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Roofing Materials and Systems

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TPO ROOF MEMBRANE SYSTEMS: A WORLD HISTORICAL PERSPECTIVE AND SUMMARY OF BEST PRACTICE

REPORT OF CIB W83 COMMITTEE ON ROOFING MATERIALS AND SYSTEMS

CONTENTS

1. ABSTRACT

Thermoplastic Polyolefin (TPO) roof membrane systems were introduced commercially in the early 1990s. They are installed in many countries worldwide, and in some countries they enjoy significant market share. Over the years products have evolved together with changes in design and construction practice. This report will present issues that have developed and been addressed, and will outline current product standards and best practices used in various countries. Sharing this information is intended to lead to further improvements in TPO product standards and result in better system performance.

The Committee has developed a summary of the key points of current best practice. These common principles are offered for the benefit of the building owner, designer, consultant, contractor and manufacturer seeking to further improve the reliability of TPO roof membrane systems.

2. INTRODUCTION

TPO is a thermoplastic material available in sheets that can be heat welded together to create a monolithic roofing membrane. In Europe the product is also called Flexible Polyolefin (FPO).

Long-term flexibility does not rely on plasticizers but on the specific internal composition of the main co-polymer. The color of the external weathering face is typically light grey or white, improving surface reflectivity and reducing solar gain. TPO membranes can also be produced in dark grey or other colors if requested for aesthetic reasons and subject to the manufacturers' guidance.

As TPO roofing membranes are polyolefin based, the compound must contain stabilizers to prevent oxidative, ultra violet (UV) and heat degradation. Many manufacturers have introduced new technologies in UV and heat stabilization that have made TPO membranes more robust than those available in the product's inaugural years. Weathering resistance is primarily provided by using a combination of anti-oxidants and a complex mix of UV stabilizers and absorbers.

TPO membrane is manufactured using an extrusion process which results in a laminate consisting of a top ply, a fabric or glass fiber reinforcement, and a bottom ply. The membrane is typically offered in thicknesses of between 1.2 mm (45 mils) and 2.5 mm (100 mils), and widths from 1.05 m to 3.6 m (3 ft 6 in to 12 ft) with national variations. The width of the sheet utilized for specific projects is dictated by building performance requirements such as wind uplift pressures as well as the membrane securement method.

The markets for TPO roofing systems in the United States and parts of Europe have grown significantly over the past decade. In general growth has been worldwide. In the past there have been concerns about the long-term performance of TPO membranes based on old formulations. Investment in plant and equipment as well as the incorporation of new formulation technology has improved the quality and reliability of TPO products.

The CIB W83 Committee

The CIB W83 Committee on Roofing Materials and Systems consists of 30 roofing specialists drawn from more than 12 countries. In March 2016, a Task Group was established to develop our understanding of the historical development of TPO roof membrane systems.

Previously the Committee has examined the topic of roof reliability and identified key points of best practice, which were published in the 2015 report 'Improving Roof Reliability'.

3. CHRONOLOGY

3.1 North America

In the late 1970s, TPOs were developed to be inherently flexible and plasticizer and halogen free. TPO membranes were initially utilized for geomembrane applications, including pond liners, and were used in the automobile industry to protect exterior surfaces and as wire covers.

The first known TPO roof membrane was produced by Montell in 1986 and installed on a roof in Michigan. The NRCA Guide for Materials in 1987 did not list TPO as the products were few and information scarce at that time. In 2000 Montell merged with two other companies to become

Basell. In 2007, that company again merged with Lyondell to become Lyondell-Basell, that still supplies base polymers for the manufacture of TPO roofing. Today there are also other producers of raw materials to produce TPO membranes, including Exxon and Dow.

In the late 1980s, following the installation of the first TPO roofing membrane, Versico, a division of Goodyear Tire and Rubber, started to promote TPO roofing membranes. They were followed by JPS Elastomerics in the early 1990s. In that era UV durability concerns were raised regarding the existing fire retardants in TPO, resulting in alterations to the fire-retardant formulations.

In the mid-1990s Carlisle Syntec Systems acquired Versico and began marketing a TPO roofing membrane. In the late 1990s, Firestone and GAF also entered the market, which led to TPO gaining a significant share of the market for single-ply roofing. Following the increase in sales, GAF, Firestone, and Carlisle added plants to keep up with demand. Since then, one of the early suppliers, Stevens Roofing Systems, formerly JPS Elastomerics, has ceased to exist. Johns Manville built its first plant in Alabama in 2008.

In the USA the market approach and product positioning for TPO membranes is seen as meeting the requirement for heat weldable white roof membranes, often for EPDM replacement in a low cost commodity market. TPO membranes have increased their market share at the expense of bituminous roofing systems as well as, but to a much lesser degree, EPDM systems.

In Canada, TPO installations began in the late 1990s, mainly as a commodity product on manufacturing, retail distribution and warehouse buildings, with thinner membrane applications as mechanically fastened or fully adhered assemblies. Today, TPO is gaining ground on higher end buildings. As for market share, modified bitumen roof systems are still prominent across Canada.

3.2 Europe

When compared to North America the development of TPO roof membranes was different in Europe with fewer manufacturers and a different market approach. The TPO roof membranes were introduced as a long lasting, environmentally sustainable product.

Sarnafil commenced production in the late 1980s with the first roofs installed with 1 m wide material in 1989. Flag Spa (now Soprema Srl) has been manufacturing TPO roof membranes in Europe since 1990.

In the 1980s TPOs were similar to Thermo Plastic Elastomers (TPE). In the 1990s and 2000s the TPOs were mostly polypropylene based.

An early driver for TPO development was to offer a direct alternative to PVC at a time when the environmental appropriateness of PVC was being considered. A barrier to TPO growth in Europe has been the cost of materials that meet demanding fire regulations. In Europe the minimum thickness of TPO membranes tends to be greater than in North America.

Early studies in Europe into the long-term performance of heat welded seams highlighted the importance of seam preparation and welding techniques. This led to the setting up of special training courses for roofers welding TPO membranes.

4. EARLY LABORATORY AND FIELD TESTING DEVELOPMENT

Since using TPO as the base polymer for roofing membranes was a brand-new technology 30 years ago, extensive testing was conducted on the material prior to commercialization. As with any new technology, the question is always, 'what type of performance characteristics are necessary for the product to function in the long-term'? Some of the testing conducted on the newly developed TPO membranes included:

- Physical property testing
    - Breaking strength
    - Tearing strength
    - Elongation
    - Brittleness point
    - Water absorption
- Heat aging
- Xenon arc accelerated weathering
- Outdoor weathering (in the USA: Miami, Florida: hot humid climate, Phoenix, Arizona: hot dry climate)
- Fire resistance
- Wind uplift resistance
- Weldability
- Field trials / installations

Other testing that may have been undertaken included:

- Hail impact resistance
- Puncture resistance
- Cold forming
- 2d thermal expansion (dilation)
- Seam strength

In Europe test requirements follow the EN 13956 Standard. For aging the QUV test is used.

Hail impact and puncture resistance are characteristics of the roof system and not just the membrane itself as the type of underlying board below the membrane is a relevant factor.

On reflection there are lessons to be learnt. TPO membrane manufacturers based in the USA have improved their product performance by an iterative process, especially for roofing in hot climates. The question is posed 'what could have been done differently to prevent some of the problems that have been encountered with different versions of TPO roof membranes and their application?'

Firstly, field trials, field trials and more field trials. There is no better method to determine how a product will perform on the roof top than to actually install it in the conditions to which it will be exposed. Performing trial installations can certainly alert the roof system manufacturer to issues that may affect how 'contractor friendly' their products will be perceived. Determining how long these installations should be monitored prior to commercializing the product is always a struggle for the inventor of a new product. Allowing the product to be monitored in real life conditions for its anticipated life span would be ideal, but in the case of roofing materials, this practice could result in a 30-year delay in the product launch.

Figure 1: Q-TRAC Natural Sunlight Concentrator

Secondly, accelerated testing. The use of a weathering device such as the Q-TRAC natural sunlight concentrator allows outdoor weathering to be conducted in a shorter time period compared to actual real-time outdoor weathering. Such equipment was not in existence 30 years ago but is now being utilized by some roofing manufacturers to evaluate performance of newly developed stabilizer packages.

5. PERFORMANCE ISSUES

5.1 Weldability

The ability for the seams of a thermoplastic roofing membrane to be welded under a variety of outdoor conditions is paramount in order to ensure a leak free roofing system. When TPO was first introduced to the marketplace, a learning curve was experienced by roofing applicators. The existing applicators that began installing TPO membrane were typically experienced with EPDM and PVC. Those installers who worked primarily with EPDM had little experience using heat welders. Those that worked primarily with PVC had to learn the differences between welding TPO and PVC roofing membranes, adjusting for speed and temperature. One of the primary differences is TPO is welded at lower temperatures than PVC. Many contractors initially overheated the membrane during the welding process such that the lapped surfaces did not bond. This also caused premature membrane degradation of the roofing system due to depletion of the heat stabilization package.

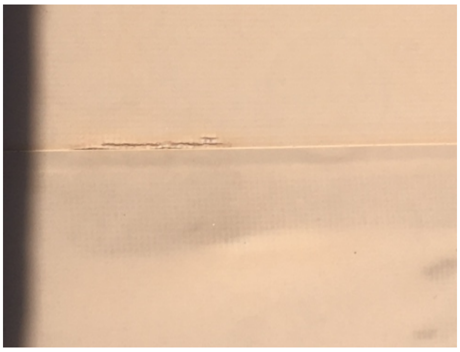

Figure 2: Membrane cracking adjacent to overheated seam

Several manufacturers experienced significant welding issues with their products during the early days of TPO membranes. In the field automatic welders which are self-propelled and have adjustable speed and temperature settings, are used to complete the seam welding process.

These auto-welders are typically checked for proper speed and temperature settings by field testing. Two pieces of TPO membrane are welded together to create a seam and a one-inch wide strip is cut across the width of the seam. After waiting for the weld to cool to ambient temperature, the sample is pulled by hand in a 'peel' mode until failure occurs.

If the failure mode is ply-to-ply failure with the top or bottom ply of the membrane delaminating from the reinforcing scrim, then the weld is deemed adequate. Subsequent welds made by the equipment with the same heat and temperature settings will remain watertight over the life of the roof.

In some instances, the failure may occur outside of the weld area with the membrane rupturing. The failure mode is influenced by the type of reinforcement layer used, for example, scrim (of different types), glass fibre or composite (scrim + glass fibre).

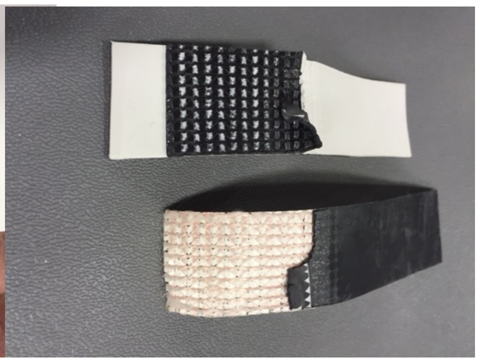

Figure 3: Field testing weld ***Figure 4: Good weld – ply to ply delamination***

While field testing the welds is important to ensure quality of the roof installation, probing is another good method to field check seams. Probing is especially effective at finding voids in welds caused by stopping and starting the auto-welder or when a hand welder is used to complete details.

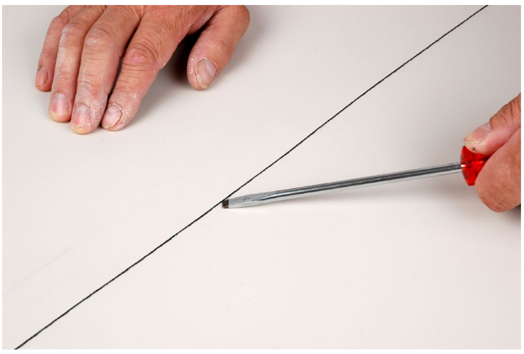

Figure 5: Probing TPO membrane seam

An interesting phenomenon observed early on in the history of TPO development was reports of TPO welds coming apart after the roof had been in service for some time. When heat welding equipment is not set up properly, thus providing inadequate heat and pressure to create total fusion between the sheets of the membrane, a cold weld will result. This type of condition is not always uncovered during the probing process since in some cases, the two pieces of membrane are tacked together just enough to resist the pressure of the probe. In this situation, the membrane will appear to be properly welded after the probing process, but after the membrane experiences temperature cycling, the welds will begin to open due to forces exerted by expansion and contraction of the membrane. This situation will occur only if the seam was not properly welded. Once the membrane seams are properly fused together, the welds will not come apart since they are stronger than the membrane material itself.

It is important to recognise that when welding aged TPO membranes it is necessary to carry out proper treatment or activation of the existing membrane by washing it and by preparing it with adequate TPO cleaner. All TPO manufacturers have developed within their accessories range specific cleaners for this purpose.

It is reported that today most roofing contractors have gained experience in welding TPO membranes and the importance of checking their completed work. Consequently, the number of cold welds has been significantly reduced.

5.2 Stress cracking

During the installation of TPO membrane, the membrane is folded back on itself either to apply bonding adhesive in a fully adhered system or to expose the seam area where fasteners and plates are placed to secure mechanically fastened membrane. In many cases, applicators would stand on, or place weighted buckets on the fold causing a permanent crease in the surface of the membrane. Due to the stress in these areas, some early membranes displayed premature cracking at any creases. Education of applicators by the TPO roofing manufacturers and roofing organizations regarding proper installation methods to eliminate creases has all but eliminated this issue together with the incorporation of enhanced stabilization packages in the membrane

5.3 Bonding

When TPO membranes first became commercially available, some manufacturers attempted to use existing bonding adhesives which had been formulated for use with other single-ply membrane materials to adhere TPO membrane. Within a relatively short time period it became obvious that this application was not going to perform in the long-term. Due to the smoothness of the TPO surface, the determination was made that special adhesives containing an adhesion promoter component were necessary to provide proper long-term adhesion.

Fully bonded (adhered) systems are available with either a fleece-backed or a smooth surface to enhance bonding to the substrate. Several manufacturers also produce self-adhered TPO membranes with factory-applied pressure sensitive adhesives or using self-adhering geotextiles.

5.4 UV resistance

Some early generations of TPO membrane in North America that were compounded with just enough stabilizers to meet the minimum accelerated weathering resistance requirements of the original ASTM D6878 standard, did display some surface cracking in high UV areas of the USA. With stabilization technology developed over the past two decades and the specification of thicker membranes, most new TPO membranes will perform at levels well above the minimum weathering requirement of the current ASTM TPO standard.

5.5 Heat resistance

Building designs have become more complex and sometimes incorporate reflective facades above roof level. There have been reports of some white TPO roofs adjacent to such reflective building components showing isolated signs of degradation. The location of the degraded membrane suggested that the cause was reflected sunlight and heat from adjacent reflective vertical surfaces. Several examples of prominent buildings, such as the Vdara Hotel in Las Vegas, Nevada, USA, which has a south facing highly reflective concave façade, show how there can be unintended consequences of building designs with such surfaces.

Figure 6: Reflective parapet walls

Figure 7: Isolated area of degradation

Figure 8: Solar reflection from metal duct onto TPO roof membrane

Figure 9: Local damage caused by concentrated heating

The findings from field studies to record local increases in roof membrane surface temperature are given in the references. Dirt build-up on the membrane also affects surface temperatures.

In severe cases the exposed roof membrane should be covered by a green roof construction, gravel or other ballast loose laid over geotextile protection sheets. Another possible solution, subject to the membrane manufacturer's approval, is to apply a non-reflective coating system such as referred to in the Italian Norm UNI 8178-2.

5.6 Slip resistance

TPO membranes, in common with other membrane types, can be slippery to walk on in wet conditions. There is anecdotal information from contractors, building owners and maintenance personnel that the number of reported slips and falls has been growing. Snow will cover icy surfaces and will be difficult to see. Rain events and ponded surfaces create slip hazards on low sloped surfaces, slips compound on steeper sloped surfaces.

Notices should be posted at roof access points to outline the hazards of slipping, and specific slip resistant membrane walkways need to be installed from roof access points to serviceable equipment and other key locations. Other types of walkways may need to be installed to straddle drain locations, and valleys with pooled areas.

Sliding snow and ice can cause damage to roof surfaces and equipment or may fall off roofs endangering property and people on the ground. Increased snow loads caused by falls from upper roofs onto lower roofs have resulted in Canadian building codes implementing a coefficient of slippage of snow for slip resistance between roofs.

The Technical Note on snow friction coefficient for commercial roofing materials published in the ASCE Journal of Cold Regions Engineering shows that PVC and TPO membranes have a low coefficient of friction.

A specific norm for slipperiness of floor coverings exists in Europe, EN 13983:2002. This test method has also been introduced for roofing membranes in the approved EAD 030351-00-0402 'Systems of mechanically fastened flexible roof waterproofing sheets' published in February 2019 which has superseded ETAG 006. Paragraph 2.2.2.4 on the 'slipperiness of the sheets' states that the coefficient of friction is determined in accordance with EN 13893:2002.

5.7 Uneven finished surface

Occasionally the finished surface of the TPO roof membrane has ripples or shallow waves. This is often as a result of the mechanically fastened membrane being laid out and secured in cold weather conditions. When the temperature increases, the membrane expands and the resulting excess membrane causes a distorted roof surface. Once the temperature of the membrane decreases, the membrane will once again lay flat. Typically, after several season changes, the amount of ripples and shallow waves will reduce.

As with most types of roofing materials supplied in roll form it is good practice to roll out the membrane and allow it to relax for a short period before fixing or adhering.

Some manufacturers in Europe advise that thermal expansion can be avoided or reduced by using a double reinforcement: polyester scrim for resistance against wind uplift, and glass fleece to reduce thermal movement.

6. PRODUCT STANDARDS HISTORY

6.1 North America

When TPO membranes were first installed on roofs in the mid-1980s and commercially introduced in the early 1990s, there were no product standards that defined physical properties or performance characteristics. ASTM standards were in existence for PVC and EPDM roofing membranes at that time but not for TPO.

Work began at ASTM in 1993 to develop a TPO standard which was finalized in 2003 and designated ASTM D6878 - Standard Specification for Thermoplastic Polyolefin Based Sheet Roofing. Since TPO membrane was in its infancy, and was more closely aligned with EPDM than other single-ply materials, the EPDM standard (ASTM D4637) was used as a template for the TPO standard. Physical property requirements such as breaking and tearing strength, elongation, and water absorption were developed based on the characteristics of TPO membranes that were in existence at the time and have remained mostly unchanged during the duration of this standard.

Heat aging and weather resistance were the most difficult properties to define. The heat aging and weather resistance test parameters contained in ASTM D4637 for EPDM materials were essentially copied into the TPO ASTM standard. Heat aging was specified to be conducted at 116 degrees C (240 degrees F) for a duration of 28 days. Accelerated weathering test parameters, using the xenon arc apparatus, were set at 80 degrees C (176 degrees F) black body temperature with a total radiant exposure of 5040 kJ/m² at 340 nm.

While the TPO heat aging and weather resistance test parameters were set at the same levels as EPDM, the requirements for a membrane pass were different. After heat aging exposure, the original TPO standard specified that the membrane must retain 90% of the original breaking strength and elongation at fabric break, 60% of the original tearing strength, and could experience no more than 1% fluctuation in weight. After xenon arc exposure, the standard stated that samples could display no surfacing cracking when bent around a 3-inch mandrel and inspected under 7 x magnification.

Based on field observations over the years, several changes have been made to the TPO standard regarding the heat aging and accelerated weathering requirements. In 2006, the total radiant exposure portion of the xenon arc accelerated weathering test was increased to 10,080 kJ/m² at 340 nm where it has remained to this day. In 2011, the duration of the heat aging test was increased to 224 days (32 weeks) and in 2016 the criterion for membrane pass was changed to a visual inspection for surface cracking instead of retention of physical properties.

The choice of 32 weeks was based on the Arrhenius equation that for every 10 degrees C of temperature increase, the reaction rate essentially doubles. This is a lab based theory developed on solution chemistry and care is required in interpreting the results for solid materials. Further background is given in the ASTM paper of Xing and Taylor in 2011.

Using the assumption that the membrane surface would remain at such an elevated temperature consistently for 12 hours every day of the year is probably unrealistic but this has built a substantial safety factor into the heat aging requirement. To comply with the new heat aging provision, some TPO manufacturers in North America have re-evaluated their products and changed their stabilizer packages.

6.2 Europe

The European standardization activity for TPO membranes was originally based on the experiences of the DIN 16726 series, SIA 280 and Onorm B 3651 series and all the main test standards reported in these norms. Nowadays the European harmonized product standard for TPO membranes used in roofing applications is EN 13956, ‘Flexible sheets for waterproofing - Plastic and rubber sheets for roof waterproofing - Definitions and characteristics’.

This harmonized standard is not only for TPO roofing membranes but also covers other types of synthetic membranes for the same intended use including PVC and EPDM. It has the scope to specify the relevant characteristics of synthetic membranes when used for roof waterproofing and also to give indications about how to assess and verify the constancy of performances of the product to the European Standard and factory production control procedures. Annex ZA sets out all of the requirements of CPR (EU) No 305/2011which allows the European CE mark to be given to the product. The essential characteristics are stated in the Declaration of Performance (DoP).

TPO membranes for roofing applications are subject to an evaluation of conformity task under system 2+ as reported in the annex ZA of the European Standard EN 13956. The manufacturer needs to conduct all tests related to the assessment of the performance of the membranes produced, the Factory Production Control and the test on samples produced according to the plan reported in the European Standard. All this is done under the initial inspection and the continuous surveillance of a notified factory production control certification body.

The Declaration of Performance has to be provided by the manufacturers once they introduce the product in the EU market. The essential characteristics to be declared, according to the European Standard EN 13956 for TPO membranes to be used in roofing applications are set out in the table below. According to the CPR n. 305/2011, the manufacturer has to declare the essential characteristics set out in the table, relevant for the specific roofing system; mechanically fixed, fully adhered or ballasted. The European standard does not measure a minimum thickness for the top ply over the reinforcement layer.

External fire performance is a whole system test and cannot be specified in a single product standard. The performance must be tested in accordance with CEN / TS1187 and classified according to EN 13501-5 for the specific systems and to the test required in the specific country. This is for roof membranes sold in European countries and where there is a specific regulation for external fire performance.

Most TPO membranes are based on their formulation principles established over decades. They consist of a reactive blend of a temperature resistant weldable thermoplastic polypropylene polymer and an elastomer to achieve a good flexibility (therefore also named flexible Polyolefin, FPO) and chemical resistance. During the decades the components of these membranes need adjustment to changing local regulations and the improved processing.

Artificial aging according to EN 1297 is defined in the standard as a ‘screening’ test of a defined time (1,000 hours) to compare the behaviour of similar membranes. Nevertheless, European producers used to test roofing membranes for a period longer than 5,000 hours. The length of testing can also be extended significantly for research and development purposes.

The declaration about dangerous substances follows, in general, the European REACH regulation and, if existing, national regulations.

Essential characteristics	Test method	Harmonised technical specification
External fire performance	EN 13501-5 *(Limited to class F)*	EN 13956:2012
Reaction to fire	EN ISO 11925-2 EN 13501-1	
Watertightness	EN 1928 met. B	
Tensile properties: - Tensile strength (N/50 mm) - Elongation (%)	 EN 12311-2 EN 12311-2	
Resistance to impact (mm)	EN 12691	
Resistance to static loading (kg)	EN 12730	
Tear resistance (N)	EN 12310-2	
Joint strength: - Peel resistance (N/50 mm) - Shear resistance (N/50 mm)	 EN 12316-2 EN 12317-2	
Foldability at low temperature	EN 495-5	
Resistance to roots	EN 13948	
Durability: Exposure to UV radiation, elevated temperature and water	EN 1297	
Dangerous substances	*(Test method not defined)*	

Summary of harmonized essential characteristics as listed in EN 13956 Annex ZA

In some cases essential characteristics are related only to specific applications as recorded in table ZA.1 of Annex ZA.

6.3 Rest of the world

Most countries throughout the world will accept roof membrane conforming to the North American and British / European material standards. Other national standards are listed below.

- Japan
  - Japanese Industrial Standard, JIS A 6008
- China
  - Chinese Standard GB 27789 – 2011, ‘Thermoplastic Polyolefin (TPO) Sheets for Waterproofing’, implemented 1st November 2012
- Singapore
  - Buildings are required to be designed with sustainability in mind
  - Singapore Environmental Council
  - Green Label Singapore

7. REGIONAL TRENDS

7.1 North America

As of 2018 in the USA, TPO has a dominant market share with more than 50% of roofing membranes with an annual installation in excess of 185 million m² (2 billion square feet). In Canada, although on an upward trend, TPO has not gained as much market share, as modified bitumen roof systems are predominant.

When TPO membranes were first introduced, the most common thickness was 1.14mm (45 mil). Over the years the trend has been to increase the overall thickness such that today in the USA the most common thickness specified and used is 1.52 mm (60 mil). Currently 80% of TPO membranes are mechanically fastened, with a trend towards using more adhered systems. Polyisocyanurate insulation board is widely specified for the substrate often in conjunction with a high-density cover board.

7.2 Europe

In Europe the area of PVC single ply membrane installed would be broadly 3 times that of TPO membrane. In general, mechanically attached systems are predominant, with significant numbers of ballasted and vegetative roofs. In 2018, the IFD young roofer world championships held in Riga, Latvia used TPO membranes for the first time recognizing the wider usage of the membrane across Europe.

The most common membrane thickness in Europe is also 1.5 mm (60 mil), although there is a trend to adopt 1.8 mm (75 mil) thick material. Beneath photovoltaic installations 2.0 mm (90 mil) thick membranes are often specified where mechanical resistance, greater traffic resistance and high service life are important requirements. It would be helpful to have written guidance relating geographic location with recommended membrane thickness required to give long term performance.

It is recognized that the color of roof membranes is a regional issue. For example, in northern Europe roof membranes tend to be grey colored, compared to Spain and Italy where membranes are white. Dark colored membranes may have a shorter life span due to increased temperatures upon exposure to the sun.

In France, Scandinavia, and the UK, the more demanding fire tests have resulted in the need for greater flame retardant within roofing products. Also, in other European Countries the external fire performance is a requirement. This is a big challenge for the definition of special formulations to pass class B roof tests t1, t2, t3, and t4. Fire retardants can also affect membrane performance. Membranes that meet specific fire performances levels have special identification within the product range of European manufacturers.

7.3 Japan

It has been reported that TPO roof membranes were introduced in Japan more than 20 years ago. Some manufacturers started producing TPO roofing sheets in 1998. It was adopted within the Japanese Industrial Standard JIS 6008 (Roofing sheets of Synthetic Polymer) as one of the roofing sheets in 2002.

Although it was expected that TPO roof materials would steadily grow in the Japanese market, this has not happened. Approximately 710,000 m^2 of TPO sheets were laid in 2016, all of which were imported products from the USA. It occupies just 1.1% in the Japanese market (62 million m^2, total area of all kinds of waterproofing membranes applied in 2016).
The reasons why TPO market share has not grown in Japan have been given as follows:

(1) PVC sheet manufacturers have dominated in the roofing sheet market.

(2) Japanese roof workers preferred not to use TPO due to the stiff mechanical property of the sheet material.

7.4 Future trends

Manufacturers continue to develop their products. A new generation of TPO products to be introduced from 2020 onwards is based on hybrid technology that claims to be highly flexible, easy to apply and durable.

8. CURRENT BEST PRACTICE

The challenge for the Committee has been to summarize and group together the main points of good practice to produce a simplified short document that would be useful and relevant to the construction and property industries globally. The best practice guidance follows the sequence of a typical project: design, materials selection, installation, maintenance.

8.1 Adopt a holistic approach to roof design

As with all low slope single ply membranes it is good practice to adopt an holistic approach to roof design considering at an early stage the relevant factors and interactions. These may include, but not necessarily limited to:

- site exposure to wind, precipitation and other local factors
- building orientation and relationship with neighbouring buildings affecting solar gain
- internal building usage, internal operating conditions
- passive system to reduce energy use/ active system to reduce carbon footprint
- anticipated longevity and the need for resilience in extreme events

Consider the roof system being designed as an interconnected whole, which is part of something larger and integrated into the existing environment. The roof design should mesh aesthetically and functionally whist incorporating the basic tenets of sustainability.

8.2 Select the appropriate means of attachment

A positive decision should be taken on how to prevent the lightweight membrane becoming detached in strong winds. There are three principal means of achieving this:

- mechanically fastened: determine the number of fasteners and spacing to safely withstand design wind suction pressure
- fully adhered: preferred in high wind zones, reduced installation noise when reroofing over operational buildings, less aesthetic issues
- ballasted, including vegetative and green roofs: good resistance to micro-organisms, provide protective layer to reduce puncture risk

8.3 Minimise heat deflection effects

This phenomenon is described in an RCI Interface article by French and Ober in February 2012. Heat reflected off adjacent glazed walls, tall parapet walls and other rooftop equipment can cause localised increases in surface temperature and intensity of UV radiation. These issues are particularly apparent in southern USA states, the Middle East, and southern European countries.

Practical guidelines to avoid these local issues are needed. In the Italian Norm UNI 11540 for the maintenance of roofs, there are specified treatments to avoid heat deflection issues. These are also specified in the Italian Norm UNI 8178-2.

8.4 Slope

Ensuring minimum falls, or slopes to drains, including around penetrations, results in less dirt accumulation and improved longevity. Local standards and regulations should be followed.

There is a concern that local standards are not necessarily adequate. Many jurisdictions require a minimum of 1% - 1.5% slope for new construction, depending on the system, while some jurisdictions have no standards. For re-roofing the requirement is provide a slope to drain. Slopes of less than 1% do not provide proper drainage. It is good practice to avoid localised ponding.

8.5 Increase overall product thickness

This is generally seen as good practice in both North America and Europe. Currently the minimum standard in North America is 1.14 mm (sold as 45 mil). In Europe the minimum standard is 1.2 mm with most production being 1.5 mm (60 mil) or more.

There is a consensus that performance is improved with thicker membranes specified with an overall thickness of at least 1.5 mm (60 mil). However, it is recognised that this design choice is market driven. Many owners seek a roof system as inexpensive as possible. This is considered a mistake. With insulation layers having doubled in thickness in recent years, the impact of the membrane cost on the full package has been greatly reduced. In the meantime, the membrane responsibilities have increased and roofs are used as location for air conditioning equipment and photovoltaic modules such that a greater membrane thickness is justified. In these cases, a thickness of 1.8 mm or 2.0 mm (70 or 80 mills) is more suitable.

For thicker membranes, 2.0 mm (80 mil) overall thickness, there is a concern about workability. Also, there is a risk of forming leak paths at T joints (three way laps) where the raised edge within the lap has not been chamfered. Trained and experienced roofers can address these issues, by using non-reinforced T joint covers to eliminate any water channel created by the step-off.

It is recognised that some building owners may not be seeking longevity of their roof, particularly if sale of the property is foreseen in the near future. Different consumers face different commercial realities. There remains the consensus that best practice is to specify a reinforced product that has minimum overall thickness of 1.5 mm (60 mil).

8.6 Ensure minimum membrane coating thickness over reinforcing fabric

This is a critical performance issue. Initially a minimum thickness was required in the ASTM material standard, but recently that requirement has been revised to a percentage of the sheet thickness. The requirement is that the thickness of membrane over the reinforcing fabric shall be at least 30% of the overall thickness, ensuring the top ply that is exposed to UV light and extreme weather is as robust as possible. This is not currently a requirement in Europe.

The bottom ply below the reinforcing fabric also needs to be heat weldable. It is understood that recycled content can be used in the bottom face, such as from production wastage to roll edges which is ground up and reused.

8.7 Colour choice

Currently the standard choices are between white and grey. Some manufacturers produce a tan coloured membrane. Custom colours can be manufactured, but consideration for formulation, impact on fire ratings, geographical application and performance are important. As of 2019 there are over a dozen colour choices in the USA. It is recognised that these colour variations require changes to the composition of the membrane’s heat stabilizer.

In the past, colour choice has been dictated by politically driven mandates from regional governments. In geographical areas with high UV impact, it is important to choose a TPO membrane with white or light colour exposed surface.

Membranes with light colour get a cooler surface temperature and high durability. It was found a difference of temperature of 30 °C between a white and a dark grey TPO on a roof exposed to the sun in May at 25°C air temperature. This difference means higher ageing impact on the dark grey membrane compared to a white one with the same formulation.

If an adequate amount of insulation is included in the roof assembly, the membrane colour plays less of a role in the energy efficiency of the building envelope. Performance of the whole assembly is the critical issue. A ‘one colour fits all’ approach is not correct.

8.8 Traceability and product marking

The specifier, roofing contractor, and building owner rely heavily upon the integrity of the roof product manufacturer to deliver materials that will perform. Typically, the specifier, contractor, and building owner do not have specific information regarding the formulation of the membrane or quality control testing that was conducted during production.

Concerns have been raised regarding the inability to identify the membrane manufacturer and membrane type of roofing materials that have experienced performance issues. It is good practice for the membrane to have product marking to the external face. This could take the form of text added by ink jet or by laser marking. The ink has a life expectancy of at least five years, the laser even longer. Alternatively, some manufacturers have a shallow imprint on the exposed membrane surface. In the future, roof membranes with factory embedded chips may be introduced that allow details of the specific product information to be read using Radio Frequency Identification.

As part of routine roof inspections, it is good practice to record the name of the manufacturer and product references and other relevant information in a project file. This information can then be added to product guarantees, Operations and Maintenance manuals and Building Information Models.

8.9 Weldability

Heat welding different membrane types requires different techniques. In particular, the welding window temperatures for TPO membranes are different than those for PVC membranes. This has been described in technical papers. Also, in the RCI paper ‘critical components in welding thermoplastic membranes’ presented in March 2017, it was recognised that welding of thermoplastic membranes requires attention to detail and conditions.

Some applicators have more experience in heat welding one type of membrane. Contractors have encountered difficulties when applicators swap between welding materials without adjusting welding temperatures and procedures for the different welding windows. Some TPO manufacturers offer resources to advise on optimum settings for different welding equipment to increase the probability of good welds.

Determining the correct temperature and speed for heat welding under the specific environmental conditions during installation is of great importance. Downward pressure applied by the welding machine and air flow may also be adjusted.

Welding can be affected by dirt deposited on the membrane surface. When welding onto existing TPO membranes, it is important that the surfaces are adequately prepared immediately before welding. It is important to underline that applicators must be properly trained by the manufacturer. Problems have occurred in cases of ‘do-it-yourself’ applicators without any proper technical training.

8.10 Detailing

TPO membranes are typically stiffer than PVC membranes of the same thickness. As a consequence, it can be more difficult to form details such as internal corners of upstands with tight internal radii, particularly in cold weather conditions.

The use of prefabricated components is seen as good practice. These may include products such as molded pipe seals, inside and outside corners, T joint covers and edge metal components. Installation of accessory components needs to follow the specific projects construction details as well as the manufacturer’s requirements.

8.11 On site testing of seam welds

Test welds are a necessary procedure to ensure that a good seam is being formed. A general rule of thumb is that the contractor should take a test weld every 60 – 120 m (200 – 400 ft) of seam welded. A proper weld will show a film tearing bond, exposing the reinforcement over the majority of the 25 - 40 mm (1-1.5 in) weld width. In Europe there are some national regulations giving specific acceptance criteria. For example, in Germany 20mm is the minimum acceptable weld width.

The exposed edge of welded seams should also be checked by running a blunt-tipped probe along the full length of the seam edge. Any skips or anomalies discovered must be repaired for the membrane to be watertight. Inspectors are advised that TPO membranes do not exhibit a bleed-out from the edge of welded laps, in contrast to other thermoplastic materials.

Other non-destructive test methods can be used for locating punctures and cold welds in TPO membrane roofs. These include the electrical earth leakage technique originally developed by Geesen in Germany. Also the bubble vacuum test where a 400 mm (16 in) diameter transparent plastic half sphere is placed over a test area, and a suction pressure of -0.2 bar (-3 lbf/in^2) developed from a compressor. Any air leakage through the membrane is shown by bubbles in the soap solution placed over the test area, a useful method for checking welds at lap intersections.

8.12 Slippage and safety issues

In wet conditions, TPO membranes usually have less slip resistance. For foot traffic walking across roof surfaces there is an increased risk of slippage. This can be overcome by overlaying with walkway material with a textured top surface and requiring use of these walkways. Walkways should be installed at locations where water and ice do not accumulate. The walkway material should be of a different color than the membrane that is clearly visible. Most manufacturers produce walkway material compatible with their TPO membranes.

8.13 Maintenance

Maintenance is often overlooked as an important component of a successful roof system, yet is often a requirement within a manufacturer's warranty/guarantee. Maintenance should be completed twice a year in the spring and fall and after any major weather event.

Some types of general maintenance can be done by the building owner/facility staff. Examples of general maintenance include keeping the roof clear of debris and construction trash, clearing vegetation and tree limbs, and ensuring drains and gutters flow freely.

Roofing-system specific maintenance should be done by a trained roofing contractor who is familiar with TPO roof systems. Examples of items a roofing contractor should inspect include, but are not limited to:
- roof surfaces to verify if there are any visible issues developing
- copings and edge metal for open joints, missing sealant, and loose fasteners
- membrane flashings at perimeters and penetrations for open seams and tears/punctures
- field of the roof for open seams or unusual wear and tear of the field sheet

A maintenance program should be implemented to ensure maintenance is completed annually.

8.14 Product sustainability

TPO roof membranes are relatively thin, lightweight products with reduced demands of raw materials and transport costs. As established in the CIB Publication 271 'Towards Sustainable Roofing' published in 2001, sustainability is not a single attribute concept.

Manufacturers claim that the constituents used in TPO manufacture are not harmful to the environment and are respecting regulations about dangerous substances in force at the time of production. In North America it is claimed that there are no 'red list' chemicals used.

Of particular interest to building owners and specifiers is that TPO roof membranes can offer a long service life which is a basic tenet of sustainable roofing. As shown on the front cover of this report, a TPO membrane laid on a roof in Switzerland in 1992 remains in a serviceable condition.

9. CONCLUSIONS

The introduction of TPO roofing systems reaching a market share of more than 50% in the USA has occurred over just three decades. Performance issues relating to weldability, UV resistance and heat resistance have resulted in investment in plant and equipment together with the incorporation of new formulation technology

In North America, the ASTM standard for TPO membranes has been updated with more stringent heat aging and UV resistance now being specified. These requirements now demand significantly higher performance levels than in the past. In Europe there has also been growth in the use of TPO roof membranes, particularly over the last decade. Roofing contractors who have gained experience in working with TPO membranes are able to form heat welds with reliable confidence.

There are lessons to be learnt about new product development and in particular the importance of field trials. Accelerated weathering testing can provide useful performance data when product formulations are revised. The class of TPO roof membranes covers a broad range of product formulations. Specifiers and contractors are not told of these formulations or aware of the consequences of changes. Instead reliance is placed on the manufacturers who develop and produce roof systems. The importance of the integrity and significant long-term responsibilities of the TPO roofing manufacturer should be recognized.

Fourteen points of best practice for design, application and maintenance of TPO roof membrane systems have been identified. Of particular importance in the future will be product marking and traceability. Looking ahead, new TPO roof membranes with unknown product formulations and performance histories will present a challenge to the roofing industry and its clients, particularly if the lessons learned, as illustrated in this report, are not taken into consideration.

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TRANSLATIONS OF SUMMARY OF BEST PRACTICE APPENDIX A

The summary of best practice has been translated into the following languages, in the hope that the concepts will be more widely circulated, discussed and implemented.

1 English

2 French

3 Portuguese

4 Spanish

5 German

6 Italian

7 Hebrew

8 Arabic

A1: English

TPO ROOF MEMBRANES: SUMMARY OF BEST PRACTICE

Objective:

To summarize and group together the main points of good practice to produce a simplified short document that would be useful and relevant to the construction and property industries globally.

1. Adopt an holistic approach to roof design

As with all low slope single ply membranes it is good practice to adopt an holistic approach to roof design considering at an early stage the relevant factors and interactions. These may include site exposure, building orientation, internal building usage, anticipated longevity and resilience.

2. Select the appropriate means of attachment

A positive decision should be taken on how to prevent the lightweight membrane becoming detached in strong winds. There are three principal means of achieving this: mechanically fastened, fully adhered and ballasted.

3. Minimise heat deflection effects

These issues are particularly apparent in southern states of USA, the Middle East and southern European countries.

4. Slope

Ensuring minimum falls, or slopes to drains, including around penetrations, results in less dirt accumulation and improved longevity. Local standards and regulations should be followed.

5. Increase overall product thickness

There is a consensus that performance is improved with thicker membranes specified with an overall thickness of at least 1.5 mm (60 mil).

6. Ensure minimum membrane thickness over reinforcing fabric

This is a critical performance issue. The requirement in North America is that the thickness of coating over the reinforcing fabric shall be at least 30% of the overall thickness, ensuring the top ply that is exposed to UV light and extreme weather is as robust as possible. This is not currently a requirement in Europe.

7. Colour choice

Currently the main choices are between white and grey. As of 2019 there are over a dozen colour choices in the USA. It is recognised that these colour variations require changes to the composition of the membrane's heat stabilizer.

8. Traceability and product marking

It is good practice for the membrane to have product marking to the external face. This could take the form of text added by ink jet. The ink has a life expectancy of at least five years. Alternatively some manufacturers have a shallow imprint on the exposed membrane surface.

9. Weldability

Applicators must be properly trained by the manufacturer. Problems have occurred in cases of 'do-it-yourself' applicators without any proper technical training. It is important to check equipment settings after interruptions or changes in weather conditions.

10. Detailing

TPO membranes are typically stiffer than PVC membranes of the same thickness. As a consequence it can be more difficult to form details such as internal corners of upstands with tight internal radii, particularly in cold weather conditions. The use of prefabricated components is seen as good practice.

11. On site testing of seam welds

Test welds are a necessary procedure to ensure that a good seam is being formed. A proper weld will show a film tearing bond, exposing the reinforcement over the majority of the weld width. The exposed edge of welded seams should also be checked by running a blunt-tipped probe along the full length of the seam edge. Other non-destructive test methods can be used for locating punctures and cold welds in TPO membrane roofs, including the electrical earth leakage technique and the bubble vacuum test.

12. Slippage and safety issues

In wet conditions TPO membranes have less slip resistance compared to other roof membranes. This can be overcome by overlaying with walkway material with a textured top surface and requiring use of these walkways.

13. Maintenance

A maintenance program should be implemented to ensure maintenance is completed annually.

14. Product sustainability

TPO roof membranes are relatively thin lightweight products with reduced demands of raw materials and transport costs. Manufacturers claim that the constituents used in TPO manufacture are not harmful to the environment. TPO roof membranes can offer a long service life which is a basic tenet of sustainable roofing.

A2: French

LES MEMBRANES DE TOITURE TPO: RESUME DES BONNES PRATIQUES

Objectif:

Répertorier et résumer les points essentiels des bonnes pratiques dans un document succinct qui serait utile et relevant pour le secteur de la construction et de l'immobilier à l'échelle mondiale.

1. Considérer une approche globale dans la conception des toitures

Comme pour toute membrane monocouche destinée aux toits plats, il est de bonne pratique que la conception prenne en compte tous les facteurs pertinents et leurs interactions dès le départ; tels que l'environnement, l'orientation du bâtiment, sa fonction, la durée de vie prévue et la résilience souhaitée.

2. Sélection d'une méthode de fixation appropriée

Il y lieu de choisir une méthode de fixation pour éviter que la membrane, légère, s'envole en cas de vents violents. Il y a trois techniques : l'usage de fixations mécaniques, membrane collée en plein ou lestée.

3. Réduire l'effet de la réflexion de la chaleur

Cette problématique est particulièrement présente dans les Sud des Etats-Unis d'Amérique, au Moyen-Orient et dans les pays au Sud de l'Europe.

4. Pente

S'assurer d'un drainage minimum, ou pentes vers les évacuations de toiture, y compris autour des pénétrations, diminue l'accumulation de saletés et augmente la durée de vie de la toiture. Les normes et règles locales doivent être respectées.

5. Augmentation de l'épaisseur

Il y a un consensus sur le fait que la performance de la membrane est améliorée lorsque son épaisseur moyenne est de minimum 1.5 mm (60 mil).

6. Epaisseur de membrane minimale au-dessus de l'armature

Cela est critique pour la performance de la membrane. L'épaisseur de membrane au-dessus de l'armature doit représenter au minimum 30% de l'épaisseur totale dans le marché Nord-Américain; s'assurant que la couche supérieure, exposée aux UV et aux conditions climatiques extrêmes, soit aussi résistante que possible. Cette exigence n'existe pas en Europe.

7. Choix de couleur

Le gris et blanc sont les couleurs les plus courantes. Depuis 2019, il y a plus d'une douzaine de choix de couleurs aux E-U d'Amérique. Ces variations de couleurs nécessitent des modifications dans la composition du stabilisateur thermique.

8. Traçabilité et marquage du produit

Il est de bonne pratique qu'un marquage soit visible sur la face exposée de la membrane. Cela peut être une inscription créée par jet d'encre. L'encre possède une longévité de minimum 5 ans. Une alternative est une empreinte sur la face exposée de la membrane.

9. Soudabilité

Les installateurs doivent être formés par le fabricant. Des problèmes se sont déclarés dans le cas d'installateurs « autodidactes » qui n'ont pas bénéficié d'une formation technique. La vérification des paramètres de l'outillage est à réaliser après chaque interruption du travail ou modification des conditions climatiques.

10. Détails d'étanchéité

Pour une même épaisseur, les membranes TPO sont habituellement plus rigides que les membranes PVC. En conséquence, il peut être plus difficile de réaliser des détails tels que les coins intérieur de relevés avec un petit rayon interne, d'autant plus dans des conditions climatiques froides. L'usage de pièces préfabriquées est une bonne pratique.

11. Le contrôle des soudures sur site

Des essais de soudure sont nécessaires pour s'assurer qu'un joint de qualité est réalisé. Un joint de qualité montrera une déchirure nette qui expose l'armature sur la majorité de la largeur du joint lors d'un essai destructif. Le bord des soudures devrait aussi être contrôlé par une sonde avec embout arrondi. D'autres tests non-destructifs pour trouver les trous ou mauvaises soudures des membranes TPO peuvent être utilisés, tels que des tests avec courant électrique ou mise sous vide.

12. Glissade et dangers

Les membranes TPO sont plus glissantes que les autres types de membrane de toiture lorsqu'humide. Le danger peut être résolu par le placement de chemins de circulation avec une surface texturée et l'exigence d'y circuler.

13. L'entretien

Un programme devrait être implémenté pour s'assurer que l'entretien de la toiture est réalisé annuellement.

14. Durabilité des produits

Les membranes de toiture TPO sont relativement minces et légères impliquant un besoin réduit en matières premières et coûts de transport. Les fabricants affirment que les composants utilisés pour la fabrication du TPO sont sans danger pour l'environnement. Les membranes de toiture TPO peuvent offrir un bonne longévité; ce qui est un principe de base pour une toiture durable.

A3: Portuguese

MEMBRANAS PARA COBERTURAS EM TPO: RESUMO DAS BOAS PRATICAS

Objetivo:

Resumir e agrupar os pontos principais das boas práticas de modo a produzir um documento ligeiro e simplificado que seria útil e relevante para a construção e industrias imobiliárias em geral.

1. **Adotar uma abordagem holistica do design da cobertura**
   Em todas as coberturas planas de baixa pendente com membranas monocamada é de boa prática adotar uma abordagem holística da conceção da cobertura considerando desde uma fase inicial todos os fatores relevantes e as interações.
   Estes poderão incluir a exposição do local, a orientação do edifício, o uso do seu interior, a longevidade e resiliência em antecipação.

2. **Selecionar os meios apropriados de fixação**
   Deve ser tomada uma decisão adequada sobre como prevenir que a membrana com peso próprio ligeiro venha a ser arrancada por ventos fortes.
   Existem 3 principais maneiras de conseguir chegar a este resultado:
   A fixação mecânica, a colagem integral da membrana e a cobertura com proteção pesada.

3. **Minimisar os efeitos do calor nos materiais**
   Estas questões são particularmente pertinentes nos estados sul dos EUA, no Médio Oriente e nos países da Europa do Sul

4. **Pendente**
   Assegurando as pendentes mínimas para os pontos de drenagem, incluindo nos elementos penetrantes circundantes, resulta numa menor acumulação da sujidade e assim uma longevidade aumentada.

5. **Aumentar a espessura total dos materiais**
   Existe um consenso que a performance das coberturas é melhorada com a especificação de membranas mais espessas com uma espessura em total, superior a 1,5mm.

6. **Assegurar uma espessura minima de membrana cobrindo a armadura de reforço**
   Esta é uma questão critica para a performance.
   O requisito na America do Norte é que a espessura do recobrimento da armadura interna deve ser pelo menos 30% da espessura total, assegurando que camada superior que é exposta aos raios UV e às agressões do meio ambiente é tão robusta quanto possível.
   Este ainda não é atualmente um requisito na Europa.

7. **Seleção da cor**
   Atualmente as escolhas principais estão entre os brancos e os cinzas.
   A partir de 2019 há mais de uma dúzia de opções de cor nos EUA.
   É reconhecido que essas variações de cores requerem mudanças na composição do estabilizador de calor da membrana.

8. Rastreabilidade e marcação do produto

É uma boa prática para as membranas exibirem a marca do produto na sua face externa. Isto pode assumira a forma de texto impresso a jato de tinta.
A tinta tem uma expetativa de vida mínima de 5 anos.
Alternativamente alguns fabricantes colocam uma impressão em baixo relevo na superfície exposta da membrana.

9. Soldabilidade

Os aplicadores devem ser devidamente formados pelo fabricante.
Já ocorreram problemas em casos de aplicadores do tipo "faça você mesmo", sem qualquer tipo de formação técnica.
É importante verificar os ajustes dos equipamentos depois de interrupções no trabalho ou variações nas condições metereológicas.

10. Remates

As membranas em TPO são tipicamente mais rijas que as membranas em PVC com a mesma espessura.
Em consequência pode ser mais difícil moldar remates tais como cantos internos ou elementos emergentes com um raio apertado, especialmente em condições de tempo muito frio.
O uso de componentes pré-fabricados é visto como uma boa prática.

11. Teste das soldaduras, em obra

Os testes das soldaduras são um procedimento necessário para assegurar que foi executada uma boa soldadura.
Uma soldadura bem feita ou romper vai mostrar um filme de membrana ainda aderido expondo a armadura de reforço na maioria da largura da soldadura.
O bordo exposto da soldadura pode ser também verificado, passando uma ferramenta com a ponta romba ao longo de todo o comprimento da junta soldada.
Outros métodos de teste não destrutivos podem ser utilizados para localizar perfurações ou soldaduras deficientes em coberturas com membranas TPO, incluindo a técnica elétrica de ponto ligação à terra e o teste com campânula de vácuo.

12. Questões de segurança, escorregamentos

Em situações em que a sua superfície está molhada, as membranas em TPO têm menos resistência ao escorregamento comparando com outras membranas de coberturas.
Isto pode ser resolvido com a sobreposição de material para vias de circulação com uma superfície texturada apropriada, requerendo a colocação destas vias de circulação.

13. Manutenção

Um programa de manutenção deverá ser implementado para assegurar que a manutenção é executada anualmente.

14. Sustentabilidade dos produtos

As membranas em TPO para coberturas são materiais relativamente finos, com um peso reduzido, com necessidades reduzidas de matéria prima e custos de transporte também.
Os fabricantes declaram que os componentes utilizados na produção das membranas de TPO não são prejudiciais para o ambiente.
As membranas em TPO podem oferecer uma longa vida útil, que é um dos princípios básicos das coberturas sustentáveis.

A4: Spanish

MEMBRANAS DE TPO PARA CUBIERTAS: RESUMEN DE BUENAS PRÁCTICAS

Objectivo:

Resumir y agrupar los principales puntos de buenas prácticas para elaborar un documento breve y simplificado que sea útil y relevante para los sectores de la construcción y las propiedades industriales a nivel mundial.

1. **Adoptar un enfoque integral en el diseño de la cubierta**
Al igual que con todas las membranas monocapa para cubiertas planas, es una buena práctica adoptar un enfoque integral en el diseño de la cubierta, teniendo en cuenta en una fase temprana los factores e interacciones relevantes. Estos pueden incluir la exposición del lugar, la orientación del edificio, el uso interno del edificio, la durabilidad prevista y la resiliencia.

2. **Seleccionar el método de fijación adecuado**
Hay que decidir cómo evitar que la membrana salga volando por acción del viento. Hay tres maneras principales para conseguirlo: fijación mecánica, adhesión total y protección pesada o lastre.

3. **Minimizar los efectos del calor**
Estos problemas son especialmente evidentes en los estados del sur de Estados Unidos, Oriente Medio y los países del sur de Europa.

4. **Pendiente**
Garantizar unas pendientes mínimas, o cáidas hacia los desagües, incluso alrededor de los elementos que penetren la cubierta, para dar como resultado una menor acumulación de suciedad y una mayor durabilidad. Deben respetarse las normas y regulaciones locales.

5. **Aumentar el espesor total del producto**
Hay consenso en que el rendimiento mejora con membranas con un espesor total de al menos 1,5 mm (60 mil).

6. **Garantizar un espesor mínimo de la membrana sobre el tejido de refuerzo**
Ésta es una cuestión de rendimiento crítica. El requisito en Norteamérica es que el espesor del revestimiento sobre el tejido de refuerzo sea al menos el 30% del espesor total, garantizando que la capa superior que está expuesta a la radiación UV y a las condiciones climáticas extremas sea lo más robusta posible. Este requisito no existe actualmente en Europa.

7. **Elección del color**
Actualmente las principales opciones están entre el blanco y el gris. A partir de 2019 hay más de una docena de opciones de color en Estados Unidos. Se reconoce que estas variaciones de color requieren cambios en la composición del estabilizador térmico de la membrana.

8. Trazabilidad y marcado de productos

Es una buena práctica que la membrana tenga un marcado del producto en la cara externa. Puede ser un texto añadido por impression de tinta. La tinta tiene una esperanza de vida de al menos cinco años. Como alternativa, algunos fabricantes tienen una impresión poco profunda en la superficie expuesta de la membrana.

9. Soldabilidad

Los aplicadores deben recibir una formación adecuada por parte del fabricante. Se han producido problemas en casos de aplicadores "hágalo usted mismo" sin una formación técnica adecuada. Es importante comprobar los ajustes del equipo después de las interrupciones o los cambios en las condiciones meteorológicas.

10. Ejecución de detalles

Las membranas de TPO suelen ser más rígidas que las de PVC del mismo espesor. En consecuencia, puede ser más difícil hacer detalles como las esquinas tanto internas como externas, especialmente con condiciones de clima frío. El uso de componentes prefabricados se considera una buena práctica.

11. Pruebas in situ de las soldaduras

La prueba de las soldaduras es un procedimiento necesario para asegurar que se está formando un buen cordón. Una soldadura adecuada mostrará una unión con desgarro de parte de la membrana, exponiendo el refuerzo en la mayor parte del ancho de la soldadura. El borde expuesto del solape también debe comprobarse pasando un objeto de punta roma a lo largo de todo el borde de la soldadura. Se pueden utilizar otros métodos de ensayo no destructivos para localizar pinchazos y soldaduras en frío en las cubiertas de membranas de TPO, incluyendo la técnica de localización por corriente eléctrica y la prueba de la campana de vacío.

12. Resbaladicidad y problemas de seguridad

En condiciones húmedas, las membranas de TPO presentan menos resistencia al deslizamiento en comparación con otras membranas de cubierta. Esto puede solucionarse colocando pasillos transitables con superficie texturizada y exigiendo el uso de los mismos.

13. Mantenimiento

Se debe implementar un programa de mantenimiento para asegurar que el mantenimiento se realice anualmente.

14. Sostenibilidad del producto

Las membranas TPO para cubiertas son productos ligeros y de poco espesor con una reducida demanda de materias primas y costes de transporte. Los fabricantes afirman que los componentes utilizados en la fabricación de TPO no son perjudiciales para el medio ambiente. Las membranas de TPO para cubiertas pueden ofrecer una larga vida útil, lo que constituye un principio básico de las cubiertas sostenibles.

A5: German

TPO DACHBAHNEN: ZUSAMMENFASSUNG VON BEWÄHRTEN VERFAHREN

Zielsetzung:

Zusammenfassung und Aufstellung der wichtigsten Punkte bewährter Verfahren, um ein vereinfachtes kurzes Dokument zu erstellen, das für die Bau- und Immobilienbranche weltweit nützlich und relevant wäre.

1. Übernahme eines ganzheitlichen Ansatzes bei der Dachgestaltung

Wie bei allen einlagigen Abdichtungen für flachgeneigte Dächer ist es eine gute Praxis, bei der Dachgestaltung einen ganzheitlichen Ansatz zu verfolgen, der die relevanten Faktoren und Wechselwirkungen frühzeitig berücksichtigt. Diese können einschließen Anforderungen aus dem Gebäudestandort, der Gebäudeorientierung, der Gebäudenutzung, der erwarteten Langlebigkeit und Widerstandsfähigkeit.

2. Auswahl der geeigneten Befestigungsarten

Es sollte eine gute Auswahl getroffen werden, wie verhindert werden soll, dass sich die leichte Dachbahn bei starkem Wind ablöst. Es gibt im Wesentlichen drei Maßnahmen um dies zu erreichen: mechanische Befestigung, vollflächige Verklebung und Auflast.

3. Minimieren von Effekten der Wärmeformbeständigkeit

Diese Aspekte treten besonders in südlichen Staaten der USA, des Nahen Ostens und südeuropäischen Ländern auf.

4. Gefälle

Die Sicherstellung einer Mindestneigung, oder Gefälles zu Entwässerungen, auch um Durchdringungen herum, führt zu geringerer Schmutzansammlung und verbesserter Lebensdauer. Örtliche Standards und Vorschriften sollen berücksichtigt werden.

5. Erhöhen der Gesamtproduktdicke

Es besteht Einigkeit darüber, dass die Leistungsfähigkeit durch dickere Bahnen verbessert wird, die mit einer Gesamtdicke von mindestens 1,5 mm (60mil) spezifiziert ist.

6. Sicherstellung einer Mindestbahndicke über Trägereinlagegewebe

Dies ist ein kritischer Aspekt für die Leistungsfähigkeit. In Nordamerika wird gefordert, dass die Bahnendicke über dem Trägereinlagegewebe mindestens 30 % der Gesamtdicke beträgt, damit die Oberschicht, die U-Licht und extremen Witterungseinflüssen ausgesetzt ist, so robust wie möglich ist. Es gibt derzeit in Europa keine solche Vorschrift.

7. Farbwahl

Derzeit liegt die Hauptauswahlmöglichkeit zwischen Weiß und Grau. Seit 2019 gibt es in den USA über ein Dutzend Farboptionen. Es ist bekannt, dass diese Farbvariationen Änderungen in der Zusammensetzung der Hitzestabilisatoren der Bahnen erfordern.

8. Rückverfolgbarkeit und Produktkennzeichnung

Es wird empfohlen, dass die Bahnen eine Produktkennzeichnung auf der Außenseite aufweisen. Dies könnte in Form von Text durch Tintenstrahldruck erfolgen. Die Tinte hat eine Lebenserwartung von mindestens fünf Jahren. Alternativ haben einige Hersteller einen flachen Eindruck auf der freiliegenden Bahnoberfläche.

9. Schweißbarkeit

Verarbeiter müssen vom Hersteller ausreichend geschult sein. Es sind Probleme aufgetreten, wenn Heimwerker ohne entsprechende technische Ausbildung tätig werden. Es ist wichtig, die Geräteeinstellungen nach Arbeitsunterbrechungen oder Wetteränderungen zu überprüfen.

10. Detaillierung

TPO-Bahnen sind typischerweise steifer als PVC-Bahnen. Infolgedessen kann es insbesondere bei kalten Wetterbedingungen schwieriger sein, Details wie Innenecken bei Aufkantungen mit engen Radien zu formen. Die Verwendung von vorgefertigten Elementen wird als bewährte Praxis angesehen.

11. Baustellenprüfungen von Nahtschweißungen

Probeschweißungen sind ein notwendiges Verfahren, um sicherzustellen, dass eine gute Naht hergestellt wird. Eine ordnungsgemäße Schweißnaht zeigt eine Filmrissbindung, die die Trägereinlage über dem Großteil der Schweißnahtbreite zeigt. Die sichtbare Kante der Schweißnaht soll ebenfalls geprüft werden, indem eine Prüfnadel über die gesamte Länge der Naht geführt wird. Zur Lokalisierung von undichten Stellen und nicht verschweißten Nahtstellen auf TPO Dächern können auch andere zerstörungsfreie Prüfungen verwendet werden, darunter die elektrische Leckage-Technik und das Blasen-Vakuum-Verfahren

12. Ausrutsch- und Sicherheitsprobleme

Bei Nässe weisen TPO-Bahnen einen geringeren Widerstand gegen Ausrutschen gegenüber anderen Bahnen auf. Diese Gefahr kann durch Aufbringungen von begehbaren Materialien mit strukturierter Oberseite und durch die Nutzung dieser Laufwege verringert werden.

13. Wartung

Ein Pflege- und Wartungsprogramm sollte vereinbart werden, um eine jährliche Wartung zu gewährleisten.

14. Nachhaltigkeit der Produkte

TPO Dachbahnen sind relativ dünne leichte Produkte mit geringem Bedarf an Rohstoffen und Transportkosten. Ziel der Hersteller ist es, dass die Bestandteile der TPO Bahnen nicht umweltschädlich sind. TPO-Dachbahnen können eine lange Lebenserwartung bieten, was eine Grundvoraussetzung für eine nachhaltige Bedachung ist.

A6: Italian

MEMBRANE TPO PER TETTI: RIEPILOGO DELLE BUONE PRATICHE

Obiettivo:
Riepilogare e raggruppare i principali punti di buona pratica per produrre un breve documento semplificato che sia utile e rilevante per le industrie delle costruzioni ed immobiliari a livello globale.

1. Adottare un approccio olistico nella progettazione delle coperture

Come per tutte le membrane monostrato a bassa pendenza, è buona norma adottare un approccio olistico alla progettazione del tetto, considerando in una fase iniziale i fattori e le interazioni rilevanti. Questi possono includere l'esposizione del sito, l'orientamento dell'edificio, l'uso interno dell'edificio, la longevità attesa e la resilienza.

2. Utilizzare sistemi di vincolo appropriati

Devono essere prese decisioni progettuali concrete per evitare che la membrana leggera si stacchi in caso di forte vento. Ci sono tre principali sistemi di vincolo per raggiungere questo obiettivo: fissaggio meccanico, adesione e zavorramento.

3. Minimizzare gli effetti della deformazione al calore

Questi problemi sono particolarmente evidenti negli stati meridionali degli Stati Uniti, nel Medio Oriente e nei paesi dell'Europa meridionale.

4. Pendenze

Garantire pendenze minime verso gli scarichi, anche intorno agli elementi passanti, si traduce in un minore accumulo di sporco e una maggiore longevità. Devono essere comunque seguiti gli standard e le normative locali.

5. Aumentare lo spessore complessivo dei prodotti

È opinione comune che le prestazioni siano più elevate se si utilizzano membrane più spesse con spessore complessivo di almeno 1,5 mm (60 mil).

6. Garantire uno spessore minimo della membrana sulla rete di rinforzo

Questo è un aspetto prestazionale critico. La prescrizione in Nord America è che lo spessore della membrana al di sopra della rete di rinforzo sia almeno il 30% dello spessore complessivo della membrana, assicurando che lo strato superiore esposto alla radiazione UV e alle condizioni meteorologiche estreme sia il più robusto possibile. Questa non è un requisito attualmente vigente in Europa.

7. Scelta del colore

Attualmente le scelte principali sono tra il bianco e il grigio. A partire dal 2019 ci sono oltre una dozzina di scelte di colore negli Stati Uniti. È riconosciuto che queste variazioni di colore richiedono modifiche nella composizione dello stabilizzante al calore della membrana.

8. Tracciabilità e marcatura del prodotto

È buona norma che la membrana abbia una marcatura del prodotto sulla faccia esterna. Questa potrebbe assumere la forma di testo aggiunto a getto d'inchiostro. L'inchiostro ha un'aspettativa di vita di almeno cinque anni. In alternativa, alcuni produttori marcano le membrane una leggera impronta sulla superficie esposta della membrana.

9. Saldabilità

Gli applicatori devono essere adeguatamente formati dal produttore. Si sono verificati problemi nel caso di applicatori "fai da te" privi di un'adeguata formazione tecnica. È importante controllare le impostazioni dell'apparecchiatura dopo interruzioni o cambiamenti delle condizioni meteorologiche.

10. Dettagli

Le membrane in TPO sono in genere più rigide delle membrane in PVC dello stesso spessore. Di conseguenza può essere più difficile formare dettagli come angoli interni di risvolti verticali con raggi interni stretti, in particolare in condizioni climatiche fredde. L'uso di componenti prefabbricati è considerato una buona pratica.

11. Test in loco delle saldature continue

Il test delle saldature è una procedura necessaria per garantire che si formi una buona giunzione. Una saldatura corretta mostrerà una resistenza alla pelatura della giunzione, che può essere evidenziata con l'esposizione del rinforzo interno per la maggior parte della larghezza della saldatura. Il bordo esposto delle linee di saldatura dovrebbe anche essere controllato tramite un attrezzo apposito a punta smussata (welding tester) lungo l'intera lunghezza delle saldature stesse. Altri metodi di prova non distruttivi possono essere utilizzati per localizzare forature e saldature non corrette su coperture realizzate con membrane in TPO, compresa la tecnica di dispersione elettrica a terra ed il vacuum test.

12. Scivolamento e problemi di sicurezza

In condizioni umide le membrane TPO hanno una minore resistenza allo scivolamento rispetto ad altre membrane per tetti. Ciò può essere superato sovrapponendo materiale per camminamenti (pedonabile) con una superficie superiore texturizzata e richiedendo l'utilizzo di questi camminamenti.

13. Manutenzione

Dovrebbe essere previsto un programma di manutenzione per assicurare che questa venga effettuata con cadenza annuale.

14. Sostenibilità dei prodotti

Le membrane per tetti in TPO sono prodotti relativamente sottili e leggeri con una ridotta richiesta di materie prime e costi di trasporto. I produttori dichiarano che i componenti utilizzati nella produzione di TPO non sono pericolosi per l'ambiente. Le membrane per tetti in TPO possono offrire una lunga durata, che è un principio fondamentale per le coperture sostenibili.

ממברנות TPO לגגות : סיכום הפרקטיקה המיטבית

מַטָרָה:
לסכם ולרכז את הנקודות העיקריות של שיטות העבודה המיטביות כדי לייצר מסמך קצר ופשוט שיהיה שימושי ורלוונטי לענף הבנייה, נכסי הנדל"ן והמבנים ברחבי העולם.

1) **אימוץ גישה הוליסטית לתכנון גגות**
כמו כל הממברנות החד שכבתיות המיושמות על גגות שטוחים, הפרקטיקה הנאותה היא לאמץ גישה הוליסטית לתכנון הגגות, תוך התחשבות כבר בשלב מוקדם בגורמים והאינטראקציות הרלוונטיות. אלה עשויים לכלול את החשיפה של האתר, אוריינטציה של המבנה, השימוש הפנימי של הבניין, אריכות ימים צפויה, גישור וכושר התאוששות מאירועים חריגים.

2) **בחירת אמצעי החיבור המתאים לגג**
יש לקבל החלטה ביצד למנוע מהממברנה קלת המשקל להתנתק ברוחות עזות.
ישנם שלושה אמצעים עיקריים להשגה: קיבוע מכני, הדבקה מלאה והנחת נטל (משקל)

3) **לצמצם את השפעות החום (heat deflection)**
סוגיות אלה ניכרות במיוחד במדינות דרום ארצות הברית, המזרח התיכון ודרום אירופה.

4) **שיפוע**
הבטחת שיפוע מינימלי (השיפועים לניקוז) כולל מסביב להגבהות וחדירות דרך הגג. שיפועים טובים מקטינים הצטברות של לכלוך ומשפרים את אריכות ימי איטום הגג. יש להקפיד על התקנים והתקנות המקומיים.

5) **הגדלת עובי המוצר**
יש הסכמה כי הביצועים משתפרים עם ממברנות עבות יותר, בעובי כולל של לפחות 1.5 מ"מ (60 מיל).

6) **הקפידה על מינימום של עובי ממברנה מעל לשכבת השריון**
זוהי בעיית תפקוד. הדרישה בצפון אמריקה היא שעובי הציפוי מעל בד החיזוק יהיה לפחות 30% מהעובי הכולל, מה שמבטיח שהשכבה העליונה שנחשפת ל- UV ומזג אוויר קיצוני תהיה חזקה בכל האפשר. כרגע באירופה זו לא דרישה.

7) **בחירת צבע**
נכון לעכשיו האפשרויות העיקריות הן בין לבן לאפור. נכון לשנת 2019 יש יותר מתריסר אפשרויות צבע בארה"ב. ידוע, כי וריאציות צבע אלה דורשות גם שינויים בהרכב מייצב החום של הממברנה.

8) **אפשרות למעקב וסימון מוצרים**
פרקטיקה טובה היא שלממברנה יהיה סימון מוצר על הפנים החיצוניות. זה יכול להיות בצורה של טקסט שנוסף על ידי הזרקת דיו. תוחלת החיים של הדיו היא לפחות חמש שנים. לחלופין לחלק מהיצרנים יש חותם מוטבע רדוד, על פני הממברנה החשופה.

9) **שלמות הריתוך**
על המיישמים להיות מאומנים כראוי על ידי היצרן. בעיות התרחשו במקרים של מיישמי 'עשה זאת בעצמך' ללא הכשרה טכנית מתאימה. חשוב לבדוק את הגדרות ציוד הריתוך לאחר הפרעות, הפסקות או שינויים בתנאי מזג האוויר.

10) פרטים

ממברנות TPO בדרך כלל קשיחות יותר מממברנות PVC באותו עובי. כתוצאה מכך יכול להיות קשה יותר ליצור באתר עיבודים ופרטים כגון פינות פנימיות בעלות רדיוס פנימי קטן, במיוחד במזג אוויר קר. השימוש ברכיבים מוכנים מראש נחשב כפרקטיקה נאותה.

11) בדיקות באתר של ריתוכי התפרים

בדיקת הריתוכים הם הליך הכרחי כדי להבטיח שנוצרת ריתוך תקין. ריתוך תקין יראה כעין קילוף של סרט, ויחשוף את יריעת השריון על פני רוב רוחב הריתוך. יש לבדוק את הקצה החשוף של התפרים המרותכים גם על ידי בדיקה עם אביזר קהה לכל אורך קצה החפיה. ניתן להשתמש בשיטות בדיקה לא הרסניות אחרות לאיתור פנצ'רים ו"ריתוכים קרים". בגגות עם ממברנות TPO , כולל טכניקת איתור זרמים תועים והארקה ובדיקת ואקום.

12) בעיות החלקה ובטיחות

בתנאים רטובים יש לממברנות TPO התנגדות פחותה בפני החלקה בהשוואה לממברנות גג אחרות. ניתן להתגבר על כך על ידי יצירת שבילי הליכה עם משטח עליון בעל מרקם ודרישה תיקנית נגד החלקה לשימוש בשבילים כאלה.

13) תחזוקה

יש ליישם תוכנית תחזוקה כדי להבטיח שהתחזוקה תבוצע מדי שנה בשנה.

14) קיימות המוצר

ממברנות גג TPO הן מוצרים דקים וקלים יחסית עם דרישות מופחתות של חומרי גלם ועלויות הובלה. היצרנים טוענים כי המרכיבים המשמשים בייצור TPO אינם מזיקים לסביבה. ממברנות גג TPO יכולות להציע חיי שירות ארוכים המהווים עיקרון בסיסי של איטום וגג ברי קיימא .

תרגום מאנגלית לעברית

חגית אוגניסתוף. הנדסאית. יועצת איטום

מהנדס מיכאל מרטון. מהנדס יועץ לאיטום

A8: Arabic

ملخص لأفضل الممارسات الخاصة بأغشية العزل TPO

الهدف:
لتلخيص النقاط الرئيسية للممارسات الجيدة وتجميعها معًا لإنتاج وثيقة قصيرة مبسطة تكون مفيدة وذات صلة بالانشاءات والممتلكات على مستوى العالم.

1. اعتماد نهج شامل لتصميم السقف
كما هو الحال مع جميع أنظمة العزل من طبقة واحدة ذات المنحدر المنخفض ، فمن الممارسات الجيدة اعتماد نهج شامل لتصميم السقف مع مراعاة العوامل والتفاعلات ذات الصلة في مرحلة مبكرة. قد يشمل ذلك خصائص الموقع ، وتوجيه المبنى ، والاستخدام الداخلي للمبنى ، العمرالمتوقع والمرونة.

2. حدد وسيلة التثبيت المناسبة
العزل الخفيف الوزن من الانفصال في الرياح القوية. هناك ثلاث وسائل رئيسية يجب اتخاذ قرار إيجابي بشأن كيفية منع غشاء ان يكون مثبَّتًا. لتحقيق ذلك: ان يكون مثبت ميكانيكيًا ، ملتصقًا بالكامل و

3. تقليل تأثيرات انحراف الحرارة
تظهر هذه القضايا بشكل خاص في الولايات الجنوبية للولايات المتحدة والشرق الأوسط ودول جنوب أوروبا.

4. المنحدر
يؤدي ضمان الحد الأدنى من الانحدار أو المنحدرات إلى المصارف ، بما في ذلك حول الاختراقات ، إلى تقليل تراكم الأوساخ وتحسين عمراغشية العزل. يجب اتباع المعايير واللوائح المحلية.

5. زيادة سمك المنتج الكلي
هناك إجماع على أن تحسين الأداء يتم بتوصيف أغشية عازلة أكثر سمكًا وبسماكة كلية لا تقل عن 1.5 مم (60 مل).

6. ضمان الحد الأدنى من سماكة الغشاء فوق نسيج التقوية
هذه مشكلة أداء حرجة. المطلب في أمريكا الشمالية هو أن يكون سمك الطلاء فوق نسيج التقوية 30٪ على الأقل من السماكة الكلية ، مما يضمن أن الطبقة العلوية التي تتعرض لضوء الأشعة فوق البنفسجية والطقس القاسي تكون قوية قدر الإمكان. هذا ليس شرطًا حاليًا في أوروبا.

7. اختيار اللون
حاليا الخيارات الرئيسية هي بين الأبيض والرمادي. منذ عام 2019 ، هناك أكثر من عشرة خيارات للألوان في الولايات المتحدة الأمريكية. من المعروف أن هذه الاختلافات اللونية تتطلب تغييرات في تركيبة مثبت حرارة غشاء العزل.

8. إمكانية التتبع ووسم المنتج
من الممارسات الجيدة أن تكون علامات المنتج على الوجه الخارجي لغشاء العزل. يمكن أن يتخذ هذا شكل نص مضاف ومطبوع بواسطة الحبر. يبلغ متوسط العمر المتوقع للحبر خمس سنوات على الأقل. بدلاً من ذلك ، تمتلك بعض الشركات المصنعة بصمة ضحلة على سطح الغشاء المكشوف.

9. قابلية اللحام
يجب أن يتم تدريب اليد العاملة بشكل صحيح من قبل الشركة المصنعة. حدثت مشاكل في حالات تطبيق "افعلها بنفسك" بدون أي تدريب تقني مناسب. من المهم التحقق من إعدادات المعدات بعد الانقطاعات أوعند التغيرات في الأحوال الجوية

10. التفصيل
التي لها نفس السماكة. نتيجة لذلك ، قد يكون من الصعب تكوين PVC أكثر صلابة من أغشية TPOعادة ما تكون أغشية تفاصيل مثل الزوايا الداخلية ذات نصف قطر داخلي ضيق ، خاصة في ظروف الطقس البارد.
يعتبر استخدام المكونات الجاهزة ممارسة جيدة.

11. اختبار اللحامات في الموقع

تعتبر لحامات الاختبار إجراءً ضروريًا لضمان تشكيل توصيل جيد. سوف يُظهر اللحام المناسب رابط تمزق الفيلم مما يكشف طبقة التعزيز على غالبية عرض اللحام. يجب أيضًا فحص الحافة المكشوفة للوصلات الملحومة عن طريق تمرير مسبار غير حاد على طول حافة التماس بالكامل. يمكن استخدام طرق اختبار أخرى غير مدمرة لتحديد مواقع الثقوب واللحامات الباردة في أسطح غشاء TPO، بما في ذلك تقنية تسرب الأرض الكهربائية واختبار الفراغ بالفقاعات.

12. قضايا الانزلاق والسلامة

لأغشية TPO مقاومة أقل للانزلاق مقارنة بأغشية السقف الأخرى في الظروف الرطبة. يمكن التغلب على هذا من خلال تركيب منتج ممرات ذات نقوش محكمة ويطلب استخدام هذه الممرات.

13. الصيانة

يجب تنفيذ برنامج صيانة لضمان اكتمال اعمال الصيانة سنويًا.

14. استدامة المنتج

أغشية السطح TPO عبارة عن منتجات خفيفة الوزن رقيقة نسبيًا وذلك تماشيا مع انخفاض الطلب على المواد الخام وتكاليف النقل. يفيد المصنعون بأن المكونات المستخدمة في تصنيع أغشية السقف TPO ليست ضارة بالبيئة. يمكن أن توفر أغشية السقف TPO عمر خدمة طويل وذلك مبدأ أساسي للأسقف المستدامة.

APPENDIX B

Designation: D6878/D6878M – 17

Standard Specification for Thermoplastic Polyolefin Based Sheet Roofing[1]

This standard is issued under the fixed designation D6878/D6878M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ʹ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers flexible sheet made from thermoplastic polyolefin (TPO) as the principal polymer, intended for use in single-ply roofing membranes exposed to the weather. The sheet shall contain reinforcing fabrics or scrims.

1.2 The tests and property limits used to characterize the sheet are values intended to ensure minimum quality for the intended purpose. In-place roof system design criteria, such as fire resistance, field seaming strength, material compatibility, and uplift resistance, among others, are factors which should be considered but are beyond the scope of this specification.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.

1.5 This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D471 Test Method for Rubber Property—Effect of Liquids
D573 Test Method for Rubber—Deterioration in an Air Oven
D751 Test Methods for Coated Fabrics
D1149 Test Methods for Rubber Deterioration—Cracking in an Ozone Controlled Environment

D1204 Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature
D2137 Test Methods for Rubber Property—Brittleness Point of Flexible Polymers and Coated Fabrics
D5538 Practice for Thermoplastic Elastomers—Terminology and Abbreviations
D7635/D7635M Test Method for Measurement of Thickness of Coatings Over Fabric Reinforcement
G151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources
G155 Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials

TABLE 1 Physical Requirements for TPO Sheet

Thickness, min, mm [in.]		
Sheet-overall		1.0 [0.039]
Coating over fabric or scrim, weathering side only		0.38 [0.015]
Breaking strength, min, N [lbf]		976 [220]
Elongation at reinforcement break, min, %		15
Tearing strength, min, N [lbf]		245 [55]
Brittleness point, max, °C [°F]		-40 [-40]
Ozone resistance, no cracks	Pass	
Properties after heat aging:		
Weight change (mass), max %		±1.5
Inspect at 7× magnification for cracks when bent over a 3 in. diameter mandrel		Pass
Linear dimensional change, max, %	±1	
Water absorption, max, mass %		±3.0[A]
Factory seam strength, min, N [lbf]		290 [66]
Weather resistance:		
Visual inspection	Pass	

[A] Test performed on top coating material only. (Use Test Method D471, Procedure for Change in Mass.)

1 This specification is under the jurisdiction of ASTM Committee D08 on Roofing and Waterproofing and is the direct responsibility of Subcommittee D08.18 on Non bituminous Organic Roof Coverings.
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2 For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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