on Air Change Number - No Wall Opening, Large Building, Open Country Exposure, 0° Azimuth.

from those calculated for the open country exposure. This is due to the reference velocity at eave height which is significantly lower in the case of suburban exposure. As a result, air change numbers given in this paper can be considered representative of various terrain roughnesses.

5. Applications - Comparisons with Codes and Standards

Roofs of low-rise buildings have, in general, larger areas than external walls. Given that the highest wind suctions dominate on flat or low-sloped roofs, significant air exfiltration may take place through small cracks, skylights, etc. there. It has been found that in cases of no sufficient openings in the windward wall, infiltration may occur in the leeward wall of a low building. The latter is normally neglected in most standards, but it may affect the heating and air-conditioning load of leeward spaces of low buildings.

A direct comparison between standards, codes of practice of different countries and the present results cannot be carried out since infiltration rates depend not only on the wind action but also on temperature differences (stack or buoyancy effect). The Canadian Code [7] suggests for mechanically ventilated residential buildings a minimum of 1 ac/hr, whereas Swedish specifications recommend a minimum of 0.5 ac/hr [8]. American standards [3] specify minimum and recommended values (the latter are about 50% higher than the former) for buildings serving different purposes. Minimum values, however, range up to 10 ac/hr. If the Canadian requirement has to be satisfied only by wind-caused natural ventilation Fig. 7 shows that for wind speed of 10 ft/sec at eave height, a porosity higher than 0.5% would be needed (assuming that all openings are closed). This is a rather high value when compared to permeability measurements of typical Canadian houses carried out by Tamura [4] indicating values ranging between 0.02% and 0.09%. It is important, however, to consider the stack effect in the calculation as well.

A recent study by Peterson [9] based on the statistical analysis of infiltration measurements for typical Canadian and American dwellings, suggests values of 0.1 ac/hr for tightly constructed houses and 0.2 ac/hr for loosely constructed houses. These values have been calculated for wind speed of 10 ft/sec at eave height under the assumptions that all openings are closed and that inside and outside temperatures are equal. Results of the present study for the 16' high small building, which corresponds to the average geometry of buildings considered in Peterson's study, have led to values of 0.12 ac/hr for tightly constructed houses and 0.45 ac/hr for loosely constructed houses. Again, the stack effect has to be considered to attain values corresponding closer to reality.

6. Conclusions and Recommendations

In summary, the following conclusions can be made :

i) Mean internal pressures measured in the wind tunnel agree well with analytically predicted values calculated by using external pressures and typical air leakage constants. Internal flow simulation also appears to be adequate.

ii) Accurate evaluation of internal pressures is necessary to calculate building air infiltration.

iii) For low-rise industrial buildings, air exfiltration from the roof appears to be very large and infiltration may occur through all four walls.

It is suggested that further experimental work be carried out by measuring internal pressures in model buildings with horizontal and vertical partitions for the evaluation of air flow patterns inside low buildings. These patterns affect strongly the ventilation efficiency of these buildings. Also, as long as temperature stratification inside buildings cannot be avoided, it appears that the energy efficiency of the building depends not only on the infiltration effect, but also on the temperature of the exfiltrated air. Further study is required on the interaction between wind and stack action and their effect on the performance of mechanical ventilation systems.

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The thermal insulation-index of buildings

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Summary

Early 1980 a new edition of the Dutch standard NEN 1068: "Thermal insulation of buildings" will be published. In this edition the thermal insulation-index (I_t) will be introduced as a quantity that characterizes the level of thermal insulation of a building as a whole.
Two buildings that have the same I_t-value can be considered equally well insulated, no matter how much they may differ in size and shape. This paper explains how the thermal insulation-index has been developed.

Résumé

Une nouvelle édition de la norme néerlandaise NEN 1068: "l'Isolation thermique de bâtiments" sera publiée au commencement de 1980. Cette édition introduira l'indice de l'isolation thermique (I_t) comme une quantité qui caractérise le niveau de l'isolation thermique d'un bâtiment en totalité.
Deux bâtiments ayant le même I_t peuvent être regardés comme ayant été tout aussi bien isolés, n'importe leurs différences de dimensions et de forme. Cet article-ci explique comment on a développé l'indice d'isolation thermique.

The mean coefficient of heat-transfer of a building

Let Φ be the heat flux through a structure with area A, that is caused by a difference in ambiant temperature ΔT, than the following relation holds:

$$\Phi = A \cdot k \cdot \Delta T \quad (1)$$

The constant of proportionality k, as defined by this relation, is the coefficient of heat-transfer or - in short - the "k-value" of the structure. The lower the k-value, the better are the insulating properties of the structure.
The quantity of heat passing the structure per K difference in ambiant temperature is found from:

$$\frac{\Phi}{\Delta t} = A \cdot k \quad (2)$$

The following notation will be used:

structure	weighing factor	area	k-value
groud-level floor	a_1	A_1	k_1
roof	a_2	A_2	k_2
windows	a_3	A_3	k_3
exterior walls	a_4	A_4	k_4

The transmission-loss of a total building per K difference between indoor and outdoor ambiant temperature equals:

$$\Sigma aAk = 0{,}5\ A_1k_1 + A_2k_2 + A_3k_3 + A_4k_4 \quad (3)$$

Due to the fact that across the ground-level floor there is a smaller temperature difference than across the other structures, the weighing factor a_1 is (arbitrarily) fixed at 0,5 as for the other factors a figure of 1 is maintained.

Further it is convenient to write:

$$A_1 + A_2 + A_3 + A_4 = A_o \quad (4)$$

Subsequently the mean coefficient of heat-transfer ($\bar{k}$) of a building is defined by the relation:

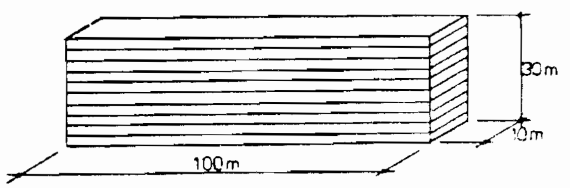
$$\bar{k} = \frac{\Sigma a\ A\ k}{A_o} \quad (5)$$

In the quantity $\bar{k}$ the heat-transmission properties of the components of a building have been brought together into one figure. The question arises whether this quantity is suitable for comparing the thermal insulation of different buildings and subsequently for being used from a point of view of standardization.
To answer this question the $\bar{k}$-value will be calculated for 4 different types of buildings (A, B, C and D) and for 4 different levels of thermal insulation (a, b, c and d).

Types of building

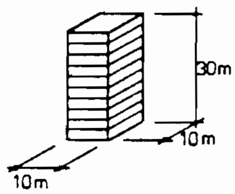
For all buildings it is supposed that the window area (including frame and sash) is 20% of the floor area.

A. Sliced-shaped building (10 stories)



leghth :	100 m	A_o =	8600 m^2
depth :	10 m	V =	30000 m^3
height :	30 m	A_o/V =	0,29 m^2/m^3

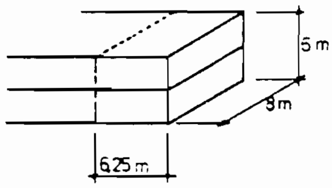
B. Tower-building (10 stories)



lenght : 10 m
depth : 10 m
height : 30 m

A_o = 1400 m^2
V = 3000 m^3
A_o/V = 0,47 m^2/m^3

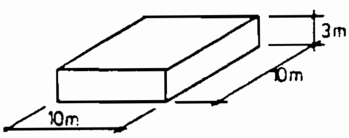
C. One-family house (at the end of a row)



lenght = 6,25 m
depth = 8 m
height = 6 m

A_o = 223 m^2
V = 300 m^3
A_o/V = 0,74 m^2/m^3

D. Bungalow



lenght = 10 m
depth = 10 m
height = 3 m

A_o = 320 m^2
V = 300 m^3
A_o/V = 1,07 m^2/m^3

Levels of thermal insulation

The levels of insulation: a, b, c and d are defined by the k-values of the different structures as is shown in the table below.

Structure	k-values in W/(m2·K)with insulationlevels			
	a	b	c	d
1. groudfloor	2,2	1,3	1,3	0,8
2. roof	1,2	0,7	0,7	0,4
3. windows	5,7	5,7	4,5	3,0
3. outer walls	1,7	0,7	0,7	0,7

Level a corresponds with a situation that was common practice in the Netherlands in the period preceding the energy crises. Level d is about the maximum that can be reached within the traditional forms of Dutch house-building.

As an example the calculation of $\bar{k}$ is illustrated for type B-building in the table on the next page.

Structure	weighing factor a (-)	A (m^2)	a.A.k (W/K) for insulation levels			
			a	b	c	d
1. ground-floor	0,5	100	110	65	65	40
2. roof	1	100	120	70	70	40
3. windows	1	200	1140	1140	870	600
4. outer walls	1	1000	1700	700	700	700
$\Sigma a.A.k = A_o\bar{k}$ =			3070	1975	1705	1380
$\bar{k}$ (W/(m^2·K))			2,19	1,41	1,22	0,99

The total result of these calculations is presented in figure 1, giving $\bar{k}$ as a function of A_o/V. It appears that $\bar{k}$ varies with A_o/V for each level of insulation. A $\bar{k}$-value of 1,1 W/(m^2·K) would - in case of a building of type A - indicate a good insulation level. In case of a bungalow however, that $\bar{k}$-value would create much less enthousiasm.

In view of these results $\bar{k}$ does not appear to be the most suitable quantity to be used for standardization-purposes.

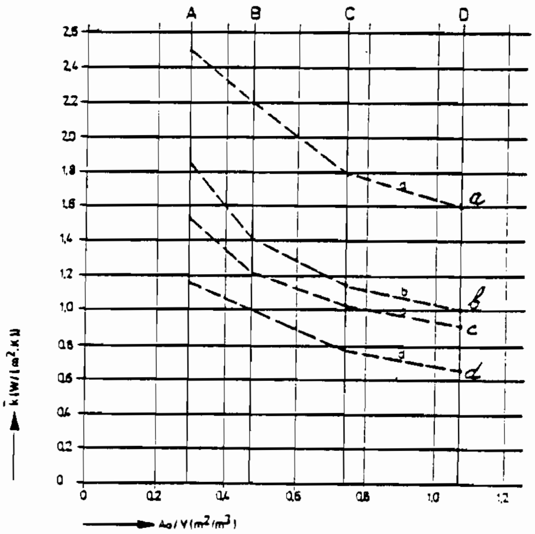


Figure 1. The mean coefficient of heat-transfer as a function of A_o/V

Calculations analogous to the ones described in the foregoing have been carried out on a representative sample of Dutch houses and appartment-buildings that have been completed in recent years [1]. The values that were found were plotted in a ($\bar{k}$ - A_o/V)-diagram. For each of the different insulation-levels a "cloud of dots" was obtained that could reasonably be approximated by a hyperbole*. These hyperboles form together a system that can well be expressed in one equation:

$$\bar{k} = \frac{0{,}2 + 0{,}25\ B}{A_o/V} + 0{,}22 + B \qquad (6)$$

The parameter B in this relation indicates the level of insulation. The higher the value of B the higher $\bar{k}$ will be. In fact B could be considered as a kind of transmission-index of the building. The following numerical values appear:

insulation-level a: B≈1,0
insulation-level d: B≈0,2
Scandinavian insulation-level B≈- 0,1

The thermal insulation-index

However, the parameter B is not the most suitable to serve as characteristic for the thermal insulation of a building

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* It should be observed that the dotted lines in figure 1 fit into that picture reasonably well.

as a whole. One reason among other things is that the (Dutch) building industry prefers a quantity of which the numerical value will rise when the insulation of a building is improved. One could of course choose for the complementary value (1-B). In that case the insulation-level a would correspond with an index-value of ≈ 0 and the Scandinavian insulation level with an index-value of ≈1,1. The decimals in this indexation however are quite meaningless. There is no objection whatsoever to select the "0-point" and the scalar unit of the index in a more practical way. If one chooses (15-20 B) instead of (1 - B), the "0-point" of the scale corresponds roughly with the upper limit of the poorest class of insulation according to the Dutch standard of 1964; the insulation-level d on the other hand would yield an index-value of about 10. The scalar unit is such, that a difference of 1 index point is just about to be considered significant.

Solution of B from relation (6) and substitution of the obtained value in the expression: (15 - 20 B) yields:

$$15 - 20\,B = \frac{77{,}6\,\frac{A_o}{V} - 80\,\frac{A_o}{V}\,\bar{k} + 31}{4\,\frac{A_o}{V} + 1} \qquad (7)$$

Finally the thermal insulation-index (I_t) of a building is defined by the following formulae:

$$I_t = \frac{80\,\frac{A_o}{V}\,(1 - \bar{k}) + 30}{4\,\frac{A_o}{V} + 1} \qquad (8)$$

The quantity I_t, as defined by (8), pretends to be principally independant of A_o/V, because B is independent of A_o/V. This will be verified by calculating I_t for the four buildings A, B, C and D and the four levels of insulation a, b c and d that have been considered previously. The results of these calculations are given in figure 2.

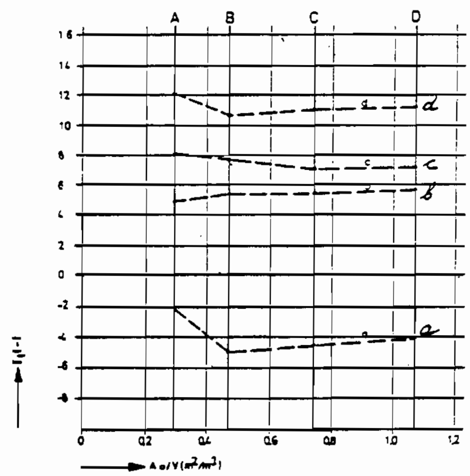

Figure 2. Thermal insulation index as a function of A_o/V

It can be observed that the four insulation-levels are not represented by exact horizontal lines.
However, any expectations in that direction would have been out of place from the beginning.
It appears that (for the better levels of insulation) the variation of I_t within one level is restricted to approximately one scalar unit. This seems to be just acceptable.
With I_t a quantity is obtained that makes it possible to compare directly the levels of thermal insulation of buildings that may largely differ in size and shape.
It should be emphasized however that a high value of I_t does not automatically mean a good indoor-climate at a low energy-consumption of the building in question.
For a "thermally-consious" design and execution of a building also other factors and their mutual connection are of importance.
These factors however lie beyond the scope of this paper.

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SUBJECT SUJET 4B

Sanitation problems. Solutions by dry and non-waterborne systems and by infiltration

Problèmes d'hygiène. Solutions sèches, systèmes ne demandant pas d'eau et infiltration.

DISTRIBUTION ET EVACUATION DES EAUX LES PROBLEMS DES PAYS EN VOIE DE DEVELOPPEMENT

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Coordonnateur du CIB W 62.

Résumé

En introduction au thème «sanitaire» de la sujet 4B, on rappelle très brièvement les besoins des pays en voie de développement dans le domaine de la distribution et de l'évacuation de l'eau, les problèmes qui se posent à ces pays et les formes d'aide qu'ils attendent de la part des pays industrialisès.

Summary

On introducing the subject *Sanitary problems* one must be aware of the demands and requirements of the developing countries regarding water supply and sewage and also consider what remedial measures the industrialized countries can contribute with in this specific field.

Introduction

En 1978, le groupe de travail W 62 du CIB: «Distribution et évacuation de l'eau dans les bâtiments» a inscrit à son programme les problèmes d'aide aux pays en voie de développement.
Depuis cette date, une enquête a été effectuée auprès des membres du CIB pour connaître les besoins de ces pays et pour définir les actions que le W 62 pourrait entreprendre, et des contacts ont été pris avec l'Organisation Mondiale de la Santé (OMS).
Ce théme a été inscrit à l'ordre du jour du séminaire du W 62 qui s'est tenu en France en novembre 1979 et a fait l'objet de plusieurs communications de représentants de pays en voie de développement. Ce sujet sera l'unique thème du séminaire du W 62 qui doit se tenir en AFRIQUE DU SUD en septembre 1980.
Le présent papier se propose, sur la base des renseignements recueillis depuis deux ans par le W 62, de faire un tour rapide des problèmes des pays en voie de développement dans le domaine de la distribution et de l'évacuation de l'eau.

Les besoins

Dans ce domaine, deux aspects doivent être considérés: celui de l'alimentation en eau et celui de l'élimination des déchets tels que: eaux polluées (eaux usées et eaux-vannes) et excréments humains.

Bien qu'il y ait beaucoup d'eau sur la terre, celle-ci est néanmoins une matière relativement rare puisque moins de 1 % est directement utilisable par l'homme. De plus cette eau est inégalement répartie ce qui fait que beaucoup de pays, généralement des pays en voie de développement, n'en ont pas en quantité suffisante.
Ceci se traduit par l'utilisation d'eau contaminée et de mauvaises conditions d'hygiène qui sont à l'origine de nombreuses maladies: choléra, typhoïde, dysenterie, leptospirose, etc. Dans les domaines de la distribution d'eau et de l'assainissement beaucoup a été fait, mais beaucoup reste à faire, comme le montrent les tableaux I et II qui ont été établis d'après les renseignements donnés dans un rapport de l'Organisation Mondiale de la Santé.
Sur le tableau I, par exemple, on voit qu'en 1975 62 % de la population des pays en voie de développement, soit environ 1250 millions de personnes, ne disposaient pas d'une distribution d'eau convenable, et que 68 % de cette même population n'avaient pas à leur disposition de moyens valables d'évacuation des excréments humains.
Si l'on considère les populations rurales, ces pourcentages sont encore plus grands puisqu'ils sont respectivement de 78 % et de 86 %.
Le tableau II reprend, en les complétant, certaines données du tableu I et donne les objectifs 1980.
Le problème est tel que la conférence de l'Eau des Nations Unies a demandé que la décade 1981–1990 soit désignée: «Décade Internationale pour l'alimentation en eau potable et l'hygiène».

Tableau I – Estimation de la population pourvue d'une distribution d'eau publique et de services d'évacuation des excréments dans les pays en voie de développement, en excluant la Chine.
(basée sur une étude à mi-décade en 1975)

	Population desservie convenablement (raccordements aux immeubles ou accès raisonnable)				
		1970		1975	
	Zone	en millions	% de la population	en millions	% de la population
Distribution d'eau	Urbaine	315	67	445	76
	Rurale	180	14	310	22
	Total	495	29	755	38

	Population desservie convenablement (égouts publics ou systèmes domestiques)				
		1970		1975	
	Zone	en millions	% de la population	en millions	% de la population
Evacuation des excréments	Urbaine	340	72	435	75
	Rurale	115	9	195	14
	Total	455	25	630	32

Tableau II – Objectifs pour 1980 à la lumière des progrès réalisés pendant la période 1971–1975.

	Pourcentage de la population urbaine desservie									Pourcentage de la population rurale avec accès facile à de l'eau «sûre»			Pourcentage de la population totale desservie	
	Par raccordements aux immeubles			Par distribution publique			Total (raccordements aux immeubles ou distributions publiques)							
	Réalisé		Objectif 1980	Réalisé		Objectif 1980	Réalise		Objectif 1980	Réalisé		Objectif 1980	Réalisé	
	1970	1975		1970	1975		1970	1975		1970	1975		1970	1975
Distribution d'eau	50	57	68	17	19	23	67	76	91	14	22	16	29	38

	Pourcentage de la population urbaine desservie									Pourcentage de la population rurale avec dispositif adéquat			Pourcentage de la population totale desservie	
	Par raccordement à un système d'égoûts publics			Par systèmes domestiques			Total (raccordements à égoûts ou systémes domestiques)							
	Réalisé		Objectif 1980	Réalisé		Objectif 1980	Réalisé		Objectif 1980	Réalisé		Objectif 1980	Réalisé	
	1970	1975		1970	1975		1970	1975		1970	1975		1970	1975
Evacuation des excréments	28	25	38	(44)	(50)	56	72	75	94	9	14	24	25	32

L'eau et les dechets

Entre le moment où l'eau est captée, utilisée, évacuée, puis rejetée ou réutilisée, il se déroule un certain nombre d'opérations qui sont schématisées sur la figure 1.

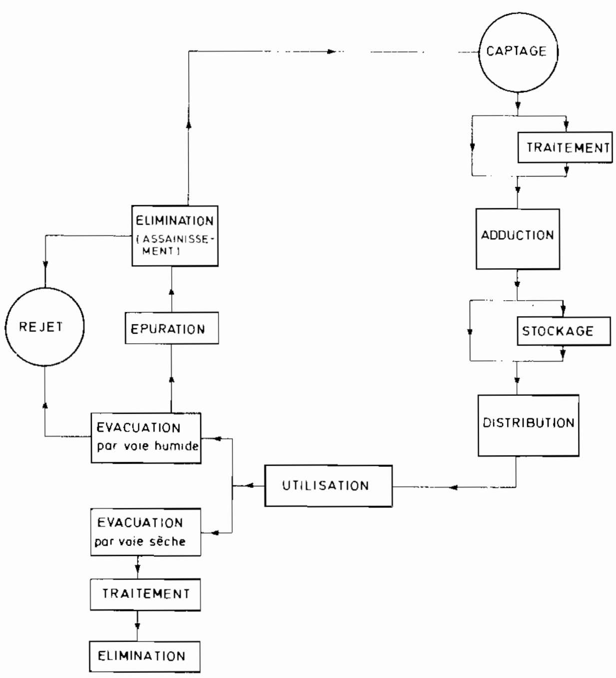

Figure 1

Les problemes

Dans les pays en voie de développement, on rencontre des problèmes à tous les niveaux de la «chaîne» représentée sur la figure 1. Nous ne les aborderons pas tous car cela nous entraînerait trop loin et sortirait du domaine du W 62. Nous nous en tiendrons donc à la distribution, à l'utilisation et à l'évacuation.

Dans les villes et les agglomérations, la distribution est très similaire à celle que l'on rencontre dans les pays industrialisés, c'est-à-dire que l'eau est fournie directement à l'endroit de l'utilisation. Dans les zones rurales et dans certaines zones urbaines, le probleme est different. Il s'agit d'avoir des points d'eau «sûre» qui soient d'un acces raisonnable à un ensemble d'utilisateurs, ce qu'on peut résumer en disant que, dans ce dernier cas, «l'usager va vers l'eau» alors que dans le premier cas, «l'eau va vers l'usager».

Par «eau sûre» l'OMS entend une eau de surface traitée ou une eau non traitée mais non contaminée telle que celle que l'on peut trouver dans des sources, des forages protégés et des puits sanitaires.

Par «accès raisonnable», l'OMS entend, en zone urbaine, une fontaine (ou tout autre dispositif équivalent) située à moins de 200 m d'une maison. Dans les zones rurales, l'accès raisonnable implique que la maîtresse de maison ou les membres de la famille n'aient pas à passer une partie importante de la journée à aller chercher l'eau nécessaire à leurs besoins.

Les mêmes problèmes se retrouvent pour l'évacuation et le traitement des excréments humains. Dans les villes et les agglomérations les techniques utilisées sont du type «assainissement par voie humide», comme dans les pays industrialisés. Par contre, dans les zones rurales où l'eau est rare, de telles techniques sont difficilement envisageables. D'autres solutions doivent être trouvées.

En plus de ces problèmes essentiels qui sont liés au manque d'eau et tout particulièrement d'eau potable, il doit être tenu compte également d'autres facteurs qui interviennent plus ou moins selon les pays: ressources financières insuffisantes, manque de main d'oeuvre qualifiée, faible niveau technologique, absence de motivations communautaires, infrastructures inexistantes, régimes politiques instables, . .

Possibilités d'aide

L'enquête effectuée auprès du W 62, pour savoir quelle aide pourrait être apportée aux pays en voie de développement, a montré que la majorité des gens voyaient mal ce qu'il y avait à faire et ce qui pourrait être fait. Elle a permis néanmoins de définir un certain nombre d'actions:

· *Diffusion des connaissances:* Les pays en voie de développement veulent avoir connaissance des travaux de recherche effectués dans les différents instituts. Mais ils souhaitent:

- des rapports de recherche clairs, indiquant bien les résultats acquis;
- des rapports de synthèse lorsque plusieurs recherches ont été effectuées sur le même sujet;
- des échanges entre les instituts travaillant dans le même domaine;
- la mise sur pied de programmes de recherches communs entre pays développés et pays en voie de développement.

Etablissement de règles techniques

Beaucoup de pays n'ont pas de règlementations ou de documents normatifs (normes, cahiers des charges, règles de calcul) et prennent ceux de pays industrialisés. Mais l'adoption pure et simple de ces documents est une erreur. Ils souhaitent une aide pour que des documents plus simples et mieux adaptés à leurs besoins soient établis.

· *Travaux de recherche*

Pour être efficaces, ceux-ci doivent satisfaire à plusieurs conditions:

- être effectués à la demande et pour les pays en voie de développement: c'est à eux de définir leurs besoins et non l'inverse;
- tenir compte des situations géographiques, climatologiques, économiques, socio-culturelles de ces pays, de leur environnement et de leur mode de vie. Beaucoup de problèmes en particulier sont des problèmes de société (mode de vie, countumes, . . .). Il est difficile de changer brutalement des habitudes ancestrales.

  Comme le souligne Mr. BALLANCE, de l'OMS:

  «A disposal system that requires periodic removal of the accumulated excreta is a non-starter in those areas of the world where the handling of excreta is cultural taboo». (Un système d'évacuation qui nécessite un enlèvement périodique des excréments amoncelés n'est pas valable dans ces régions du monde où la manutention d'excréments est un tabou culturel).
- tenir compte que ces pays souhaitent des installations sanitaires peu coûteuses, fiables et durables, faciles à mettre en oeuvre et à entretenir avec la main d'oeuvre locale, utilisant si possible des matériels ou des matériaux pouvant être fournis ou fabriqués sur place afin de limiter les frais d'importation et de transport, et de favoriser l'industrie ou l'artisanat local.

Plus concrètement, il a été souhaité des travaux de recherche sur:

- les canalisations en matières plastiques,
- les sanitaires préfabriqués sous forme de «blocs»: bloc-eau, bloc-douche, bloc-WC, . . . et blocs combinés,
- des robinetteries robustes et économiques: robinets de chasse, robinets à fermeture automatique . . .,
- des dispositifs d'évacuation des matières fécales par voie sèche
- etc.

Conclusions

Ces quelques considérations montrent qu'il y a beaucoup à faire pour les pays en voie de développement dans le domaine de la distribution et de l'évacuation de l'eau dans les bâtiments. Si l'on veut aboutir à des résultats, il faut qu'il y ait collaboration étroite entre les pays industrialisés et les pays en voie de développement, en ne perdant jamais de vue les caractéristiques socioculturelles des utilisateurs finaux: il est plus facile d'adopter les techniques que de changer les hommes.

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SOLUTION BY DRY AND NON-WATER-BORN SYSTEM AND BY INFILTRATION

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Summary

A brief survey is given of various alternative on-site wastewater systems which are or have been in use in Norway. The presentation is mainly related to rural conditions. Various toilet systems and methods for infiltration of waste water in soil are discussed. Technical descriptions of the various systems are found in other papers forwarded to this congress [1], [2].

Twelve main types of toilets (not the water closet) are treated here. Eleven of these create private and/or environmental hygienic and pollution problems which make them less suited for extended, regular use. The single most promising system is the biological toilet. With regard to the requirements set by the World Health Organization for an ideal toilet system, the biological ones compete very favourably with other systems. Three systems for soil infiltration of waste water are presented. Natural infiltration in large masses of soil works satisfactorily. However, due to shallow masses of soil, most locations in Norway need an artificial sandfilter trench system. Correctly built and used this system is quite effective. Both natural and artificial solutions may be combined with resorption trenches during the plant growth season.

An integrated solution based on these alternatives for a rural settlement of ten houses is presented.

Introduction

In my country, as well as in several others, there has in recent years been a growing interest in new alternatives to solve the domestic or sanitary waste water problem. In my opinion, the established method, based on the function of a central sewage plant connected to the source of pollution by a sewer pipe – water transportation – system, has not been open to serious and objective discussion. This traditional system has been regarded as an obvious solution to an increasingly difficult problem.

As investigations have made clear that several types of sewage plants have been operating very inefficiently, the interest in alternatives has increased. The lowest purification effects are normally found in small sewage plants from some hundred to a few thousand p.e., and especially in cases where the load varies greatly either daily or seasonally. Simultaneously the high building costs of a traditional sewage system in sparsely populated areas have become apparent. Futher, there is increasing interest in establishing small rural settlements which can be located more freely related to existing or planned municipal sewage systems. These ideas have, at least in Norway, pushed forward some new thinking around the possible use of new alternatives.

Limits for this presentation

It is necessary to point out that the future picture in this field is not painted only in black or white. The situation is not simply that you are either for the use of water closets or against it. The situation at present is much more differentiated, and for the subsequent discussion the following limitations are set:

1. The use of the well-known water closet will not be further discussed. However, it must be pointed out that in urban areas and in locations where sewer systems can be built reasonably; this is probably the best solution today.
2. The discussion is based on conditions in Norway at present.
3. The discussion is mostly restricted to conditions in rural districts.
4. The technical descriptions of the solutions are given in two separate papers in this Congress by my colleagues Dag M. Guttormsen, on non-water-born toilets [1], and Rolv Kristiansen, on soil purification systems for wastewater [2].
5. Consequences of the use of alternative toilet systems in developing countries will be only briefly discussed in this paper.

Today's situation in Norway

Let us first of all briefly review the present situation in Norway. Approximately 30% of the population lives in rural areas under such circumstances that single houses or small groups of houses need individual on-site waste water treatment systems [3]. Until a few years ago the following distribution was characteristic of the situation in Norway: 1) approximately 20% of the population had sanitary installations connected to a public sewer system, and 2) approximately the same percentage of the population did not have water closets. The alarming conclusion of these figures is that approximately 60% of the Norwegian population have water closets not connected to a public sewer system. This implies that excrement and urine from around 2 000 000 human beings are passed to soil and water systems without any form of purification treatment. A prognosis up to year 2 000 predicts that every year, 6 000 new homes will be built in scarcely populated areas.

In addition there are at present ca. 250 000 cabins scattered throughout the country. This number is expected to increase by 7 000 per year. Most of the cabins are not connected to any sewer system at all. In light of this we find it important to find alternative systems to the water closet and centralized sewage treatment plants – alternatives which in a hygienic and environmentally acceptable way take care of those domestic wastes which in the future, according to governmental authorities, can not be expected to reach public sewer plants.

It must be stressed that the closet wastes are only one important part of the domestic waste water. After separation of this material in a closed, alternative toilet system, there must be satisfactory, on-site disposal methods for the rest of the waste water. In this connection a short presentation of systems based on natural or artificial infiltration in soil media will be given.

Effluent reduction when separate toilet systems are in use

One person produces about 1.25 l of urine and 250 g feces per day. This is equivalent to approximately 110 g of organic material determined as dry matter. Around 14 g of this matter is nitrogen and 2 g is phosphorous. The latter element is normally the limiting factor for growth in Norwegian fresh water systems. In addition 6–15 l of water is used to flush the water closet after use. By using a non-water-born, closed system to collect the closet wastes separately, the uncontrolled and unwanted effluent from residences and cabins in rural areas can be drastically reduced.

A series of registrations performed by Kristiansen and Skaarer [4], show that the total volume of waste water was reduced by approximately 50%, due to water reduction, in residences where biological toilets were in use. Further, the mean total output of dry matter was reduced by 74%, while the reduction in suspended dry matter was ca. 65%. The output of nitrogen was reduced by 88% by the use of a closed toilet system.

Interesting effects are obtained on the output of phosphorous. By changing to a biological toilet the load of phosphorous in the waste water may be reduced by 48%. If a family in addition changes from using a phosphate-containing to a phosphate-free detergent a mean reduction as high as 83% can be obtained. The relative content of orthophosphate is approximately constant under the different conditions. This means that changing the habits in the daily household routines may reduce the output of phosphorous to a level comparable to the optimum results obtained after municipal sewage treatment.

An example may illustrate the consequences for a lake system receiving waste water. The largest lake in Norway is Mjøsa. It has been calculated that the yearly input of phosphorous to the lake is on the order of 430 metric tons [5]. It has been found urgent to reduce this yearly supply to approximately 1/3, to stop the increasing euthrophication of the lake. This will be achieved by building sewage plants in connection with cities and other urban centres, by treating the industrial wastes separately, and also by imposing some restrictions on farming. However, the output from scattered residences in the area should also be reduced by at least 1/2 to achieve the common goal of phosphorous reduction. Referring to the above mentioned measurements, this could be easily achieved by allowing people to use closed toilet systems (for example biological ones); and by simultaneously motivating the population to, at least partly, use phosphate-free detergents.

We all know that feces and urine may provide possibilities for transfer of pathogenic organisms. Several epidemic diseases are due to *Salmonella*-infections, and polio- and hepatitis viruses, as well as parasites, occur only rarely in Norway today. However, the growing tourism from all parts of the world calls for special caution in this field.

If the toilet wastes are collected in some kind of closed system to avoid distribution of material directly into soil or water the pollution load and the health risk are greatly reduced. To prevent spreading of pathogenic micro-organisms, vira and parasites, the collection must be combined with some kind of sanitation of the material.

Consequences of the use of different toilet systems

We will now try to evaluate in some detail the systems which to our knowledge are in use today [6]. This is done very briefly in this context, but the main environmental consequences of each group of toilets are shortly discussed. For technical details the reader is referred to the paper of Guttormsen [1].

GROUP 1. Collection of untreated toilet wastes

1.1. *Old-fashioned latrine* with collection of the material in a pit or heap below the seat. If materials have to be removed they are normally disposed of on the owner's land.

1.2. *Latrine with small containers.* The containers, which are placed below the seat, are either designed for reuse after the wastes are collected or are disposable. These containers are small and are handled easily by one or two persons.

1.3. *Latrine with large containers.* The wastes are collected in containers of at least 3 000 l capacity. In this case a water closet with reduced water consumption may be used. If the water consumption is reduced to 1.2 l per flushing, a 3 000 l tank could receive material from approximately 2 000 visits before having to be emptied.

1.4. *Vacuum toilets.* Water is used not as a transport medium, but only for cleaning of the closet bowl. The amount per flushing can consequently be reduced to 1–2 dl. A 3 000 l tank can consequently receive wastes from 5–6 000 visits before it must be emptied.

1.5. *Piston toilet.* A piston near the bottom of the closet presses the wastes down to a collection tank. This is done automatically when the closet is closed after use. Small amounts of water are used for cleaning. The capacity is similar to the vacuum toilet, but in this case the tank must be placed directly below the toilet seat.

1.6. *Toilets with circulating cleaning liquid.* After the toilet is used a valve is opened in the bottom of the bowl and the material falls down into a tank. The cleaning water is held in a separate small container, flushes the empty toilet bowl, and circulates back to the container. The same liquid is used for a certain period. When it has become dirty it is passed on into the collection tank. A similar system is based on the use of specifically refined, clear oil which is circulated in the system. In this case the cleaning liquid is not kept in a separate cistern, but the oil and the wet material are continuosly separated in the tank itself.

1.7. *Freeze toilets.* The material is collected in a bag or small box which is placed at –15 to –20 °C. As the material is frozen it is protected against futher degradation and no bad odour is developed. For the user's comfort the upper part of the toilet must be heated to a reasonable temperature.

1.8. *Packing toilets.* The material is collected in a stocking of plasticfilm. The plastic is delivered from a casette, is moved over the bowl of the closet, and each portion of wastes is enclosed in a small part of the stocking by welding. These operations are performed automatically. The small packets are collected in a bag which normally takes 40 portions.

Practical considerations of the use of toilets of GROUP 1

Except for the old-fashioned latrine the material in all these types of toilets is collected in some kind of container. The material is in its original form, is not treated in any way, and must consequently be handled with extreme care to avoid spreading pathogens and causing other environmental difficulties. Practice has shown that these systems will not function satisfactorily if the public is given the responsibility of the final handling of the material. It must consequently be based on municipal collection and adequate further treatment. Such treatment is either lacking or is difficult to establish. These systems are generally not recommended in Norway.

GROUP 2. Toilets with sanitary chemicals

Toilets of this type can be very simple. A bucket is filled with a small amount of a solution containing a disinfectant, usually formalin or sodium hydroxide. The system can also be one where the solution circulates. The purpose of the disinfectant is to hygienize the material and to prevent degradation as long as the material is in the bucket. This system was in wide use in Norway until a few years ago. Due to increasing hygienic and toxification problems, combined with pollution effects, these systems are no longer recommended for use in Norway.

GROUP 3. Direct treatment of the wastes in the toilet

3.1. *Incineration toilets.* The wastes are burnt to ashes in a chamber within the toilet at temperatures over 800 °C. The energy source is either electricity or oil. The toilet is relatively expensive to buy and in use. In addition the installation must meet official specifications for fireplaces. Mainly due to serious environmental odour problems, the system is not recommended.

3.2. *Biobed toilets.* The waste material is to be broken down in a system based on a combination of chemical treatment and degredation by added micro-organisms and enzymes. This system has not been sold in Norway, but tests show that it is not suited for use at least under our climatic conditions.

3.3. *Biological toilet.* It is not possible in this short presentation to go into detail about the biological function of these systems. Let me only point out that the decomposition which we try to establish in a biological toilet is identical to the process going on in the compost heap in the garden [7], [8], [9]. The start material in these two cases seems apparently very different, but, and this is their common denominator, in both cases it consists of naturally-produced, partly easily degradable, organic material which is the carbon and energy source for the processes going on. To ensure an active and effective composting it is recommended that some soil be added to the toilet before the first use. In this way a necessary inoculum is brought into the system from the very beginning.

The following is a very brief survey of the different types of biological toilets which are or have been on the Norwegian market.

A. *Large box-type toilets.* For various reasons this type is no longer recommended. It does not fulfil the basic requirements for a biological toilet.

B. *Large sloping-floor-type toilets.* Several of these toilets have developed a functional design which make them well fit for use.

C. *Large toilets based on other technical solutions.* This is a very heterogenous group of toilets. Some have adopted the idea of reactor composting, others have developed separatory or adsorbtive systems. In evaluating the group as a whole we may conclude that none yet function as they should.

D. *Small toilets with a grating.* The unit is divided into two chambers by a horizontal grating. A heating element is placed either below the wastes or in the back of the toilet. In this system there is need for a power supply both for heating and for ventilation. These models are designed to be placed directly on the bathroom floor and have a very restricted capacity.

E. *Small toilets with a harrow.* The two parts of the composting unit are in this case separated by a more or less vertical wall. The primary compost chamber, which is heated electrically, is equipped with a harrow. The harrow can be driven by a handle outside the toilet or by a motor. Systems of this kind have proven to function satisfactorily and are recommended under certain circumstances.

F. *Small systems based on other principles.* As far as we know only one toilet falls within this category. This toilet does not at all function as a closed system, as surplus of liquid has to be drained off continously. Consequently, this system does not fulfil the requirements set to this type of toilet.

Practical considerations of the use of biological toilets

The biological toilet functions primarily as a closed system. In addition material is degraded in the toilet. This

process needs an air supply, and is consequently a composting process. Due to degradation and evaporation a very substantial volume and weight loss is obtained. The material is simultaneously hygienized and can be removed from the toilet after a certain period of time and disposed of without any risk. Several of these systems are recommended for use in Norway and interest in these alternatives is rapidly increasing.
Finally some remarks on the common name, «biological toilet». Different names are used such as compost toilet, moulding toilet and humus toilet. By using the prefix biological we want to make it clear to the user that the function of his new toilet alternative depends on maintenance of a biological process. Certain conditions beneficial to such activities must be maintained in the system. Of course we want people to know the consequences this will have for the individual user.

The use of biological toilets in developing countries

The ordinary flush toilet cannot solve the problems of excreta disposal in developing countries [10]. Although we cannot expect to transfer the types of biological toilets used in Norway today directly to the poor countries the principles could be adopted. The climate in several countries is certainly much better fitted for effective biological processes than is our cold climate. To succeed in obtaining functional biological systems in poor countries it is a must that persons with a strong biological background are engaged actively in this development. This has not yet been the case.
Is it worthwhile to intensify the work along these lines? At least it can be interesting to compare the results hitherto obtained by the use of biological toilets with the «Ten Commandments» for an ideal toilet system developed by the World Health Organization (WHO).

Claim	Result
1. The surface soil shall not be contaminated	+++
2. There shall be no contamination of ground water that may enter spring and wells	+++
3. There shall be no contamination of surface water	+++
4. Excreta shall not be accessible to flies or animals*	+
5. There shall be no handling of fresh excreta; or when this is unavoidable, it shall be kept to an absolute minimum	+++
6. There shall be no odours	++
7. The system shall be simple and inexpensive to construct	+
8. Maintenance of the system shall be simple and inexpensive	++
9. Little or, if possible, no water shall be used for the transport of wastes	+++
10. As much as possible of the nutrients in the wastes shall be recycled and used profitably on the soil	+++

* Flies are controlled effectively by using pest strips.

With respect to these commandments the biological toilet system seems to be a large step toward obtaining the ideals put forward by the WHO.

Use of soil for on-site treatment of waste water

If the waste water is to be disposed of in the soil, Norway has regulations and directions as to how this can be done. The local health council is given the responsibility that these directions are followed [11].
The waste water is initially passed through a system of septic tanks, mainly for sedimentation purposes. The necessary septic tank volume is reduced if the closet wastes are collected separately. Three different systems are at present in use in Norway and they will be shortly treated in the following. For technical details the reader is referred to the paper of Kristiansen [2]. It must be pointed out that the application of these solutions is restricted to limited areas with up to 7 residences or cabins.

1. *Infiltration in the ground*

This system requires permeable soil suitable for infiltration, at a depth of at least 1.0 m below the lowest point of the infiltration trench. The level of the groundwater should at all times be below the bottom of the trench. The vertical distance to the ground water should if possible be at least 0.5 m. The significant variation of the groundwater level throughout the year should be taken into consideration. The localization of the infiltration system in relation to sources of drinking water, surface water, neighbours and common traffic is regulated.
The waste water is transported from the septic tank through a closed pipe to the infiltration trench. The length of one infiltration pipe should not exceed 25 m. The horizontal distance between two parallel pipes should be at least 2 m. For infiltration ordinary drainage tubes are normally used.
The infiltration must be performed under frostfree conditions. The necessary depth can be reduced by using insulation material on top of the pipe. The pipe is placed in a 20 cm thick layer of coarse gravel. The infiltration pipe should end in an areation vent protruding at least 50 cm above ground level.
Natural infiltration in the ground is accepted in Norway as an effective on-site waste water treatment system. However, due to special topographical and geological conditions in Norway only around 5% of the homes and cabins build in rural areas can take advantage of this system.

2. *Artificial sandfilter trenches*

If an area is not fit for infiltration in the ground an artificial sandfilter trench can be built. Transport from the septic tank to the trench is the same as in the case of infiltration. If more than one trench is necessary, they have to be built parallel to each other, at least 2 m apart. The length of one sandfilter trench should not exceed 25 m. A one-family residence with a water closet must have a 20 m trench. For a cabin with a separate toilet system the necessary length is reduced to only 5 m. From the sandfilter trench the treated waste water is led by a closed pipe to a water recipient. The infiltration pipe is placed in a 20 cm thick layer of coarse gravel. The trench construction must be such that danger for freezing at this level is eliminated. From the infiltration pipe the waste water passes a 75 cm thick filter of sand of specified composition, and is finally collected by a drainage pipe at the bottom of the trench. This drainage pipe is embedded in another layer of 20 cm of coarse gravel.

There has been some doubt as to the practical value of this system. Low purification efficiency has been reported in too many cases. However, if the system is properly built it is our conviction that it is an interesting alternative for on-site waste water treatment.

3. *Use of resorption trenches*

This system takes advantage of the capacity of the plant cover to absorb both water and nutrients. Consequently, the resorption system will only function during the plant growth season. The recommendation for use is restricted to cabins, preferably in the summer. The length of the infiltration pipe connected to one cabin waste water system shall be at least 10 m, preferably distributed on two 5 m long parallel trenches. If the system is built for all-year functioning it must be combined with an infiltration or artificial sandfilter system, which works in the periods of the year when the resorption trench is blocked by frost.

The resorption pipe, which is an ordinary drainage pipe, is placed at a depth of 40–50 cm. To increase the water-holding capacity of the trench the natural ground masses are often substituted by more suitable material, for example a mixture of gravel and peat.

Experience with this system is limited, but without doubt it can show excellent results under the right conditions.

An integrated system for use of biological toilets and on-site soil treatment systems for waste water. An example from Danskerud, Aas County, Norway

This research project is a co-operation between the Norwegian Building Research Institute (NBI), the Central Institute for Technical and Industrial Research (SINTEF), and the Agricultural University of Norway (NLH). NLH has the responsibility for the investigation of on-site waste water systems. For this project, ten single-family residences have been built in a cluster. All ten houses have installed biological toilets. Eight of these are of the large sloping-floor-type, two each of four models. The last two are of one type of small toilets with harrow.

The rest of the waste water (grey water) is treated by different forms of artificial sandfilter trenches and by resorption. As the soil layer in the whole area is very shallow, natural infiltration could not be used in this connection.

The experiences with this experiment is very promising. The waste water systems seem to function satisfactorily after some minor modifications. The biological toilet systems, although presenting some difficulties at the beginning, now seem to have stabilized themselves, and the persons involved seem to find the systems satisfactory.

The difficulties have mainly been connected with accumulation of liquid, especially during our very cold winters. This has been overcome by equipping the toilets with an inside, underneath heating element. Further, adequate ventilation of the toilets has been hard to obtain in some cases.

It is important that the use of biological toilets be taken into consideration already during blueprinting of the house. Experience so far indicates strongly that a biological toilet designed for use in an all-year residence must be equipped in such a way that biological activities are maintained within the toilet even in climatically unfavourable periods of the year.

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Does alternative refuse, water and sewage systems offer new possibilities for town planning?

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Introduction

In 1975 EFEM arkitektkontor started research on alternative RWS (refuse, water and sewage) systems. The project was supported by a grant from the Swedish Council for Building Research. The project was triggered off by an assignment from Härryda, a suburban commune in the Gothenburg region, in connection with the planning for a large group of second homes which the occupants have converted into permanent homes over the years. Both the problems and the solutions have proved to be of interest in a much wider context than the special problems of areas reserved for second homes. The need for alternatives to the conventional solutions to refuse, water and sewage services has been documented in connection with both housing improvement and development projects.

The aim of this research and development has been to investigate the technical possibilities offered by small-scale technique for solving present-day planning problems. During the course of this work we have carried out surveys and case studies in a housing area. We have taken pains to obtain a detailed knowledge of the people living in the area, their houses and the geography of the area in order to understand the social, economic, ecological, cultural and political possibilities of using small-scale RWS technique.

This report starts by describing the general value of small-scale technique adapted to local conditions and certain fundamental aspects we have found important. In the next section we present different planning situations. The selection is based on adaptation and development of the potential resources of the area in terms of the ecosystem, people and buildings. The ultimate aim of the research is to support the development of local culture and contribute to sound, systematic urban development and a healthy relationship between town and country.

RWS SYSTEMS, URBAN REBUILDING AND ECOLOGY

In this discussion on RWS, refuse, water and sewage supply, we will endeavour to broaden the perspective so as to include two problems that are likely to be of decisive importance for future town planning: the ecological and resource management aspect, and urban rebuilding and the conditions for town and country development.

TECHNICAL SUPPLY HAS ECOLOGICAL IMPLICATIONS!

The local ecosystems involves an interaction between different organisms to utilize energy and nutrients, build up organic material and break down organic waste into nutritive substances which can be taken up and re-utilized by the plants.

Local authorities' decisions on land utilization must in future take basic ecological laws into consideration. Man must learn to adapt this metabolism to the metabolism of the earth at all levels.

This means, for example, that breakdown of material produced must be included in the total planning process so that the material is recycled or returned to the earth. It also means that cultivable land and other factors of potential value for primary biological production must be carefully preserved and damage must be repaired as fast as possible. Forests, lakes and other watercourses must be treated with the same respect.

A community uses energy and consumes natural resources. This is called the community's metabolism. A living cell, an organism, a local ecosystem and the earth as an ecosystem all use so-called exergy for their metabolism. Exergy is the "useful" energy which can be extracted from a system. Exergy is thus present in forests, arable land, rivers, lakes and boulder ridges.

It is no longer sufficient merely to carry put research aimed at increasing our understanding of ecological laws and relationships. We must also take positive action and put our theoretical knowledge to practical use for the benefit of the community.

Planning based on ecological thinking does not represent a completely new planning process. It may be said to constitute an extension of what is already being done in many places. It also constitutes coordination and systematization of measures and investigations normally carried out in different sectors of planning. The innovations in this approach are

- firstly, that natural conditions are systematically surveyed,
- secondly, that the survey is a multidisciplinary process and the results are published in suitable form,
- thirdly, that the ecological survey is coordinated with such other surveys as may be necessary, e.g. social, economic and technical investigations,
- fourthly, that the data collected are utilized to give a balanced and comprehensive picture of the potential value of the area concerned for different purposes,
- fifthly, that the possible ecological consequences of various alternative plans are analysed and presented, and
- sixthly, that planning based on an ecological approach does not give the "best solution" but only various "possible solutions" as an objective basis for decision.

FREE TOWN PLANNING FROM THE DICTATORSHIP OF THE LARGE-SCALE SUPPLY SYSTEM!

The conflict between local and central planning is one of the fundamental problems of the planning process. During the last few decades supply systems have increasingly governed town and country planning. An exaggerated concentration on large-scale regional systems for waste water and sewage disposal, and systems of planning adapted to these, have had a devastating influence on local authorities' possibilities of renewing existing building. Large parts of the boroughs surrounding large towns and cities have been declared prohibited building land for want of suitable technical solutions and planning. Alternative RWS systems offer a possibility of changing this situation and achieving balanced urban and rural renewal.

The alternative RWS systems are based on the "three-in-one" principle, according to which the refuse, water and sewage problem is always regarded as a single entity. Only solutions directed at the whole complex can be accepted in the long-term perspective. In our view, this approach will have to be adopted in the long run for planning of both new housing and renewal of existing building. This need not necessarily lead to a decentralized building structure. Increased local supply should instead be regarded as an opportunity for freer location, where the choice of building structure is dictated by factors other than earlier investment in technical supply systems.

If local solutions are a technically feasible possibility, the local authorities can instead give priority to economic factors and resource management when choosing between coordinated local and regional solutions. In most municipalities the building is recentred around one or more focal points. Most conurbations are planned for development in a certain direction, within which technical and social service is successively extended. Existing building clusters within the development zone are incorporated in the service systems of the conurbation, while those outside the zone have so far lacked an alternative form of development. Even within the development zone there are clusters which cannot be incorporated into the service systems at one and which therefore need temporary RWS systems.

It is the problems of these two categories of renewal areas, and of small population centres in rural areas, that prompted out efforts to find alternative RWS systems, although the principles are also valid for new development and urban areas.

THE SOCIAL DIMENSION OF TECHNOLOGY

Technical supply has a social and cultural dimension which must also be considered. Small-scale, local solutions are often feasible. They can be constructed and handled by the people who use them and thus become an integral part of the local community as such. Knowledge of the biological and technical processes and how to oontrol them must have a positive influence on poeple's awareness and sense of reality. Not knowing what happens to the sewage when one flushes the tiolet, where the rubbish goes when the dustbin is emptied or what lies under the wallpaper is bound to increase the sense of alienation which increasingly characterizes our culture.

In every community, whether small or large, there is a potential fund of knowledge, ideas and initiative. There are also material resources such as nature, houses, technical investments, machines and tools etc. How can the technical solution utilize these resources? And what would this interplay between new technology and local resources mean for the poeple living in the community and for their social relations?

A simple example. Some RWS systems are based on active utilization of the ground; these are called "nature-active" systems. Examples are infiltration and biological beds. The other category, e.g. prefabricated sewage treatment plant or closed tanks, are known as "nature-passive" systems. The active systems are labourintensive and require extensive excavation, work which is relatively simple and only requires knowledge and thoroughness. The passive systems entail only about half the work input of active systems but the material cost is about double. Constructions of a prefabricated sewage treatment plant usually requires a high level of technical know-how, which means that specially trained external experts have to be consulted, for example, for the guarantee to be valid. At present, a government grant can be prefabricated sewage treatment plant but not for an active system.

The type of purification plant thus has implications for the local economy and the level of employment. The need to create local jobs may be one important factor when we choose a technical system.

Another important aspect to be considered is the rate of development. Rapid realization and intensive construction work, which is a feature of most passive systems, limits our possibilities of utilizing local resources. The active system can often be realized phasewise, which means jobs for local people over a longer period of time.

Which RWS system we should choose and what form it should take is not determined by the systems as such. The answer will only be obvious when the aims of the community's development have been clarified and local conditions with respect to geographly, buildings and economic and social factors have been investigated. The RWS solution offers opportunities for developing communities in a way which benefits the local population but also the community and the country as a whole.

RWS SYSTEMS - A TOOL FOR SYSTEMATIC RENEWAL AND IMPROVEMENT

RWS systems must be designed so as to be compatible with long-term development planning aimed at solving the particular buildings, small groups of houses, larger groups of buildings and densely populated districts. They need not constitute the final solution but may be used as a tool in different phases of urban improvement. Study of the transition from one solution to another and from one level to another is therefore important.

Successive urban improvement by means of specially adapted RWS systems enables a local authority to:

- adapt its investments to the total planning needs in the area
- adapt its policy so as to maintain the social structure of the area, i.e. the cost level is adapted to the resources of the population
- preserve and develop the existing environment
- retain its freedom of action with respect to the long-term use of land
- influence the rate of conversion of second homes to permanent housing
- control private and public investment in the area so as to prevent land speculation
- develop the area in accordance with the wishes of the population in terms of the extent and rate of investment and methods of improvement, e.g. work by the people themselves
- coordinate investment in technical service with investment in social service.

Seen from an ecological point of view, we find it natural to recommend active methods of treatment where they can be utilized.

OUR METHOD OF TACKLING THE RWS PROBLEM AND CHOOSING A TECHNICAL SOLUTION

When choosing a RWS system we have at least three factors to consider:

o Ecological factors and building conditions.

o The feasibility and consequences of different possible systems.

o The overall situation with respect to RWS service. In this total analysis various alternative supply systems, including conventional systems, must be weighed against each other.

1. The situation

In order to be able to analyse conditions in the area, we need to be able to define the "area" with clear boundaries. The boundaries may vary for different types of supply. The local water and sewage supplies may not cover exactly the same area, for example. In fact, it may be important, from the pollution point of view, that they do not.

Definition of the boundaries may be done at different levels and with different aims. For example:

o The local authority level - how does the RWS service for the area fit into the overall system for the whole borough? (Geographical position, planning situation etc.)

o The local level - how good is the standard of the existing water and sewage services, roads, electrical service etc.?

o Local level - what is the geological and ecological pattern in the area? (Watershed,rock formations,vegetation etc.)

The catchment basin for an area constitutes a practical and useful boundary in connection with water and sewage services, for instance.

o The local level - the nature of existing buildings and groups of buildings, the proportion of permanent housing and second homes etc.

At the local authority level it is important to decide when it is appropriate to arrange service on a municipal scale and when it is best arranged locally, and on what time scale.

A supply area thus consists of a geographically defined group of buildings. Conditions with respect to RWS should be as uniform as possible within the group.

2. Possible RWS systems

At this stage we seek to identify various possible RWS systems for a supply area. (Each supply area is treated in the same way until the entire development area has been considered.) Possible RWS systems are defined as systems which are compatible with conditions in the area.

Work in this phase is divided into different stages. First, we investigate different components and principles and see how they fit the area - geographical features, the local population, building etc. We can then combine different components to form systems which function according to different principles. The various alternative systems satisfy the overall situation in the area in different ways.

As previously stated, a method of treatment which utilizes natural breakdown processes is called an nature-active method. If we are to be able to use this method as main treatment for waste water, for example, the ground must satisfy certain requirements. If it does not, we may use technical methods entailing biological breakdown, i.e. nature-passive methods. A small prefabricated sewage treatment plant is an example of a nature-passive method. The final treatment of the waste water and the sludge formed in a sewage plant is always an active process in the recipient, however.

3. Consequences of different RWS systems

We can predict how an RWS system will "function" in the supply area by analysing various consequences of using the system. Technical function is included in this description. We also analyse possible interaction between the system and other measures carried out in the area, and how well the system satisfies the requirements of the population living in the area and the local authority.

The most interesting question is whether the system has a favourable influence in the total context, for example, as one of a number of measures in an improvement project. Whether a water and sewage system constitutes a good solution to the sanitary problem will depend on the extent to which it contributes to the total improvement of the area.

The sanitary problem is only one aspect of housing improvement and the RWS project must therefore be regarded as one of several tools for achieving the standard of housing aimed at.

A system which is an excellent solution to the sanitary problem but constitutes an obstacle to the total improvement project or leads it in the wrong direction can thus not be regarded as a "good" solution. The same solution may thus be appropriate or inappropriate, depending on the situation, the context and the phase which the project has reached.

When analysing the consequences of RWS systems, we thus start with the following assumptions:

- they constitute part of a continous process and are not to be regarded as the best or final solutions
- they must be compatible with other measures included in the total improvement programme for the area
- the choice of solution (RWS system) is determined by factors outside the purely functional requirements of the RWS systems themselves
- an RWS system can only be judged in its practical context in each particular planning situation
- a specific RWS system constitutes only one alternative. Only when the consequences of using it have been analysed in relation to the total improvement programme can it constitute a solution
- possible RWS systems can in principle be described in objective terms, whereas solutions necessarily entail subjective judgements
- the subjective judgements inherent in the analysis of the consequences of adopting a certain system are inevitable and should be accepted as a basis for the work. These subjective judgements should be clearly specified.

The presentation of the consequences is based on two analyses: a system analysis and an interest analysis. The system analysis describes the ecological consequences - relationships and conflicts between technology and nature. The interest analysis describes the consequences for the community - relationships and conflicts between technology and community. The starting point is the population's and the local authority's needs and resources.

The presentation of the consequences of adopting a certain system should include the following three main points:

1. A characterization of the RWS system.

2. Ecological consequences - technology and nature
   - the effect of the treatment
   - the impact on the environment
   - the dependability of the process

3. Consequences for the community - technology and the community
   - realization of the RWS plant
   - operation and responsibility
   - costs and financing
   - the flexibility of the plant
   - coordination with other measures in the improvement programme
   - the degree of freedom of action for the future.

THE CHOICE OF THE RWS SYSTEM IS A POLITICAL QUESTION!

The final step in the project is its execution. Political, social, technical and economic factors all dictate that the solutions we choose should be adopted after penetrating discussions and in consultation with the local population. Our hypothesis is that the consultative process, i.e. the dialouge with the local population, is of decisive importance for execution of the improvement programme and that provisions for this consultation must be included as an integral part of the total project.

From the point of view of the local population, the consultation will be completely meaningless if it is merely used as a means of gaining acceptance for decisions already taken. In order to be meaningful, the consultation must take place at every stage of the project, from the initial survey to the choice, planning, projecting and execution of the solution.

The approach we have described provides the basis for consultation as the project proceeds. We present our survey of the situation in the area - our diagnosis, as it were - and then describe a number of possible solutions and their consequences. This provides a balanced basis for study and discussion in the housing area and the borough. We do not think that this basis can be so comprehensive that there is nothing more to add. Nor do we think this desirable, since the whole aim to the consultation would then partly be missed. It is absolutely essential, though, that the whole problem is presented, i.e. all the aspects needed for proper town planning and for the political decision.

We believe our approach represents a contribution to the realization of the politicans' expressed wish to democratize the planning process. The public must be given an opportunity to influence this process at all levels. This democratization must include all the essential problems which govern planning, particularly technical problems. During the last few decades there has been an increasing tendency to exclude technical problems from public scrutiny, on the grounds that the problems are too complicated. The result has been that technology has become the realm of the expert and is shrouded in mystery.

This tendency must be combated in order to make way for a humanistic and democratic development of both technology as such and the solution of technical problems.

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Infiltration of waste water
Some Swedish experiences

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Background

Infiltration of waste water has been utilized for a long time in Sweden. The method has mainly been used in rural areas, but in recent years an increasing number of holiday villages, nursing homes, motels and communities up to 500-1000 inhabitants have solved waste water disposal by infiltration.

There does not exist any definite information as to how many infiltration systems are built each year in Sweden. The estimated number is probably within the region of 30000. The majority of these plants are for single households. Approximately 100 larger plants (>10 m^3/d) are built each year.

Normally infiltration plants are constructed completely underground. Some of the plants with large amounts of waste water have been constructed as open dams.

The question of small waste water systems was taken up in a serious way during the 1940s, when some investigations were started. A manual for small waste water treatment systems were given out in 1962. The design principles were based partly upon Swedish investigations and partly upon equivalent manuals from other countries, e g Great Britain, USA, Switzerland and Germany.

At the end of the 1960s the interest for waste water infiltration increased. For example The National Swedish Environmental Protection Board (SNV) carried out investigations about the effects some infiltration plants had on ground water. These preliminary studies were followed by an increasing amount of more systematic research.

Methods

Broadly speaking infiltration can occur in two types of plants, rapid infiltration plants and subsurface sand-filters (figure 1). Sand-filters are chosen when the natural conditions for infiltration are unsatisfactory.

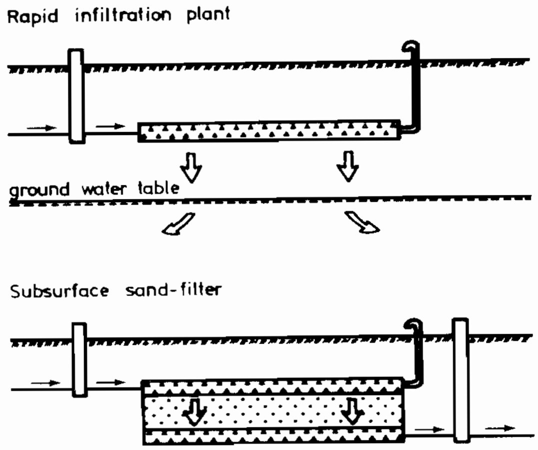

Figure 1. Principle section of rapid infiltration plant and subsurface sand-filter.

Usually it is considered that the essential difference between the two systems is that the sand-filter has an outlet to surface water, while the rapid infiltration plant uses ground water as the recipient.

With regard to ground water the difference should rather be made between tight (plastic encased and embeded) sand-filters on the one hand, and infiltration plants and other filter-beds on the other. The reason for this is naturally that a larger or smaller amount of waste water that passes through the sand-filter normally penetrates down to the ground water.

The plants can be constructed in different ways in accordance with local conditions. For example a rapid infiltration plant can be built-up under conditions of high ground water (figure 2). A combination of subsurface sand-filter and infiltration plant can be built where the soil is fine-grained but not impermeable. The lower macadam layer is given such an extension so that all the waste water can infiltrate down to the ground water (figure 3).

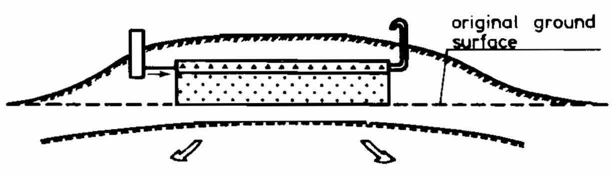

Figure 2. Built-up infiltration bed

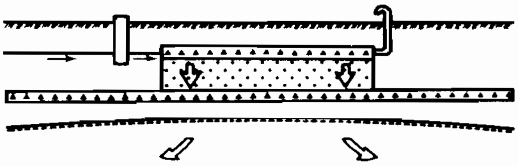

Figure 3. Extended infiltration bed in fine-grained soil

Before waste water is led to the infiltration plant it must have undergone some kind of pretreatment. Normally presedimentation is chosen, for example in a septic tank. Also biological pretreatment can be chosen in larger plants (>200 pe). In these cases the infiltration surface can be decreased somewhat, normally by 25-50 %.

According to both Swedish and Norwegian experiences chemical pretreatment appears to be unsuitable in combination with infiltration. Clogging, which has been related to the occurrence of remnant flocculent from chemical precipitation has been established.

Research

Research within the area of waste water infiltration has grown rapidly during the 1970s. The projects have normally been small and uncoordinated involving a number of different research workers. A larger project has, however, been carried out by the consulting firm VIAK AB, with a grant from SNV.

The aim of this project has been mainly to elucidate different environmental consequences of waste water infiltration, e g:

a) A more dependable evaluation of infiltration conditions and treatment effects
   - in different soils
   - with different waste water composition
   - with different load conditions
   - with different temperatures
b) Clarification as far as possible of the chemical and biochemical processes which take place during the infiltration of waste water
c) Clarification of the effect of waste water infiltration upon ground water at different distances from the plant

The investigations, which were carried out during the period 1974-1978, followed three main lines:

- Column experiments
- Evaluation of subsurface sand-filters
- Evaluation of waste water infiltration plants

During the column experiments certain developments such as clogging as well as physical-chemical and biological processes were studied more deeply. Different parameters, such as water quality, filter construction as well as load conditions were varied during these experiments.

Besides column experiments the function of five subsurface sand-filters and five rapid infiltration plants were evaluated. These plants, which were designed for waste water amounts of 15-65 m^3/d and 30-100 m^3/d respectively, were loaded with presettled waste water. The aim of these investigations has been to obtain a connection between the results from column experiments, which were carried out under controlled conditions, and the treatment effects obtained during full-scale operation.

The results are presented in reference [1]. In reference [2] and [3] the results have been summarized in English.

The above mentioned projects have been accompanied by a major research venture from SNV concerning purification processes in soils. Among other things it is intended to study in more detail microbiological processes, denitrification, pathogenics and indicator organisms survival and transportation in soil and ground water.

The present research in Sweden concentrates mainly upon environmental effects and less upon the development of methods and systems. For example, such important problems as the development of better and more reliable preliminary investigations and dimensioning methods for infiltration systems have not as yet been seriously undertaken.

Operation experiences

Important experiences have been gained during the last ten years, not just as regards treatment effects and environmental influence, but also the operation and management of plants.

The investigations carried out have shown that with correctly dimensioned and constructed infiltration plants one can expect a practically complete reduction of organic substance, bacteria and phosphorus. Nitrogen is normally only reduced to a small extent during the infiltration process. In certain cases far-reaching reduction of nitrogen has, however, been noted during the waste water transport in the ground water zone.

From the point of view of treatment an infiltration plant is normally tolerant against even large variations in load, pollution concentration and temperature.

In principle the treatment effects are the same for subsurface sand-filters and rapid infiltration plants, on the precondition that one considers the character of the infiltrated waste water from the latter directly under the infiltration surface.

In practise, however, the treatment results from subsurface sand-filters are usually poorer. This is due to the forced reduction of sand-filter volumne for economical reasons. Reduction of the filter is carried out partly by limiting the surface of the sand-filter through the use of coarse-grained uniform material and partly by decreasing the filters thickness (normally a thickness of 0,7-1,0 m is chosen).

In normally loaded sand-filters, built-up of sand and loaded with presettled waste water, the treatment efficiency is usually as follows:

	Reduction, %
Organic substance	80-90
Bacteria	90-99,9
Nitrogen	10-30
Phosphorus	30-60

The stated values refer to the reduction in the sand-filter. To obtain the total effect the reduction in pretreatment facilities should be added.

The above mentioned observations concerning treatment effects apply to presettled waste water. Treatment effects are less complete when waste water is pretreated in a biological plant. The reason for this is probably due to the lower nutrient-level after biological treatment. This retards the biological activity in the infiltration surface, where the most important reduction occurs. As mentioned above the surface-load can on the other hand be held at a higher level.

Management and maintenance

The need for management and maintenance is very limited for both rapid infiltration plants and subsurface sand-filters. The distribution devices should be inspected regularly and when needed cleaned.

At regular intervals change-overs should be made in the distribution system so that a part of the plant is always in repose. During repose the infiltration surface is drained so that organic material within it is given a chance to decay.

It is very important that the pretreatment part of the plant is managed and maintained carefully because its function is decisive even for the proper functioning of subsequent sand-filters and rapid infiltration plants. It is specially important that sludge flight is prevented, since a large sludge load on an infiltration system can cause serious clogging.

Management is needed to a little extent if the pretreatment part of the plant only consists of a septic tank. Naturally the sludge should be removed when necessary. Regular supervision should be carried out and eventual scum removed. With biological pretreatment more considerable supervision is necessary, preferably daily.

Separation of BDW- and WC-waste water

In many cases instructions are given that BDW- and WC- (Bath+Dish+Wash and Water Closet respectively) waste water should be separated and treated separately. WC waste water is taken care of in a sealed tank, multrum, dry toilet, incinerator toilet, freezing toilet or something similar. BDW waste water is normally led by way of a septic tank to an infiltration system.

The motive for separation is, however, often unclear and sometimes directly biassed. An explaination for this could be the lack of knowledge of treatment effects and the influence on ground water in connection with infiltration.

From the treatment point of view it should, however, be emphasized that it can be necessary to separate BDW and WC waste water when the disposal of waste can be solved by composting. To obtain favourable carbon/nitrogen conditions suitable for decomposition it is desirable to mix organic solid wastes form households with WC waste water.

However, several objections can be made against separation. Investigations which have been carried out have shown that BDW and WC waste water can contain similar total amounts of pollution, for example organic material and bacteria.

Moreover, it has been shown that there does not exist any essential differences as regards treatment effects between infiltration of BDW waste water and combined waste water. Experiences are most complete with respect to primary sewage effluent (BDW+WC). These point unequivocally to a very high reduction of organic substance and bacteria in correctly designed infiltration systems.

Accordingly separation does not imply any essential difference but rather a degree of difference in the effect upon ground water with respect to organic substance and bacteria. The influence of nitrogen is, however, greater with a combined effluent as the main part of the nitrogen is supplied from WC waste water.

Normally the dimensions and costs of infiltration systems cannot be decreased very much by separation. The septic tank is dimensioned partly with regard to the hydraulic load and partly according to the sludge load. The former is mainly determined by the BDW load. Certainly sludge load decreases greatly by separation, but this does not normally affect to any high degree the total volumne of the septic tank. The succeeding infiltration system (rapid infiltration plant or sand-filter) can to a certain extent be decreased in size, mainly due to the somewhat lower hydraulic load.

Separation creates a more divided effluent solution. Management needs, running and maintenance costs will therefore be higher than in a combined plant. To this must be added the consequences of the special care necessary for WC waste water disposal, that is to say related transport and treatment problems.

Planning points of view

Waste water disposal in an area can be solved either individually or collectively. Even grouped solutions with several treatment plants can be considered in certain cases. In this sense waste water infiltration often has a high degree of flexibility. Which alternative is most suitable is determined by hygienic and environmental factors, and also to a large extent by economy. It is impossible to find general solutions, and therefore judgement should be made from case to case starting from local conditions.

The possibilities to solve the water supply can strongly infuence the choice of waste water treatment method. Joint water supply gives an increased choice of waste water disposal solution. In this way single waste water plants can be utilized without creating conflicts with the water supply.

In rural areas separate waste water solutions are possible even in combination with separate water supply. Within more urban areas, however, separate waste water infiltration plants should only come into question if the water supply is solved jointly or when waste water disposal and water supply occur in different aquifers.

Concluding points

As is shown above rapid infiltration plants and subsurface sand-filters are often a favourable technical and economic alternative for the solution of waste water disposal.

However, it is known that there are several cases where the disposal of waste water by infiltration has failed. This is sometimes due to insufficient knowledge of the hydrogeological preconditions. Usually, however, the reason lies in uncontrolled water discharge. It is therefore very important that waste water flows are known and that sufficient arrangements are taken to avoid overloading of the infiltration surface.

Due to the decisive importance of hydrogeological conditions for the functioning of an infiltration plant, it is highly essential that design and dimensions are based upon a thorough knowledge of soil layers and ground water conditions.

Unfortunately it must be stated that present regulations in Sweden are very imperfect and do not give sufficiently good guidelines for the localisation and dimensioning of infiltration systems. Further these instructions are only meant for single family dwellings at the same time as instructions for larger plants are lacking. Because the infiltration of waste water has become a rapidly increasing method, at least in Sweden, it is apparent that the need for more detailed and reliable investigating and dimensioning methods is very important.

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Features of different types of "non-water-born" toilet systems.

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Man started in his first days with letting fecal material go straight to the ground, but he soon found that the material had an unpleasant smell and could endanger his health. He also appreciated the fact that fecal material has value as a fertilizer.

Asanitation system should therefor handle the problem in a way that both retains the fertilization value and that prevents pollution and spreading of pathogenic organisms. Different types of solutions are briefly described in the paper presented by professor Tor Arve Pedersen. I will in this paper present a more detailed survey of the constru-tion and function of existing systems.

1. Latrine

a: On the ground

Fecal material is collected on the ground beneath the bench, (Figure 1). Excess liquid is drained off. After a while (some years in our climate) the fecals are decomposed and used as a fertilizer. This system is still common in Norway (in use by about 15% of the population), but with a more consentrated population the spreading of pollutants with the drainage become a larger problem.

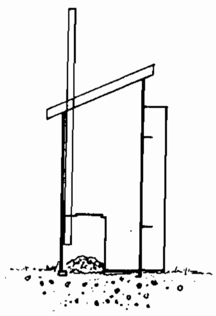

Figure 1
Latrine on the ground

The system can only be recommended in areas suited for drainage infiltration and with a scattered population.

b: Pit-latrine

Fecal material is collected in a hole in the ground (Figure 2). When the hole is filled a new latrine is to be made. With this system you neither get the value as a fertilizer nor can you be sure of not contaminating the ground water. The system can function, but does often give problems with the drainage. It is also a question whether the solution is acceptable to today's hygienic standard.

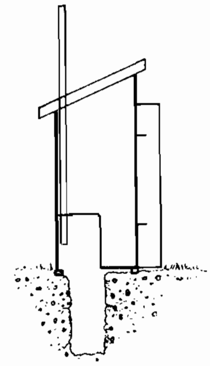

Figure 2.
Pit-latrine

2. Collecting systems

a: Small containers

These systems are based on collecting urine and feces in containers of plastic, cardboard or metal. The volume of these containers is a 20 - 30 l. The container is placed straight below the sitting bench (Figure 3). The community must have an organized collection of the containers and also have a safe way of disposing the material. If not, the problem is just transferred to another place.

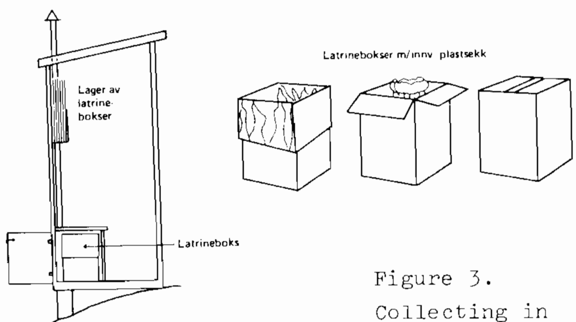

Figure 3.
Collecting in small containers

b. Large containers

These systems are based on tanks with a volume of 3-6000 l. They can be made of concrete, plastic or glassfibre, (Figure 4). The toilet used can be of the water-saving type, using aprroximately 3 l pr. fluch. This results in a requirement of emptying the tank every second to third month (family of about five). Toilets that use less water exists and in this way the frequency of emtying the tank is reduced. The content of the tank is collected by means of a aludge-vehicle. The collected material should be treated further in a sewage plant of deposited safely under controlled conditions. Id this is not, the case the problem-material is only moved around.

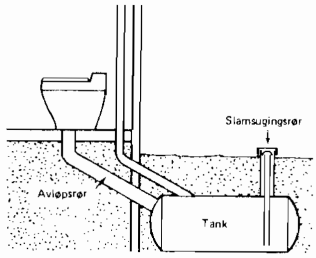

Figure 4.
Collecting in large containers.

c: Collection in special bags or parcels

I. Freezing.

The wastes are frozen down to -18°C by a freezer placed under the toilet-seat, (Figure 5). The feces and urine are collected in a "plastic-bag". The toilet has to be connected to the electric system but you have the same problem as mentioned above, - how to dispose the frozen parcels?

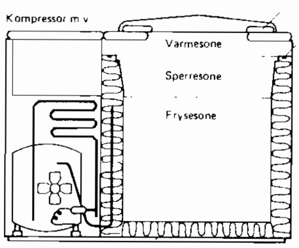

Figure 5.
Freezing the fecal material in a plastic bag.

II: In sealed parcels.

Each portion of urine and feces is sealed separately in a plastic stocking. The plastic, delivered from a casette, is moved over the bowl of the closet by a set of small wheels (Figure 6). After using the toilet the wastes are enclosed in a small part of the stocking by heat-welding. The toilet can either be connected to the main electric system or be operated by a 12 volt battery. The energy requirements are minimal, but the cost of the plastic is high. One visit to the toilet costs about 0,30 N.kr, and the same problem still exists, - where to deliver the parcels?

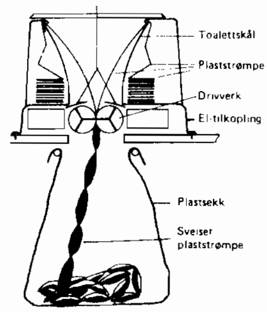

Figure 6.
Pacing toilets

3. Toilets with sanitary chemicals

The wastes are collected in a bucket which contains about 20 - 30 l. Before using the bucket ca. 2 dl of a solution containing a strong desinfectant is added (sodium hydrozide, formaline, etc.). Properly used this method solves some of the hygienic problems, but there is still a problem with the pollution effects of the wastes. The use of this system is prohibited by many local health authorities due to uncontrolled disposal of the material in practice, and possible water contamination from the feces and chemicals.

4. Incineration systems

The wastes are burnt to ashes either by gas, oil or electricity, (Figure 7). The time used for the combution is about 8-10 minutes for the gas/oil type and some 20-30 minutes for the elctric models. The end product, - the ash, - is sterile ans can be spread on the soil. This system is expensive in use with a high energy consumtion.

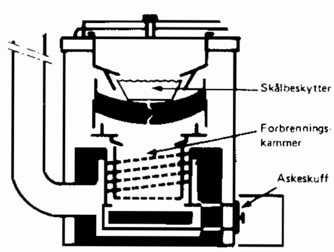

Figure 7.
Incineration toilets

5. Biological toilets

This is a toilet system where feces and urine is collected in a container and then composted. Composting is an aeribic degradation process. The mixture of feces and urine has a dry matter content of about 10%. This makes it rather lizuid. The main problem with this type of toilet is to get rid of so much water that the rest material will be sufficiently porous. This can be achieved in three ways:

I) by draining the liquid off -- may result in a pollution problem
II) by absorbing the liquid -- increases the necessary compost volume
III) by evaporating the liquid.

The last solution is the desirable one, but also the most difficult to solve tehnically.

The materials that are usually used for construction are plastic, glassfibre and metal. Concrete can be used, but precaution must be taken to prevent corrosion. Metallic parts must be made from a non-corrosive material.

a: Large toilets of the inclined-floor type

The toilet consists of a composting unit with the toilet stool connected to the tank directly or via a pipe (Figure 8). The composting unit has a slope of $15-30^{o}$. The wastes will come into the tank at the upper end. After a while the pressum of the wastes should move the material downwards to the wamptying chamber. To prevent fresh material from reaching this area a wall is mounted between these two areas. The walls extend from the roof of the tank down to about 20 cm above the bottom. The volume of the composting units is 500 - 1500 l. To get sufficient evaporation from the material air-ducts formed as "Λ" or "∩" are placed parallell to the bottom.

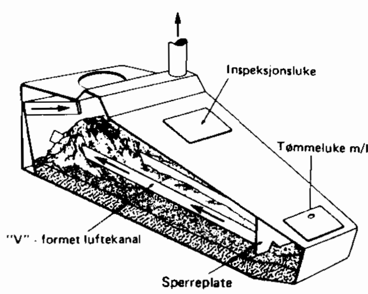

Figure 8.
Biological toilet with inclined floor

The are designed to never be filled with fecals. When these toilets are used in a hot climate it should probably not be necessary with a heating element, but in our climate an element of about 150 watt must be installed. Different models have the heating element in various locations. However, the best place to put it is at the lowest part of the tank, where eventual surplus of liquid will be collected. For this type of toilet, a ventilation fan is necessary in our climate. Most common is a radial fan of about 25 watt.

These toilets have to be emtied for the first time 1½ year after installation, later on every ½ year, - but all the material should not be removed, just the composted part. The main problem with this toilet is accumulation of liquid at the bottom of the tank, and the building up of fecal material into a pyramide that will not slide down the inclined floor. There are about 5 - 10 different models of this type on the Scandinavian Market to day.

b: Large toilets of other designs

Many different types have been tested but few can be recommended. The best are described here.

The carousell toilet.

The composting unit consist of an outer- and an inner-container. The inner-container, whish can be rotated, is divided into four chambers. Each chamber has a volume of about 300 l. In each chamber there are 3 "Λ"-formed air-ducts. Feces and urine are collected in the inner-container, excess liquid is drained out to the outer-container. Air is sucked by a fan into the system through the center pipe, (Figure 9) and goes partly through the air-ducts in the cambers and partly over the bottom surface of the outer-container. When the last chamber is filled, the inner-container is to be rolated, emptied and is then ready for use. This system prevents mixing of old compost and new wastes. Heating is provided by an element under the outer-container. The heating element is about 140 watt. It takes about half a year for a family of four to

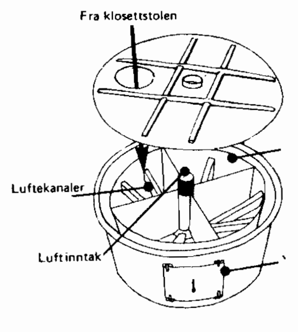

Figure 9.
The carousell toilet

fill a chamber. This means that the wastes stay at least 1½ year in the toilet, which ensures the users against unhygienic endmaterial.

The "Camo-do".

The composting tank contains a big, flat tray and a deeper, smaller bucket (Figure 10). Both have perforated bottom. The wastes are collected in the bucket (volume of about 30 l). When the bucket is full, it is tilted and the wastes are distributed into to the larger stray.

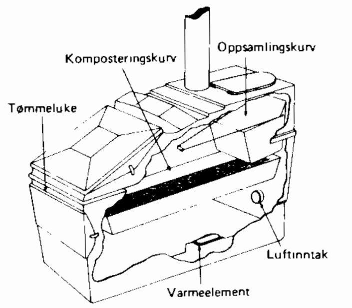

Figure 10. "Camo-do"

Excess liquid is drained from the bucket and the stray, down to the bottom of the tank. This prevents the compost of getting wet. A heating element (75 watt) is placed directly below the bottom of the tank. For a family of four it is usually necessary to empty the bucket every fortnight and the tray three times a year. A radial fan is placed in the air-outlet.

c: Small biological toilets

I. Toilets with a grating.
The composting tank is divided into a main chamber above the grating and a lower chamber for the after-composting process. (Figure 11).

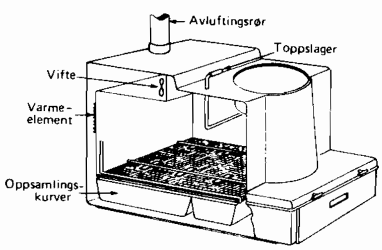

Figure 11 Biological toilet with a grating.

Air is either taken in via the seat-opening, by a fan over a heating-element and down under the grating, or taken in via holes in the lower part of the toilet and over a heating element, through the compost and out. The fan is of the radial type with an effect of a 15 watt. To get the compost down to the after-composting chamber either a permanently mounted tool or poker have to be used. The heating element is between 150 and 250 watt with a termostate set at 40 - 70°C. The capacity of these toilets are at most 2-3 persons. The composted material must be removed every second month.

II: Toilet with a mixing device.
The composting tank is divided into a main chamber with a mixing device and a chamber with a tray for after-composting. The mixing device can either be hand- or motor-driven, (Figure 12). Through mixing ensures good conditions for the composting process. A heating element is placed directly under the mixing chamber. The capacity of this type of toilet is three persons. The composted material has to be taken out every second month.

For the small toilets the mixing type seems the best one today.

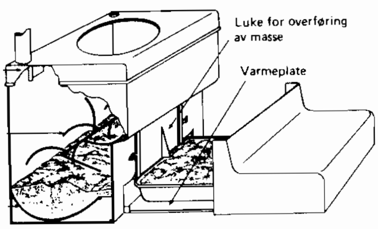

Figure 12. Biological toilet with a mixing device.

Conclusions and prospects

Today, there are biological toilets on the market that finction well and have sufficient capacity for a normal family. Still, there is great room for improvments.

To guide the consumer a standard for testing biological toilets is being developed in Norway. This standard will probably be approved in 1981.

Refereces:

Pedersen, Tor Arve. Sanitation problems. Solution by dry and non-water-born system and by infiltration. Paper presented to the Eight CIB Congress, Oslo, June 1980.

Guttormsen, D.M. and Pedersen, T.A. Alternative klosettløsninger for fritidshus og helårsboliger. PRA 21, Oslo 87 p. 1978.

On-site soil disposal of septic tank effluent

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Summary.

This paper gives an introduction to the many aspects of on-site soil management of small waste flows. Hydraulic problems, renovating processes, site selection procedures and practical systems are described.

In soil used for waste water purification a clogging mat always builds up on the infiltrative surface reducing the hydraulic but increases the renovating capacity.

The possibilities for nitrogen removal are minimal because of transformations to nitrate which leaks into the ground and surface water making the receiving water questionable for consumption. Phosphorus in septic tank effluent is effectively fixed by the soil except when coarse silica sand is used. Organic matter in the effluent is reduced to 10-20 %. Systems with a clogging mat, or systems loaded at a low rate have a large capacity for pathogen removal.

For site selection of absorption fields, the hydraulic capacity of the soil has to be tested. If the site is unsuitable, alternative systems may be constructed. These are artificially built soil filters of which the most effective systems are those using the upper soil horizons for purification.

Even in coarse soils, if distances to ground and surface water are sufficient and institutional controls are made, on-site disposal of septic tank effluent is an efficient and economic favourable method of waste water renovation.

Introduction.

In many developed countries of the world settlement in rural areas is growing. These suburban areas need a satisfactory and cheap handling of wastes.

In rural areas of developed and undeveloped countries waste water from existing settlements represents a health hazard, and proper management of the wastes is necessary. Use of septic tanks for pretreatment by settling and floating of pollutants, and final treatment of the effluent on soil at the site is a cheap and often very effective waste water renovation system for rural residences. Because of small variations between types of septic tanks, their efficiencies are not discussed in this paper.

Waste water contains a variety of pollutants including chemical elements and dangerous microorganisms. This paper describes some of the most important aspects of soil as a physical, chemical and biological filter for removing of pollutants, the hydraulic aspects of management of small waste flows in soil, and important practical types of soil filter systems. At this congress other aspects of small scale waste management are discussed by others (1,2).

Soil may be described as a three phase system, consisting of solid particles and voids, a fraction of which may be filled with liquid and another with gas. The solid particles are made up of mineral and organic components occuring together in aggregates or as ultimate particles, such as sand, silt and clay.

Because soil harbors plants, animals and a lot of microorganisms (10^9-10^{10} per g soil), it has often been referred to as "the living" filter. But it serves as a physical and chemical filter too. In most soils, the pore size distribution and the nature of water movement channels are such that suspended solids in septic tank effluent are completely removed after a short travel in the soil. In addition, the many organic and inorganic chemical reactions which occur when waste water passes through the soil, serve to immobilize pollutants which have been introduced into the profile by the addition of wastewater.

Using soil for waste water renovation two main criteria have to be taken in account. First, the soil must have sufficient hydraulic capacity to absorb the applied amount of water, or ponding of soil with wastewater will occur. Second, the soil in use must have adequate renovating capacity to protect ground and surface water against polluting elements and pathogenic microorganisms. As we shall see later on, these two criteria often work against each other when selecting sites for on-site disposal systems.

Water transport and hydraulic capacity of soil.

In soil loaded with waste water, the flow process is divided into infiltration and percolation. Infiltration is the entering of water into the soil while percolation (drainage) is the downward movement of water through the soil.

Infiltration capacity is a very dynamic property. Most often it is highest at the beginning og wastewater loading. Lowering of the infiltration capacity is caused by changes of soil structure, swelling of soil colloids and formation of pockets of soil gas which can't escape from the system. But the most important reason of reduced hydraulic capacity with time is clogging of the infiltrative surface with suspended matter from the waste water, and microbial growth in the soil pores. This clogging usually reaches an ultimate equilibrium state which defines the hydraulic capacity of the soil material in question (figure 1). For sizing of on-site waste water systems, the ultimate hydraulic capacity of the soil at the site of disposal has to be taken into account. The change in infiltrative capacity during waste water loading varies with water composition and soil type. Generally, water high in organic and suspended matter gives a more rapid and serious clogging of the infiltrative surface than less polluted water. Soils with a high fraction of silt and clay usually clog seriously and rapidly, and have a low infinite hydraulic capacity. Most often sandy soils are used for waste water renovation.

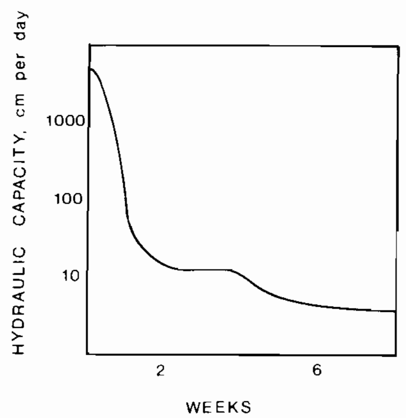

Figure 1.- Reduction of hydraulic capacity with time caused by clogging.

In practice, it is impossible to predict how a soil will respond to wastewater loading. The equilibrium flow rate through a clogged soil must be estimated from a soil test. A lot of more or less sophisticated tests have been developed for this purpose (3), but the test most commonly used is the percolation test as developed by Henry Ryon in 1926. The test is conducted by digging a specified hole in the desired depth of the soil, filling it with tap water and measuring the percolation rate (time) required for water to fall a specified depth. Unfortunately, most countries have their own special variety of this test (see reference nr. 4,5 and 6 as examples). The measured percolation rate is not the infinite acceptance rate, and has to be reduced by a factor. In some investigations, the equilibrium loading rate is found to be equivalent to two per cent of the percolation rate (3). This relationship is used in part for developing curves showing the relationship of maximum tile field loading rates to percolation test rates (4). Often loading rates are expressed as required absorption area per bedroom or person served. Sometimes, percolation tests are combined with particle size analysis of the soil in question.

The fate of pollutants in soils.

Nitrogen.

Nitrogen (N) in domestic sewage water usually has minor importance as a source of eutrophication of rivers and lakes. In U.S.A. nitrogen in the form of nitrate or nitrite has been linked to cases of methemoglobinemia in infants (7), and most countries have safety limits for nitrate and nitrite in drinking water.

The main source of nitrogen in septic tank effluent is fecal material accounting for 90% of the nitrogen (8). Usually septic tank effluent N is composed of about 80% NH_4-N and 20% organic-N, and the concentrations of totale-N usually vary between 15 and 25 mg N/l (8).

In soils ammonium may be bound to negatively charged colloids and removed from waste water, but soils with a high content of colloids have, unfortunately, unfavourable hydraulic qualities as renovating medium. This together with oxidation in aerobic soils of NH_4^+ bound to colloids leads to only minor and temporary removal of nitrogen from the waste water. Binding of NH_4^+ to minerals with a high cation binding capacity (zeolites) and exchanging the zeolite minerals after NH_4^+ saturation, have been tried with success in Canada as a method for N removal from septic tank effluent (10). A certain amount of nitrogen has to be incorporated in both soil biomass and stable organic matter. In sand filter trenches used for renovation of septic tank effluent, nitrogen bound in biomass and stable organic matter is found to amount to 20 days output of nitrogen from a one-family residence (9).

In aerobic soils (soils with O_2 solubilized in the water phase) ammonium is oxidized by bacteria to nitrate (nitrification) as it moves through the aerated unsaturated soil below the clogging zone. Nitrate is highly soluble in water, and leaks out with the percolation flow. If nitrate occurs in anaerobic zones of the soil with high content of readily decomposable organic matter, bacteria decompose the organic matter using NO_3 instead of O_2 as is normal respiration. This anaerobic respiration of organic matter is called denitrification. Nitrate is reduced to harmless nitrogen gas which is the main component of air. Denitrification is often said to give significant contribution to nitrogen removal in on-site systems, but unfortunately the environmental conditions in soil filters is unfavourable for the sequence nitrification/denitrification (9). Nitrification goes on below the zone with organic matter and anaerobic conditions, and the highly soluble nitrate leaks downward. Therefore, dilution is usually the only way of reducing the concentration of nitrogen in water leaked from on-site disposal systems.

Phosphorus.

Phosphorus (P) is a limiting nutrient for algae and aquatic weeds, and increased supply of phosphorus to lakes and rivers can accelerate eutrophication. Our great lake Mjøsa is polluted by phosphorus, and one of the main sources is sewage. To reduce phosphorus loading from rural areas to the lake, a large number of on-site disposal systems with absorption fields have been built in the last few years.

Sewage phosphorus originates mainly from detergents and fecal material,accounting for 50% each (8). In septic tank effluent from houses with water toilets the concentration of phosphorus is usually 12-20 mg P/l, depending on types of detergents and water use. Most phosphorus exists as phosphate (PO_4^{3-}).

Because phosphate is fixed in soil, phosphorus enrichment of groundwater seldom occurs below septic tank systems. The phosphate is retained in the soil by adsorption and precipitation reactions. The adsorbing capacity of soils for phosphate seems for the most part to be related to the iron and aluminium contents. The precipitation of various phosphorus compounds depends on soil factors as pH, concentrations of phosphate, the content of iron, aluminium, calcium and competing anions. In acidic soils,iron and aluminium phosphate precipitations occur,while in calcareous soils various calcium phosphate compounds are formed (11).

The amount of phosphorus retained by a soil varies. In a sandy loam soil, 100 g P/kg to 300 g P/kg soil was retained in a soil absorption system (12), while in a pure silica sand only 0,3 g P/kg soil was bound to the soil material (9). When planning for protection of surface water from phosphorus contamination using soil absorption systems for waste water renovation, the type of soil material used is very important for achieving success.

Organic matter.

Organic matter discharged to streams and lakes in amounts exceeding the capacity for microbial decomposition will accumulate and bring about overgrowth of algae and aquatic weeds,and give an unpleasant taste and odour to the water.

Household wastewater contains a variety of different organic materials which are partly decomposed by anaerobic microorganisms in the septic tank and almost completely decomposed by aerobic microorganisms in soil absorption systems. Because of the variety of natural and synthetic organic compounds in wastewater the organic matter is characterized by its BOD and COD values. The BOD and COD value is a measure of how much oxygen is needed for biological and chemical decomposition, respectively. In septic tank effluent,the BOD and COD values are found to be 52 and 84 mg/capitata/day respectively,when using water-born closet, and 14 and 34 in effluent from single family houses using non-water-born closet (8). Effluent which has passed a soil absorption system has BOD and COD values reduced 80-90% (1,7).

Other polluting elements.

Except for special situations the content of heavy metals, fluorine, boron, dissolved salts and pesticides is generally quite low in household wastewater. Under certain conditions such elements represent problems for consumption of nearby ground and surface waters. For details concerning these pollutants behaviour in soil, the reader is referred to the list of references (13, 14,15).

Pathogenic microorganisms.

Water passing soil absorption systems may create health hazard because of the human and animal pathogens in the effluent disposed. The hygienic questions concerning land application of waste water are undoubtedly the most extensively investigated ones, and rewiews have been presented (16,17,18,19).

The number of fecal organisms penetrating soil absorption fields are dependent on three main factors: the number of organisms in the material disposed, the ability of the specific soil in question to remove the organisms and the ability of the organisms to survive in the soil enviroment.

The number of pathogenic organisms in septic tank effluent varies between wide limits depending on the health condition of the family disposing the effluent. Normally very few pathogenic microorganisms occur in septic tank effluent in the more developed countries. Effluents from hotels, campgrounds etc. usually contain more pathogens than from single family houses because of visitors from countries with other epidemiological conditions than in our country.

The number of indicator bacteria (none pathogenic fecal bacteria as for instance coliforms), however, is very high, 10^7-10^8 and 10^3-10^4 coliforms per 100 ml in effluent from houses with water-born closets and closed systems,respectively (8).

The ability of soil to remove organisms applied to it, depends on interactions between many factors such as depth of unsaturated soil, pore size distribution,infiltration rate etc., but the main limitation to transit through soil seems to be the straining of organisms in the clogging layer at the soil surface (18). This is illustrated in figure 2 which shows the penetration depth of fecal coliforms in a clogged and an unclogged 75 cm deep sand filter loaded with septic tank effluent (9). Reducing the loading rate gives better contact between organisms and soil materials and thereby increases purification effiency too.

It is impossible to predict maximum transit distances for various microorganisms in soil. Maximum observed distances may vary from investigation to investigation. When planning for on-site disposal systems, wells and surface water in the neighbourhood which are used for consumption may be protected by collecting the percolation water and disinfecting it with chlorine, jodine, bromine or UV radiation (21).

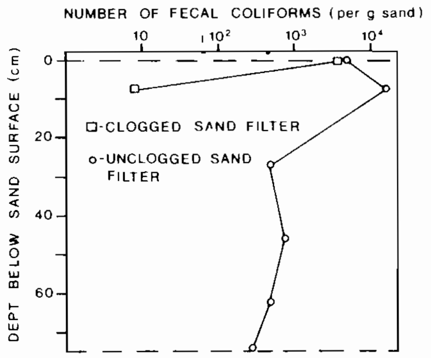

Figure 2.- Reduction of fecal coliforms in a clogged and unclogged sand filter trench

The survival of microorganisms in soil. - Reports on survival of different microorganisms in soil are numerous and show vaste differences between organisms, soil types and environmental conditions. Some general conclusions may, however, be derived from the literature. Pathogenic organisms may survive a shorter time if the temperature is raised, the soil moisture content decreased, the pH increased to 8-9 or decreased to 3-5 or the content of organic matter in the soil reduced (17). Generally, indicator bacteria have a longer survival time than pathogenic bacteria (21,22).

Site selection of on-site disposal systems.
As mentioned previously, soils for subsurface sewage disposal must have an acceptable hydraulic capacity. This is tested as described in manuals (4,5,6). Other factors which influence the design and operation of on-site absorption systems and which are described in detail in manuals, are depth of soil over zones of saturation or bedrock, the slope and topographic position and the sites management history (3). Proper planning depends on the knowledge of the site from soil maps, field tests and investigations at the site. If there is doubt about the suitability of the soil, on-site investigations provided by soil scientists and geologists are advised. When the soil are unsatisfactory for septic tank soil absorption systems, alternative systems which are independent of soil type at the site have to be chosen.

Septic tank soil absorption systems.

Systems dependent of on-site soil characteristics.

The systems with infiltration in the ground which to day are autherized in Norway are described in a separate paper at this congress (1) I, therefore will give a short introduction to the septic systems which are most popular internationally.

By 1970, approximately 16.6 million housing units or 25 per cent of all housing units in the United States disposed of their wastewater via septic tank soil absorption systems (23), and the use is growing very fast. Most of the experience on these systems concerning design, sizing and regulations therefore comes from U.S.A. The Manual of Septic Tank Practice (4) and recent research reports (3) give extensive knowledge to people planning future rural settlements, and most of the Scandinavian regulations are adopted from U.S.A. I find it natural to refer from the Manual the most usual American septic systems and add other systems. The most important systems are illustrated in figure 3.

1. Absorption trench. - A trench with a certain amount of gravel surrounding a distribution pipe, and covered with earth. The sizing is determined by soil characteristics and type and amount of waste water.

2. Seepage beds. - Absorption systems having trenches wider than 1 m are referred to as seepage beds. Seepage beds have some advantages over absorption trenches: Use of land is more efficient than a series of long narrow trenches with waste land between the trenches, and more efficient use may be made of earth moving equipment used for other purposes as excavation and landscaping.

3. Seepage pit. - Diameter of seepage pits depends on vertical wall areas and the soil characteristics. In Scandinavia they are not recommended for other than grey water.

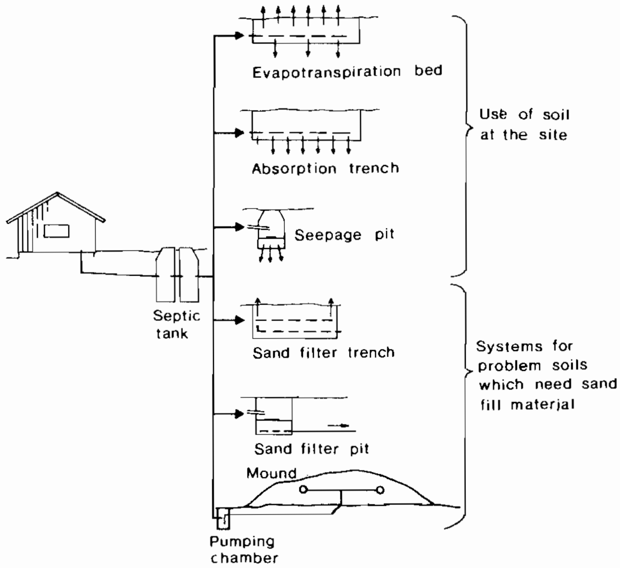

Figure 3.-Main types of on-site systems

Alternative systems for problem soils.

At sites with slowly permeable soils, excessively permeable soils, soils over shallow bedrock or high groundwater, disposal directly into the ground is not recommended. For these sites alternative systems have to be used.

1. Sand filter trench. - A trench dug into the ground and filled with sand as renovating medium. Above and below the sand layer are gravel layers, with distribution and drainpipes,respectively. The length is determined by type and amount of water. For cabins sand filter pits may be allowed if closed closet types are used.

2. Evapotranspiration bed. - Bed made in the top soil layers to take advantages of the plants ability to absorb water and nutrients. Works satisfactory in the the summer, but in the winter there may be problems with frost.

3. Mound systems. - One, ore a series of small parallell sand filter trenches built on top of the soil surface.

The system is loaded by pumping of the septic tank effluent into distribution pipes in the mound. In recent years this system has been very popular in the U.S. and has shown very good purification efficiency. In Norway one mound is built at Danskerud, Aas County for greywater renovation (1). The main limitation to the system is the big area (0,1-0,2 ha) and how it fits in the landscape.

Comments on hydraulic capacity and purification efficiency of the systems.

For systems with infiltration in the soil at the site, it is important to size the absorption area properly. The absorption area may be calculated as described in manuals or as 1% of the absorption capacity measured by percolation tests. Bouma (24) has given recommendations for maximum loading rates and operating conditions for septic tank soil absorption systems. He recommends 5 cm/day for sands, silt loams and some silty clay loams, 3 cm/day for sandy loams, 2 cm/day for loams and 1 cm/day for clays. He also recommends uniform distribution of septic tank effluent by pumps.

Infiltration in natural soil and upper soil horizons takes advantage of the soil as a heterogenous chemical and biological filter. The upper horizons are rich in aluminium and iron,and have an efficient microflora and pore size distribution for straining and destruction of nutrients and harmful organisms. Systems like the mounds and evapotranspiration beds take advantage of this. In sand filter trenches the sand is the chemical filter and often it is low in binding elements,and especially at the start of the system has a poor potential for pathogen removal. For filters laid in coarse soils with a percolation depth of less than 1 m,it may be necessary to disinfect outlet water before disposing in water which may be used for consumption. As mentioned earlier in this paper,nitrogen is not removed from the percolation water and leaks to groundwater and surface water. This happens in all kinds of septic systems and must be taken into account when planning for water supplies where on-site systems are to be used.

Experience with on-site systems in many countries has shown that if they are going to work as well as possible appropriate institutional controls are necessary. Generally, all kinds of pollutant removal increases with time and thereby with distance. Even in coarse soils, if distances to ground water and surface water are sufficient and institutional controls are made, on-site disposal of septic tank effluent is an efficient and economic favourable method of waste water renovation.

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A Norwegian Research Program for Treatment of Waste Water (The PRA project)

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Introduction

During the periode 1970 to 1978 an extensive research project on treatment and disposal of waste water was carried out in Norway. The total PRA project, at a cost of about NOK 30 million, had been splitted into 60 different projects which were subcontracted to several research institutions, consulting engineers and other private companies.

Generally, the project concentrates on treatment of waste water, also including domestic sewage. Furthermore problems related to land disposal of waste water by soakage and the use of biological decomposition toilets as alternatives to communal water-borne sanitation were dealt with in various subprojects. I have therefore found that a comprehensive description of the entire research project may be of interest to the CIB Congress delegates.

The Ministry of Industry appointed a Steering Committee for the research project in the fall of 1970. The Committee was given responsibility for the project management and comprised representatives from concerned research institutions, ministries and government departments.

Areas of research, project selection

The Steering Committee decided to split the research program into the following 6 main Research Areas:

I Quantity and composition of waste water
II Treatment of waste water. Stabilisation and dewatering of sludge.
III Use of terristrial recipients for sludge and polluted effluent.
IV Transportation systems.
V Discharge of polluted water into recipients.
VI Industrial waste water problems

Out of the total NOK 30 million available for the research program approximately NOK 28 million were spent on actual research and study activities. In Table 1 all the subprojects have been listed.

A brief description of the issues covered under each research area is given below.

Quantity and Composition of Waste Water

A total of NOK 0,8 million was allocated to this group of projects. The State Pollution Control Authority was responsible for the project with Østlandskonsult A/S (consulting engineers) as executing firm for the major part of the work.

An exhaustive knowledge of the quantity and quality of the waste water is imperative for optimum design of sewer network, treatment plant and disposal structures. The Steering Committee therefore commissioned this study early in the program in order to find the characteristics for domestic sewage from residential areas of various categories, schools, restaurants, etc. By establishing gauging stations on sewers serving well defined areas with high quality seperate systems, reliable flow data have been collected. Thus a more accurate basis for flow estimates has been made available.

Treatment of Waste Water. Stabilisation and Dewatering of Sludge

The Steering Committee gave high priority to research and studies on treatment of municipal waste water and sewage sludge. Of the total funds available for the research program 37 %, or NOK 10,5 million were allocated to this particular research area consisting of 13 major subprojects.

The Norwegian Insitute for Water Research (NIVA) has been responsible for execution of these projects, which had been granted a relatively high priority in order to meet the demand for basic data and criteria pertaining to selection of treatment processes, treatment works design and sludge handling facilities.

Foreign experience could not be readily applied under conditions prevailing in Norway. A strong emphasis on phosphorous removal rather than removal of organic matter implied that Norway would have to select treatment works systems which were not commonly employed in other countries. Consequently the know-how on the sludge handling component of the works had to be studied in detail as phosphorous removal plants produce sludges with specific properties.

A substantial portion of the research work was carried out at the NIVA research station at Kjeller outside Oslo. Also full scale investigations were conducted in existing sewage treatment plants.

The characteristic properties of the different treatment methods, including dosing of various chemical coagulants, were studied in terms of phosphorous removal, biological and chemical oxygen demand reduction etc. Operational performance was investigated for several existing full scale plants in order to avoid operation problems and excessive operating costs in future plants.

Much of the research and study work was related to municipal waste water, but also joint treatment of food processing plant waste water with municipal sewage as well as treatment of leachate from refuse landfills were thoroughly investigated.

Treatment of sludge has been a major issue during the PRA project. Primarily stabilisation, thickening and dewatering have been studied extensively. In addition it was necessary to carry out fundamental work concerning sludge characteristics.

The practical problems with delivery of sludge from septic tanks to municipal treatment plants have also been covered within the scope of the PRA project.

At NIVA's research station at Kjeller extensive studies on pollutional effects in model recipients were carried out. Municipal sewage was discharged into the model recipients as untreated effluent and as effluents from a variety of treatment processes. The extensive test results show the relationship between the load of pollutants from sewage and the biological effects on the recipient.

In order to meet future effluent standards, chemical coagulation have had to be introduced in several old treatment plants. A number of existing plants of different categories and with different loading rates were selected with a view to study application of chemical coagulation processes in old plants.

Simple treatment methods aimed at removal of coarser particles and floatables were studied in a seperate subproject. Different types of plants were considered in terms of efficiency, costs, etc.

The comprehensive research work carried out in this project group has contributed towards a considerable upgrading of the know-how on treatment technology and has indeed prepared the grounds for the large scale implementation of new treatment works in the last few years .

Use of Terrestrial Recipients for Sludge and Polluted Waste Water

Also this project group received high priority from the Steering Committee. Almost 25 % of the total budget or NOK 7,05 million was allocated for a total of 13 subprojects. Responsible institution for execution of the projects was the Agricultural University of Norway (NLH).

A central issue has been the study of soil as recipient for sludge, waste water and compost. This applies both to the positive effects in terms of utilizing nutrients for plant production and the possibility of concentrated deposition of wastes as a means of solving the water disposal problems in the society. The prime objective has, however, been to identify ways of utilizing the resource represented by the nutrients content within the limitations set by the health authorities on the possible presence and hazards of heavy metals, toxic substances or pathogens.

The research program has been comprehensive, and emphasis was placed on investigations of heavy metals content in sludges and the possible concentration of such metals in the soil profile. In particular it has been important to determine the distribution with depth in the various soils as a basis for assessment of future releases of pollutants.

Problems concerning binding and transportation of substances in soil were studied in soil columns in the laboratory. Analyses on plant substances have been carried out in order to assess the concentration of hazardous components, and some of the investigations have been aimed at studying the effect of sludge on the harvests. Sludge has been used to some extent on the fields after levelling of sloping ground, and it is essential to know the effect of sludge on surface run-off and soil erosion.

Joint composting of refuse and sludge has been studied during several full scale tests in order to develop an end-product which is acceptable from hygienic and aesthetic point of view. Reactor composting plants have been studied as a part of the research program.

A major task has been to investigate feasible and practical methods for depositing sludge and soakage of waste water in terrestrial recipients. Deposits for excreta collected from areas with leisure cabins have been studied with a view to establish suitable criteria for selection of disposal sites. Also these investigations yielded valuable information which has now been incorporated in practical guidelines.

The PRA work gave valuable input for regional investigation programs on soil as recipient for sludge, waste water and refuse. Work is in hand for preparation of a "recipient map" which will assist during the process of selecting areas suitable for residential housing, leisure housing, etc.

Apart from direct infiltration in natural soil the program also covered investigations of artificial sand filters for treatment of waste water from scattered dwellings. Filter construction and the filter's properties in terms of binding chemical components, in particular phosphorous, have been major issues in this connection. The projects have led to improved regulations and practical guidelines concerning construction and operation of such filter plants.

Pollutional load on water courses in areas with agricultural land and generally scattered population has been studied. Particular emhasis was placed on determining the relationship between pollution of water courses and the prevailing land use including various agricultural activities.

Extensive testing of biological decomposition toilets for scattered residential and leisure housing was included as one component of the work carried out by NLH. Several of the numerous makes of toilets now being marketed have been systematically tested with regard to performance. Some types have been characterized as "useless" whereas some manufactures have been advised on possible improvements of their products.

Research work in the field of terrestrial recipients for sludge and waste water has earlier been neglected. The comprehensive research work carried out by NLH has proved that use of terrestrial recipients will often offer good solutions which may be of great importance in reducing the pollutional load on water recipients.

Transportation Systems

About 20 % or NOK 5,5 million of the program funds were allocated to this group of projects. Responsible for the execution was the Department of Water Engineering, Technical University of Norway (NTH), and most of the work was carried out by this departement, the Norwegian Meteorological Institute, NIVA, the River and Harbour Laboratory at NTH and by Oslo City Council.

The subprojects in this group can be further divided into the following three groups with projects concerning: 1) Computation and design of sewer network. 2) Practical construction and operation of sewer network. 3) Pollutional load in storm water.

The reticulation and collector system of a sewerage system is often very complex. The work on developing a computer model for system analysis was therefore given an early start. The complex model which was developed, can be used for optimization of network components such as sewers, retention tanks, and weirs. In order to produce the required basic data for the model development, separate projects on short duration rainfall, urban storm run-off and need for model rain storms were carried out.

Existing data on short duration rainfall has been processed and made accessible for design purposes. About 60 new rainfall gauging stations with advanced equipment have been established in order to improve the data base in the future. These will be in operation for several years to come.

12 drainage areas were established in order to study the storm run-off pattern under urban conditions. Data from the stations are still being collected and a more reliable basis for design and operation of sewers and other components of sewerage systems will be the result.

Functional and operational performance of weirs and retention tanks have been studied on the basis of experiments. In the group of projects dealing with construction of sewer pipelines investigations of pipes, pipe materials and construction practises were given priority. Material properties, leakage proofing, structural strength, deflection due to various external loads, necessary construction and performance control, rehabilitation potentials, maintenance, etc. were thoroughly studied. Laying of rigid pipes and foundation requirements were covered in a separate subproject as were abrasion in sewers and self-cleansing in sewer pipes. Up to 1970 little or no attention had been paid to the fact that storm water being discharged into drainage systems may be severely polluted. Measurements and analyses have evidenced that such pollutional effects are significant both in central urban areas and in lesser developed residential areas, and they are to be accounted for in the planning of new sewerage systems and rehabilitation of existing systems.

The transportation system has a decisive impact on design and operation of treatment plants and thereby on the discharge of pollutants into the recipient. Investigations have shown that many existing sewerage systems are of inferior quality. Work carried out in the field of "Transportation System" has thus given valuable contribution towards improved basis for sewer systems rehabilitation and sound basis for design and construction of new sewer lines.

Discharge of Polluted Water into Recipients

The budget for this project group was approximately NOK 0,9 million. Responsible for the project work was NIVA, and in addition the River and Harbour Laboratory (NTH) and I/S Miljøplan (consultant) participated. The first subproject to commence was an extensive program for investigation of existing sea outfalls to study their performance. Consequently also a good basis for selection of further projects was established. In subsequent projects external loads acting on sea outfall systems were studied. Other projects covered sedimentation and self-cleansing in outfall pipes and prevention of air bubbles being sucked into the pipes.

Computation procedures were compiled for the hydraulic design of outfall pipes, diffusors and for dilution and dispersal of waste water in the receiving waters, and constituted important elements of this project group.

As a whole the different subprojects have yielded a good basis for construction and operation of outfall structures, as well as for computation of dilution, dispersal and distribution of the waste water in the recipient.

Industrial Waste Water Problems

About NOK 3,25 million were allocated for 21 different subprojects in this group. The projects have been executed by different research institutions, consulting firms, institutes serving industrial sectors, and a few private industries. The group covers a diversified range of problems and some of the more important industrial sectors which had their waste water problems studied, are presented in the following.

The Paper Industry Research Institute carried out extensive projects aimed at developing solutions for the wood processing industries' pullution problems, both in terms of bark and fiber discharges and in terms of dissolved and suspended organic matters from wallboard factories, and chlorinated hydrocarbons from pulp bleaching plants.

Fish oil and fish meal producing industries were given considerable attention during the research program. An exhaustive survey of the different sources of pollution was performed and proposals for measures and procedures aimed at reducing the pollutional effects were presented. Furthermore the suitability of treatment methods for fish oil plant waste water has been studied.

The pollution problems caused by potato processing industries have been covered in separate projects executed by the industries themselves. Furthermore projects dealing with the following categories of industrial waste problems have been carried out: Dairy industry, slaughter houses, metal galvanizing and plating plants and chemical wastes destruction and converting plants.

Availability of Research Information

Progress reports and a final project report setting out all details and findings of the research work have been prepared for all projects. However, these reports are available only in the Norwegian Language and therefore not readily accessible for people from outside Scandinavia.

PRA Users' Manuals

Publishing of Users' Manuals constituted the most important element of the information work. The manuals deal with a specific problem area and present results from one or more projects and other available, relevant information, and the presentation has been given in a concentrated and easily accessible form with emphasis on practical recommendations.

The manuals have been prepared by the information secretary (technical editor) in cooperation with one or more of the research institutions.

The following Users' Manuals have been issued:

1. System Analysis for Sewerage Network.
2. Storm Water Weirs and Retention Tanks.
3. Construction and Operation of Sea Outfalls.
4. Leakage Water. Economic Significance.
5. Simple Treatment Methods.
6. Selection of Model Rainstorm.
7. Pollution of Storm Water.
8. Air Bubbles in Outfall Pipes.
9. Self-cleansing in Sewers.
10. Stabilization of Municipal Sludge.
11. Abrasion in Sewer Pipes.
12. Costs for Dewatering and Transportation of Sludge.
13. Fresh Water. Biology. Effects of Treatment.
14. Submerged Outlet in Recipient - Discharge and Dilution of Waste Water
15. Sludge Disposal in Natural Soil Deposits.
16. Treatment of Leachates.
17. Rehabilitation of Sewers.
18. Use of Sewage. Sludge and Refuse Compost
19. Inspection and Control of Sewerlines.
20. Treatment of Waste Water from Scattered Residential and Leisure Housing.
21. Alternative Toilets for Leisure and Residental Houses.
22. Joint Composting of Municipal Wastes.
23. Treatment of Waste Water from Food Processing Industries in Municipal Treatment Plants.
24. Chemical Coagulation in Municipal Treatment Works.
25. Construction of Sewerlines.

Table I

List of PRA Projects:

- Quantity and Composition of Waste Water
- The Research Station at Kjeller
- Chemical Coagulation in Existing Treatment Plants
- Standardisation of Sludge Characterisation Methods
- Simple Waste Water Treatment
- Activated Carbon in Treatment of Municipal Waste Water
- Waste Water from Food Processing Industries in Municipal Treatment Plants
- Filtration of Waste Water in Stone Filters
- Treatment of Septic Tank Sludge in Municipal Treatment Plants
- Treatment of Leachates from Municipal Landfills
- Operation Studies of Treatment Works
- Disinfection of Waste Water by Ultra-violett Radiation
- Dewatering of Sludge
- The Use of Biological Systems for Recycling of Plant Nutrients in Water
- Methods and Investigations Concerning Sludge Disposal
- Disposal of Excreta Wastes in Åstadalen
- Sludge and Compost on Soil and Vegetation
- Investigation of Pollution from Agricultural Activities at Nes, Ringsaker Council
- Infiltration of Waste Water and Sludge in Soil
- Sludge Disposal in Romerike
- Joint Composting of Refuse and Sludge
- Alternatives to the Conventional Flushing Toilets
- Investigations of Potato Nematode in Various Sludges
- Litterature Studies on Leachate Problems
- Leachates from Existing Landfills
- Biological Waste Treatment Systems for Use on board Ships
- Microbiological Problems Related to the Use of Sludge as Soil Conditioner

- Data on Short Duration Rainfalls
- Run-off Conditions in Urban Areas
- Piping Material and Pipeline Construction
- Abrasion in Sewer Pipes
- Retention Tanks and Storm Weirs
- System Analysis of Sewerage Systems
- Studies on Urban Storm Run-off and Storm Weirs
- Leakage Testing of Sewers
- Laying and Foundation of Rigid Pipelines
- Preparation of Rain Storm Data
- External Loads on Sea Outfall Pipes
- Investigations of Existing Sea Outfalls
- Air Bubbles in Sea Outfall Pipes
- Sedimentation, Growth and Self-Cleansing in Pipes
- Diffusors and Initial Dilution of Waste Water
- Computer Program for Initial Dilution of Waste Water
- Fibres in Waste Water from Wood Processing Plants
- Destruction and Converting of Chemical Wastes
- Heavy Metal Removal from Industrial Waste Water
- Treatment of Diary Waste Water
- Waste Water Problems in the Wallboard Industry
- Pollution Problems in the Potato Processing Industry
- Water Consumption and Pollutional Problems in Slaughter Houses
- Separation of Oil Emulsions
- Ion Exchange in Treatment Processes for Waste Water from Metal Surface Preparation Plants
- Waste Water from Evaporators in Fish Oil Plants
- Waste Water from Cleaning and Flushing Processes in Fish Oil Plants
- Separators for Removal of Oil in Waste Water
- Chlorinated Hydrocarbons in Wood Processing Industry Waste Water
- Treatment of Textil Industry Waste Water
- Biological Treatment of Waste Water From Potato Flour Plants
- Recycling of Chromium in Tanneries

Optimization of calculation of water treatment facilities with the use of computers

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Summary. When designing and calculating systems of water supply there appear a number of problems which is connected with a big volume of calculations. The introduction of computers enable to change radically the approach toward the calculation not only of systems of water supply and their units but also of the water treatment stations.

The programs of choosing and preferable designed capacity of water treatment plant, optimum arrangement and structural parameters of different kinds of facilities have been developed.

Technological process of two-stage treatment of water is being developed. Analysis shows that the volumes of the facilities reduce and quality and reliability of their work increase by the optimization of the project solution on the base of calculation with the use of computers.

Sommaire. Lors de l'étude et des calculs des services de l'eau de certains problèmes se présentent dont la solution exhaustive dépent des volumes importants des calculs. Les ordinateurs électroniques permettent de modifier efficacement la methode des calculs du réseau de distribution et de ses éléments ainsi que celle des stations de traitement des eaux.

On a été élaboré les programmes du choix de la production théorique préférable de la station de traitement des eaux, des paramètres de construction optimaux constructifs des constructions des types différents. On élabore les programmes de l'optimisation du procédé technologique de l'épuration à deux degrés.

Grâce à l'optimisation des solutions en plans sur la base des calculs réalisés par les ordinateurs électroniques, le volume des travaux de la construction des stations diminue considérablement avec une augmentation simultanée de la fiabilité de leur fonctionnement.

When designing and calculating systems of water supply and their basic units there appear a number of problems, a comprehensive solution to which is connected with a big volume of calculations. One of the most complex of them is the calculation of municipal water mains and co-operation of its components, testing of system reliability in case of hydraulic impact; choosing the best variant when elaborating water treatment facilities, etc. The choice of an optimum solution asks for consideration of numerous variants or estimation schemes with regard of all the factors of substantial influence, which is, actually, impossible with manual methods of calculation.

A wide introduction of computers into home practice enabled to change radically the approach towards the solution to similar questions. For instance, as a result of work done by the VNII VODGEO for ever greater number of projects, now advantagely the estimate of water mains and of hydraulic impact is made with the help of computers. That gives an opportunity to adopt the most rational design solutions based on more true results.

In the late sixties a number of research and design institutes terned to computerized optimization of the most complex component of water-mains system - a composite of facilities for water treatment.

When designing and estimating water treatment facilities one must solve the problems of determining optimum arrangement and structural parameters of facilities for preparattion of water. The difficulty is that the number of possible standard dimensions and of variants of arranging technological cells of facilities is rather great. For example, for the filtration room of a 100 thnd m^3/day capacity plant according to experiments, there might be about 30 admissible arrangements with a different number of different size tanks to be placed in buildings different in their dimensions and structure.

The TsNIIEP has developed a series of algorithms covering the following facilities: horizontal settling tanks, clarifiers with suspended sediment, rapid filters and contact clarifiers for plants of 30 thnd m^3/day capacity and over. With regard of basic technological and building requirements algorithms provide for such elaboration by computer itself, of design variants of the solution to the reservoirs of designed capacity the calculation of costs on the basis of specially developed enlarged costs indices and of the choice of optimum solution.

A similar job with the use of part of the above algorithms by the TsNIIEP for Utilities was done by the VNII VODGEO and SOYUZVODOKANALPROEKT for water treatment plants with the capacity of 1 thnd to 30 thnd m^3/day.

At present an ever greater attention is paid to improving water treatment facilities with regard to the kind of water quality changes throughout the year. It enables, in addition to "purely designed" optimization of facilities, to gain their most efficient and economical operation during maintenance.

As a background to this use is made of the theory of modelling the filtration process through granular media of water with suspension processed by coagulant, one of the founders of which is D.M.Mintz (USSR), and of the theory of modelling process of settling this kind of water.

For treatment of water in settling tanks and filters, uniflow filters, contact clarifiers as well as for some other technological schemes, there are established in general, mathematic relations between the quality of initial water and designed parameters of facilities.

The TsNIIEP for Utility has elaborated the complex of algorithms for mathematic modelling of the process of two-stage treatment of water with optimization of estimated technological parameters of such facilities as horizontal settling tanks incorporating built-in flocculation chambers with suspended sediment, and rapid filters - one-flow, two-flow and two-layer, with regard to the use of different filter body materials. These algorithms provide for variation of basic parameters of the process: distribution of sludge load among the facilities of the first and the second stages of treatment in different seasons of the year, variation of the kind of filter body, its height and fractional composition, etc. Similar work was done in the automatization sector of the Academy of communal utilities (AKKh) and LNII AKKh.

Out of other works in this field there should be mentioned the use of computers for correlation analysis of different characteristics of operating water treatment facilities (for example, work done in UVKH, Kiev) on determination of optimum dose of coagulant depending on the quality of water and consumption of reagents used. To optimize the operation of acting facilities, use can also be made of the above complex of algorithms for mathematical modelling of treatment process.

The relevant programs have been compiled on the basis of earlier elaborated algorithms and necessary calculations are being made on the small and medium computers. Programs are, in general, recorded in the algorithmic languages ALGOL or ALGAMS as well as in codes of relevant machines.

At present the USSR is continuing the work on optimization of estimate of water treatment facilities - both in elaboration of programs on the available algorithms and in setting and solving new tasks; improvements and sediments to the acting programs are under way.

The main purpose of conducting such work in the creation of a single all-Union library of programs covering all aspects of the problem in order to reduce labour costs and to ensure a high level of design for water treatment facilities and their efficient operation.