EUROPEAN EXPERIENCE WITH NEW ROOFINGS

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Over the past decade, high-polymer sheets and bitumen polymer sheets have largely replaced conventional built-up, hot or cold-applied bituminous roof membranes in Western Europe. This membrane revolution is highly diversified among the different European countries. In Western Germany, the dominant single-ply material is high-polymer sheets, notably polyvinyl chloride (PVC); in Italy, it is single-ply bitumen polymer; in France, two-ply membranes of homogeneous bitumen polymer (styrene-butadene-styrene, SBS) sheet; and in Great Britain and The Netherlands, built-up bitumen polymer membranes.

Apart from the obvious role of economics, the West European nations' diversity in the new roofing membrane technology apparently springs from three determining factors:

- Roofing contractors' attitudes toward new installation techniques
- Existing technical codifications concerning responsibilities and guarantees
- Manufacturers' support roles

In France, for example, that nation's conservative roofing contractors prefer membranes with installation techniques similar to that of traditional built-up bituminous membranes. French contractors are suspicious of single-ply roofing sheets whose integrity depends on totally reliable field seams. They are moreover, subject to 10-year liability for their roofs. These factors combine to favor the two-ply polymer roofing sheets.

On the other hand, West German contractors are more familiar with the sensitive techniques of field-seaming of single-ply membranes. The manufacturers of plasticized PVC roofing sheets provide support for their materials and application techniques. Moreover, the West German contractors' liability is more limited than the French contractors'. In West Germany, accordingly, these factors all favor the single-ply sheet.

There is, however, a technological osmosis among the West European nations. Within the next five years, single-ply high-polymer sheets should develop in the French market, and the bitumen-polymer sheets should take a larger share of the West German market. Development of these membranes has promoted joint action by European nations, by organizations responsible for their technological evaluation. The next section of this report discusses the primary performance attributes considered in these evaluations.

Performance Attributes of New Membranes

Here are the principal performance attributes:

- Wind resistance
- Watertightness under hydrostatic pressure
- Dimensional stability
- Slippage resistance, (applicable to pitched roofs)
- Low-temperature fatigue stress
- Resistance to sudden temperature change (thermal shock)
- Penetration resistance (static and dynamic)
- Integrity of lap seams
- Durability (i.e., retention of major performance characteristics in service)
- Installation practicability and workmanship

Membrame performance is judged via laboratory tests, which are correlated with the various membranes' behavior in service. This process has required development of laboratory tests for the foregoing list of performance attributes. Brief descriptions of these tests follow:

The **wind-resistance test procedure** features a box measuring 2 m x 1 m x 0.25 m in depth, with one side hermetically sealed and the other side covered by the roof system test specimen. The cover is connected to a vacuum system, designed to apply progressive cycles of reduced pressure. Membrane behavior is observed at each low-pressure stage through an inspection window fitted on one side of the box and the amount of reduced pressure corresponding to failure is recorded. Failure is defined as follows: (1) delamination of the roofing system, (2) a loss of bonding in the adhesive or at the interface of the roofing membrane and substrate, and (3) loss of cohesion in the substrate.

In conjunction with the low-pressure wind-resistance test, peel tests of the roof membrane on various substrates (especially insulation boards) are carried out as a preliminary study to reduce the number of large-scale wind-resistance tests.

To test **watertightness under pressure,** the test sample is subjected to a given water pressure. Any leakage is noted.

For **dimensional stability** under heat, there are two tests:

- a free-shrinkage test on a sample placed in a drying oven, with dimensional variations measured.
- a restrained shrinkage test, with the roof membrane bonded to its substrate, simulating in-service conditions. The sample is then subjected to thermal radiation, with dimensional variations measured.

This latter test is performed only when the dimensional variations observed in the free-shrinkage test appear relatively high.

In the **slippage test**, the test membrane sample is applied to an inclined plane, heated by thermal radiation, and any slippage down the slope noted and evaluated.

Low-temperature fatigue is tested with an apparatus comprising two adjacent concrete slabs as substrates for the membrane test sample. At 0°C, for normal conditions (lower for more severe testing), the joint between the slabs is alternately opened and closed to simulate low-temperature thermal cycling in service. At the end of the prescribed number of cycles, membrane defects — tears, splits, ridges, folds along seams, etc. — are noted and evaluated.

Resistance to sudden temperature change (i.e., thermal shock) is indexed to testing of membrane sample subjected cyclically to thermal radiation followed by rapid, water-spray cooling. Following the test, the defects — e.g., loss of adhesion, blistering, rupturing of field seams — are determined.

Penetration resistance is determined by two tests:

- a static indentation test of the roof membrane on its substrate under the load of a steel ball of 24 hours, after which the test sample is inspected for evidence of puncturing.
- a dynamic indentation test, currently consisting of determining the diameter of a cylindrical punch falling with a given force and perforating the membrane. (Another dynamic test method is under study.)

Field-seam performance of single-ply membranes is tested by (a) imperviousness to water under pressure and (b) mechanical properties, notably tensile strength.

Durability testing requires a knowledge of membrane chemistry. The general method for assessing durability comprises the following steps:

- Selecting the degrading weathering agents for each family of membrane materials
- Choosing one (or several) significant degradation indices
- Determining the changes of these degradation indices, under the action of weathering agents, and correlating these changes with the natural aging rate

At this stage, the minimum durability level is established.

In some Western European countries (e.g., France and Belgium), where builders have a 10-year liability, minimum 10-year durability must be anticipated. Even in countries lacking such regulations, 10-year minimum service life is nonetheless recognized as the objective.

This overview has covered the principal performance attributes to be considered for roof membranes. The remainder of this paper will review the new membrane materials used in Western Europe and their major problems.

Western Europe's Experience with New Membranes

This section discusses first the high-polymer sheets, then the modified bitumens.

The principal high-polymer sheet materials include:

- plasticized PVC
- synthetic rubber (butyl, EPDM)
- Chlorosulphonated polyethylene (CSPE)
- Polyisobutylene (PIB)

Plasticized PVC Sheets

These are mainly single-ply plasticized PVC roofing sheets that are incompatible with bitumen. Field seams are solvent or hot-air welded.

Unreinforced PVC sheets, 0.8 mm thick, are now more often 1.2 to 1.5 mm thick in loose-laid ballasted systems. Unreinforced PVC roofing sheets have reportedly failed from heat shrinkage or puncture.

These sheets have had widespread use in West Germany and Austria, relatively little use in France, Belgium, Great Britain.

The present trend in PVC sheets is toward reinforced sheets (thicker and not subject to heat shrinkage) and incorporation of a resilient underlayment.

Synthetic Rubber Sheets

In the past, single-ply, butyl rubber-based roofing sheets 1 to 1.5 mm thick, usually unreinforced, posed problems in their field seams, which featured an adhesive tape inserted between the lapped sheets.

They have often been used in loose-laid ballasted systems (mainly in the form of factory preassembled sheets). But they have also been used in adhered systems, with special adhesives (notably bitumen-butyl adhesives). The adhesives have sometimes presented application problems.

Butyl sheets have been used in Belgium, and to a lesser extent, in France and Great Britain. In some other countries, however, butyl has declined, if not disappeared, as a roof membrane material.

EPDM rubber, 1.5 mm thick, has made its appearance in West Germany and in Belgium. Despite its recognized weather resistance, EPDM applications in Europe are still too recent for a definitive verdict. In countries where butyl roof coverings have been used, questions have arisen as to whether the single-ply EPDM membranes may not display the same defects, owing to their similar field seaming.

Polyisobutylene (PIB) Roofing Sheets

Single-ply roofing sheets, 1.5 mm thick, are the best known PIB membranes. The seams between sheets are usually made either by an added bonding tape between the sheet overlaps or, by superficial dissolution of the lapped surfaces by cold welding. In addition to loose-laid systems, they have also been used in adhered systems, with bitumen-based adhesives.

Because of problems of puncturing and splitting under tensile stress, PIB sheets have been declining in use in some countries.

A variation of these membranes has appeared with resilient underlayment. Yet despite the apparently improved performance, their application appears limited.

CSPE Roofing Sheets

These roof membranes are usually made of an asbestos felt support with a top film of CSPE. Total thickness is usually 1 mm, with the top layer being about 0.5 mm.

The sheets are designed to be installed as totally adhered roof systems with appropriate adhesives. Field seams are made with a hot-air welded cap strip.

Although a correctly formulated top layer has good weathering characteristics in normal use, low penetration resistance and joints have resulted in some failures.

This material has found some applications, notably on visible roofs. But its general use has diminished, if not disappeared from the market.

Bitumen Polymer Sheet Roofing

These consist primarily of several types:

- reinforced roofing sheets of SBS bitumen-elastomer
- reinforced roofing sheets of APP bitumen polypropylene
- unreinforced roofing sheets of ECB
- unreinforced roofing sheets of bitumen polymers

Reinforced Roofing Sheets of SBS Bitumen-Elastomers

These are made of reinforced, usually non-woven, glass and/or polyester sheets whose coating is made by the addition of an SBS type polymer to a directly distilled bitumen. The bitumen-polymer mix is characterized by an inversion phase where the polymer network becomes the backbone. Sheet thickness is generally from 2 to 4 mm.

For the most part, they are employed in two-ply membranes: homogeneous or mixed (the first ply with an air-blown bitumen felt). The sheets are bonded to each other or to the substrate with hot bitumen. They are used in loose-laid ballasted system, or with a factory-applied mineral surfacing.

These membranes, were initially developed in France, where over the last 10 years they have enjoyed a considerable expansion, currently representing 35% of the roofing market. They have also experienced some growth in West Germany (nearly 30 manufacturers) and in The Netherlands (especially in the mixed systems).

Their performance attributable chiefly to high splitting resistance, owing to their elastic rheological characteristics and the reduction of their thermal susceptibility at both high and low temperatures in comparison with air-blown bitumen roof membranes, makes them a very attractive roofing material. Their use as a single-layer roofing sheet, although seldom exploited at the present time, nevertheless appears possible.

Reinforced Bitumen Polypropylene Roof Coverings

This system consists of reinforced non-woven polyester sheets with bitumen **modified by the addition** of polypropylene (generally atactic) and sometimes other polymer additives to a directly distilled bitumen.

Sheet thickness is generally 4 mm or more, sometimes 3 mm. They are used most often in single layers and sometimes in mixed two-ply membranes (the first sheet being an air-blown bitumen felt).

The sheets are bonded together or to the support by flame welding (torching). This roof membrane is usually employed as an adhered system, but can also be loose laid and ballasted.

This type of roofing was originated in Italy where it has developed considerably over the past 15 years. Now, it is also used in Belgium, and to a lesser degree, in The Netherlands, Great Britain, and Spain.

These membranes have reduced thermal susceptibility in high temperature applications compared to air-blown bitumen roof membranes. The addition of certain polymers also partially reduces their thermal susceptibility in low-temperature applications.

The use of atactic polypropylene (residue of the manufacture of isotactic polypropylene) make it an economic material. But requires great control of the manufacturing process as well as quality control to make it a material suitable as waterproof roofing.

Unreinforced ECB Roof Coverings

Extruded from a mixture of copolymer of ethylene and a special bitumen, these sheets, 2 mm thick, include a non-woven polyester on the underside.

In general, the sheets are used in single-ply loose-laid ballasted systems, sometimes in mixed two-ply adhered systems. The seams between sheets are sealed by overlapping and hot air welding. Adhesion to the substrate is with hot bitumen.

This roofing system is used chiefly in West Germany and Austria, to a much lesser degree elsewhere.

Unreinforced Roof Coverings of Bitumen—Diverse Polymers

These are calendered sheets of bitumen with various additives, generally elastomeric, developed especially in Great Britain. There, they have been used mainly in mixed, two-ply systems with an air-blown bitumen as a first layer. Their use, however, is virtually restricted to Great Britain, where they have seen considerable growth.

The Technical Codification of Roof Membranes in Europe

About 10 years ago, faced with the growing evolution of roof membranes on the European market, the organizations involved in the processes for the technical evaluation of roof membranes to the issuance of Agrement Certificates, began some work that has culminated in a series of documents listed below.

These organizations are regrouped in the European Union Agrement (U.E.A.t.c.) which includes the Common Market countries as well as Spain, Portugal and Austria. They have published two documents:

- General Directives for the Agrement of roof membranes[1]
- Special Directives for the Agrement of loose-laid roofing systems using unreinforced, plasticized PVC sheeting[2]

A third document, Special Directives for the Agrement of Bitumen Polymer Sheet Roofing Systems, is near completion.

These documents, based on the performance approach, constitute guidelines for the delivery of Agrement Certificates in each country of the U.E.A.t.c. These certificates may be the subject of equivalence declaration, by means of adaptation to nonharmonized regulation in the other countries of the U.E.A.t.c.

These documents describe the test methods and the specifications that should be considered for the delivery of Agrements. They are also for people concerned with the technical evaluation of new roof membranes.

References

1. Cahier du CSTB (Centre Scientifique et Technique du Batiment) Paris, France, No. 1812, Part 234, November 1982.
2. Cahier du CSTB (Centre Scientifique et Technique du Batiment) Paris, France, No. 1813, Part 234, November 1982.