EMPLOYMENT OF NON-CONVENTIONAL MEMBRANES IN THERMALLY EFFICIENT ROOFING SYSTEMS

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INTRODUCTION

This paper discusses the achievement of thermally efficient roof insulation using non-conventional membranes, comprising

(a) liquid or sheet-applied elastomers; and,
(The term "elastomer" in this paper follows the ASTM definition: "a macromolecular material that at room temperature returns rapidly to approximately its initial dimensions and shape after substantial deformation by a weak stress and releases of that stress" [Ref. 2]).

(b) modified bitumen, aluminum-faced composite sheets.

To protect insulation from moisture invasion, a membrane must function in ponded water. Despite the recommendations of roofing manufacturers and other industry experts for minimum slope to provide positive drainage, few roofs in service satisfy this desired ideal. Among the vast majority of flat roofs that pond water are roofs designed for slope. The majority of non-conventional membrane manufacturers interviewed for this report are producing water-resistant materials that can protect below-membrane insulation from ponded water.

Moisture invasion poses a triple threat to the roof system: drastic reduction in insulating value as well as destructive deterioration of the insulation itself and leaks into the building interior. Protection from this hazard thus requires protective shielding of the insulation from moisture invasion or use of closed-cell insulation unaffected by moisture. Since moisture can enter the roof system via water vapor migrating upward from a warm interior as well as liquid flowing downward through membrane defects, the dew-point location within the roof system can affect moisture damage to the insulation [Ref. 1]. Combined thermal cycling and moisture contamination can cause destructive stresses in the membrane. When the membrane fails, the roof system fails, insulation loses thermal efficiency, and the building leaks.

This paper examines the potential of non-conventional membranes to accomodate stresses resulting from changes in the insulation, therby preventing leakage and total loss of insulating value. It will also discuss such unconventional alternatives as the Protected Membrane Roof (PMR), use of membranes over monolithic rather than board insulation, and below deck insulation.

SINGLE-PLY ELASTOMERIC MEMBRANES

Though a few non-conventional membranes have had over 15 years' successful experience, many more have been withdrawn from the market because of in-service failures. Most such systems in use today have had relatively little service exposure, particularly since many manufacturers are constantly making formulation changes to improve their products or to adapt to raw material supply changes. These concerns and others were recently expressed in a publication entitled *Preliminary Report on Single-ply Systems,* by the Midwest Roofing Contractors Association, June, 1978. MRCA's Technical and Research Committee, investigating European experience with PVC sheet systems, found numerous problems evolving after a few years' field exposure.

A major problem in selecting a non-conventional membrane concerns the difficulty of comparing different materials tested by different methods. Moreover, some materials perform differently on different substrates. Adequate criteria are lacking for evaluating or predicting job performance of non-conventional membranes. These problems, combined with the lack of long-term exposure, create a rather pessimistic picture for dependable design and installation of non-conventional roofing.

Despite these drawbacks, there are other forces at work lightening the risks associated with these new materials and making their prospects for successful performance appear far better than past industry experience with conventional bituminous membranes. These positive factors are:

- The superior guarantee offered by manufacturers of non-conventional membranes
- Improved applicator-approval programs
- Improved non-conventional membrane/insulation assemblies

These positive factors, reinforced by the many inherent advantages of many non-conventional membranes over conventional, hot-applied bituminous systems, brighten their prospects despite the drawbacks of generally inadequate track records establishing their durability.

IMPROVED GUARANTEES

As the primary factor alleviating concerns about the new non-conventional membrane roof systems, more than half the manufacturers surveyed in the preparation of this report offer from 5 to 10 year performance guarantees. Current guarantees contrast with past guarantees, which did little more than assure the purchaser that a one gallon pail would contain 232 cubic inches of material.

Today's responsible manufacturer assumes total liability for 100% replacement of labor and materials if the material fails to perform as advertised during the warranty period. We have had excellent experience with many manufacturers, and we have called them more than once about field problems. We are most reluctant to recommend a material or system that the manufacturer fails to back with a guarantee and an approved-applicator program, as well. Carefully analyze all guarantees for Catch 22 clauses and the guaranteeing company's financial integrity and history. No guarantee is a substitute for good material, but it helps to know that the producer of a new product is betting on good performance along with you. I know of only one manufacturer of conventional bituminous materials who will guarantee his materials' performance, and then only in the Protected Membrane Roof assembly. Bonds generally offered on conventional roof materials are expensive and extremely difficult to collect when problems arise.

IMPROVED APPLICATOR-TRAINING PROGRAM

Closely associated with improved guarantees are approved-applicator training programs. Poor workmanship – notably improper joint-sealing techniques – constituted a primary cause for the past failures of new non-conventional systems. In addition to a guarantee, an architect or owner specifying a new membrane should insist on an approved applicator program from any manufacturer whose material he specifies.

In summary, to minimize risk in specifying non-conventional membranes consider the following check list:

- Request a list of completed projects giving date completed, substrate covered, and roof area, with owner's name and address. Interview projects owners about results.
- Demand a performance guarantee from the manufacturer and read carefully for Catch 22 clauses.
- Deal with established manufacturers possessing sufficient financial integrity to back their guarantees.
- Use only manufacturer-approved roofers.
- Carefully follow manufacturer's specifications and details.

IMPROVED NON-CONVENTIONAL MEMBRANE/INSULATION ASSEMBLIES
PROTECTED MEMBRANE ROOF CONCEPT

The development of the Protected Membrane Roof (PMR) (insulation atop membrane) is an advanced engineering concept providing a healthful environment for both conventional as well as non-conventional membranes. In a PMR, the membrane is applied to the structural deck with insulation above it. The PMR arrangement generally offers the following advantages:

- A stronger substrate, making the membrane less vulnerable to puncture.
- Drastically reduced thermal movement in the membrane, because of its protected location under the insulation.
- Shifting of the roof system dew point above the membrane, where it has no effect on membrane performance.
- Protection of the membrane from freeze-thaw cycling (again because of its location below the insulation).
- Membrane protection from ultraviolet radiation, a major cause of plasticizer loss and general membrane degradation.
- Shielding of the membrane against puncture by hailstones, dropped tools, falling tree limbs, and roof traffic.

In addition to these engineering benefits, there is again the psychological and legal assurance of guarantees. Most of these assemblies carry an excellent 10-year performance guarantee and are handled through approved roofer programs. The majority of the manufacturers I contacted preparing this paper have specifications for the use of their material in this roof assembly. With non-conventional membranes, the membrane manufacturer generally provides the 10-year warranty to the owner for the performance of his material, and the insulation manufacturer provides a 10-year warranty that the insulation will maintain 80 per cent of its insulating value and that the loose-aggregate ballast will not blow off in winds up to 70 miles per hour.

We have had good experience in the Washington, D.C., area over the past 5 years installing more than 4 million sq. ft. of protected membrane roofs with conventional and non-conventional membranes, liquid and sheet. The PMR is currently the most widely specified system in the Washington, D.C., area on concrete roof decks for commerical/industrial structures. Despite our great success with the systems, there are nonetheless some conditions that must be considered with the inverted roof:

- Flashings for non-conventional membranes must be carefully studied to be certain they can stand exposure. They should be covered in the guarantee from the membrane manufacturer.
- A PMR with non-conventional membrane is generally less expensive on cast-in-place and precast concrete roof decks (for equivalent insulation). We have found it slightly more expensive on metal decks than conventional roofing, because it requires ½" fire-code gypsum board mechanically fastened to the metal deck to provide a level substrate for the membrane and to meet the fire code.
- The system is heavy, weighing at least 10 pounds per square foot, depending on insulation thickness; therefore, the roof deck must be designed to accomodate the load. A lighter system utilizing staggered, interlocking joints weighing approximately 4½ pounds per square foot has recently been developed ad added cost.
- The protected membrane roof concept is patented by a major U.S. insulation manufacturer, and this patent precludes price competition for the above-membrane insulation.

OVER SPRAYED-IN-PLACE POLYURETHANE FOAM INSULATION

Illustrating the notable products improvements enhancing the durability of the new roof systems are the improvements made in recent years in sprayed polyurethane foam insulation and in the non-conventional membranes used to cover it. The industry generally is recommending 2½ to 3-pcf density foam as opposed to 2-pcf material used five years ago. This change has substantially improved the long-term success of sprayed foam with elastomeric roofing for the following reasons:

1. Increased insulation density increases compressive strength making the substrate less susceptible to damage by foot traffic, hail, etc. (see Table 2).
2. Increased density reduces water vapor transmission and increases dimensional stability (see Tables 3 and 4), two problems with lower density foams, particularly in remedial roofing.

Non-conventional membranes, both liquid and sheet, recommended over foam insulation are generally of much higher quality today than they were a few years ago. Responsible manufacturers are offering superior performance guarantees for their materials. The more widely used materials also offer UL fire ratings over sprayed foam. While this system may be slightly more expensive than other roofing systems and difficult to apply below 40°F or on a windy day, it offers advantages few others can give, such as:

- Ability to build up insulation to reduce ponding areas and achieve slope to drains.
- Excellent insulating values, initial K factor of 0.11 – 0.14 for 3-pcf material when tested in accordance with ASTM C-177 at 75°F.
- Total adhesion to substrate, thereby eliminating lateral water migration and making any problem easy to locate and repair. (This adhesion also protects against wind blow-off.)
- Ultra light weight, less than 1 psf average; therefore, most adaptable for remedial roofing where weight could be a factor.
- Self-flashing characteristics due to the ability of the sprayed foam to bond to almost any clean substrate.
- A seamless, monolithic substrate, ideal for the application of most non-conventional liquid or sheet-applied roofing membranes.

OVER BOARD STOCK INSULATION

Non-conventional membranes over board insulation are generally limited to sheet-applied material. Liquid-applied membranes, periodically tried, usually fail early and seldom offer any guarantee for performance. The sheet membrane manufacturers who offer performance guarantees over board insulation usually require application by approved roofers. The sheets are secured to the insulation by cold-applied adhesives, mechanical fasteners, or weighed ballast (usually 10 psf). Termination and penetration details often resemble their counterparts in conventional builtup systems, requiring cants, reglets, or metal counterflashing. As indicated earlier, lack of safety factor against poor workmanship in single-ply membranes is more than offset by simple installation and superior membrane properties. Judged by our experience, many sheet systems are cost-competitive with conventional builtup systems. In many cases, they provide the owner with a superior product.

Careful selection of the board insulation is critical. Some insulation materials behave badly in the typical roofing environment, particularly after thermal cycling and exposure to moisture. Some of these insulations expand and contract, blister, or warp. Any of these actions could impair roof membrane performance. The NRCA Bulletin #4, August 10, 1978, reflects just such concern with polyurethane foam board insulation.

POURED-IN-PLACE INSULATIONS

Poured insulation such as Zonolite®, perlite and gypsum also almost always require sheet non-conventional membranes that are installed in ways similar to board stock applications mentioned previously. Care must be exercised in these systems to insure adequate venting of the insulating fill to remove moisture. Freezing or wet weather can have an adverse effect on the placement of these insulations.

BELOW-DECK INSULATION

Below-roof-deck insulation systems in use also offer certain advantages and disadvantages in conjunction with non-conventional membranes. Some advantages:

- Since there is no requirement for compression strength and less need for dimensional stability many more insulation products can be used in this location – notably less expensive materials, such as cellulose,
- Below-deck thermal insulation also doubles as acoustical insulation.
- Membrane installation can proceed without concern for coordinating with insulation, thereby permitting faster enclosure of the building.

Some disadvantages:

- An adverse effect on the aesthics of interior spaces.
- Poor fire rating depending on insulation being used.
- Impractical location of the dew point below the structural roof deck.
- Duplication of effort on metal decks, due to the need to provide adequate substrate for roofing membrane top metal deck.
- Need for protection from moisture from within the building.

In summary, the new non-conventional membrane systems offer several notable advantages over conventional built-up roof systems, notably:

- No restrictions against use of the material on ponded roof surfaces by the majority of interviewed manufacturers,
- Lower labor costs, which are making them price competitive with conventional bituminous roof systems,
- Simpler labor, giving them a better chance to avert failures attributable to poor workmanship. (These new systems substitute joint-sealing or liquid applied membrane thickness control, a relatively simple technique, for the coordinated controls required in conventional built-up roof system installation – e.g., hot-mopped or mechanical fastening of base sheets, application of multi-ply felts in multi-layer bitumen without entrapping moisture, while controlling bitumen temperature.),
- More environmentally acceptable installation techniques, free of the polluting fumes and smoke produced by hot bitumen,
- Easier repair, since defects are more readily detectable and often repairable with caulking guns or other simple equipment and patching materials,
- Self-flashing characteristics, giving the system more monolithic waterproofing integrity,
- Safer for personnel and property by eliminating the potential fire hazard and burn injuries associated with tar kettles used with conventional membranes,
- Less energy required for installation, since most single-ply systems are cold applied and even those featuring heat-fused field joints use only small quantities of heat.

For an excellent survey of the physical and performance properties of common non-conventional roofing materials, see Ref. 3. (See Table 1 for a listing of these materials with suitable substrates and membrane thicknesses.)

REFERENCES

1. *"The Control of Moisture in Roof Structures and Roof Insulation,"* F. O. Marsh and H. Thomas, Briggs Amasco Ltd., United Kingdom, International Sumposium on Roofs and Roofing, Brighton, England, September 1974.
   "Avoidance of Condensation in Roofs," J. P. Cornish and I. W. L. Hendry, Building Research Establishment, Department of Environment, United Kingdom, International Symposium on Roofs and Roofing, Brighton, England, September 1974.
2. *"Standard Definitions of Terms Relating to Rubber,"* ASTM Resignation D 1566-77a, 1977 Annual Book of ASTM Standards, Part 37, ASTM, Philadelphia, PA 1977.
3. *"Elastomeric Roofing: A Survey,"* Walter J. Rossiter, Jr., and Robert G. Mathey, Center for Building Technology, National Engineering Laboratory, National Bureau of Standards, Washington, D.C., July 1978.
4. *"Properties of Rigid Urethane Foams,"* Elastomer Chemicals Department, E. I. DuPont DeNemours & Company, Wilmington, Delaware, 6/21/63, revised September 1966.

TABLE 1 – ELASTOMERIC ROOFING MEMBRANES, LISTED GENERICALLY, AS WELL AS THE SUBTRATES TO WHICH THE MEMBRANES ARE APPLIED AND THE APPROXIMATE THICKNESSES OF APPLICATION(1)

Type of Membrane	Membrane	Substrates	Thickness	
			mils(2)	mm
Liquid applied(3)	Acrylic	concrete, plywood, spray-in-place urethane foam, remedial roofing	20	0.5
	Butyl	concrete, plywood, insulation board, remedial roofing	15-30	0.4-0.8
	Chlorosulphonated polyethylene	spray-in-place urethane foam, weatherproof coating for elastomeric membranes	20-45	0.5-1.1
	Neoprene/chlorosulphonated polyethylene	concrete, plywood, spray-in-place urethane foam	20	0.5
	Polyvinyl chloride (PVC) and vinyl	concrete, plywood, spray-in-place urethane foam	15-30	0.4-0.8
	Rubberized asphalt	concrete	150-180	3.8-4.6
	Silicone	spray-in-place urethane foam	20	0.5
	Urethane(4)	concrete, plywood, spray-in-place urethane foam, remedial roofing	20-60	0.5-1.5
Preformed sheets(5)	Chlorosulphanted polyethylene/ asbestos backed	plywood decks on industrialized or modular construction	35	0.9
	EPDM (Ethylene propylene diene terpolymer)	concrete, plywood, insulation board, remedial roofing	45	1.1
	Neoprene	concrete, plywood, insulation board	63	1.6
	Polyvinyl chloride (PVC)	concrete, spray-in-place urethane foam, remedial roofing	48	1.2
Composite preformed sheets	Nylon reinforced PVC backed with neoprene or butyl	concrete, plywood, insulation board, remedial roofing	30	0.8
	Non-woven glass reinforced PVC	concrete, plywood, insulation board	47	1.2
	Modified asphalt/polyethylene sheet	spray-in-place urethane foam, remedial roofing	68	1.7

(1) The information presented in this table has been assembled from the literature of various manufacturers. It is presented for purposes of comparison to give the reader an overview of the materials available and the substrates to which they may be applied. Individual products should be applied to substrates and in thicknesses recommended by the manufacturers.
(2) 1 mil = 0.001 inch.
(3) Liquid membranes are commonly applied by a number of techniques including brush, roller, squeegee, trowel and conventional and airless spraying.
(4) A number of widely varying membrane systems are classified under the title urethane including asphalt and coal-tar modified urethanes.
(5) Sheet membranes are applied bonded to or loose-laid on the substrate.

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1. *"The Control of Moisture in Roof Structures and Roof Insulation,"* F. O. Marsh and H. Thomas, Briggs Amasco Ltd., United Kingdom, International Sumposium on Roofs and Roofing, Brighton, England, September 1974.
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TABLE 2

EFFECT OF DENSITY ON COMPRESSIVE STRENGTH

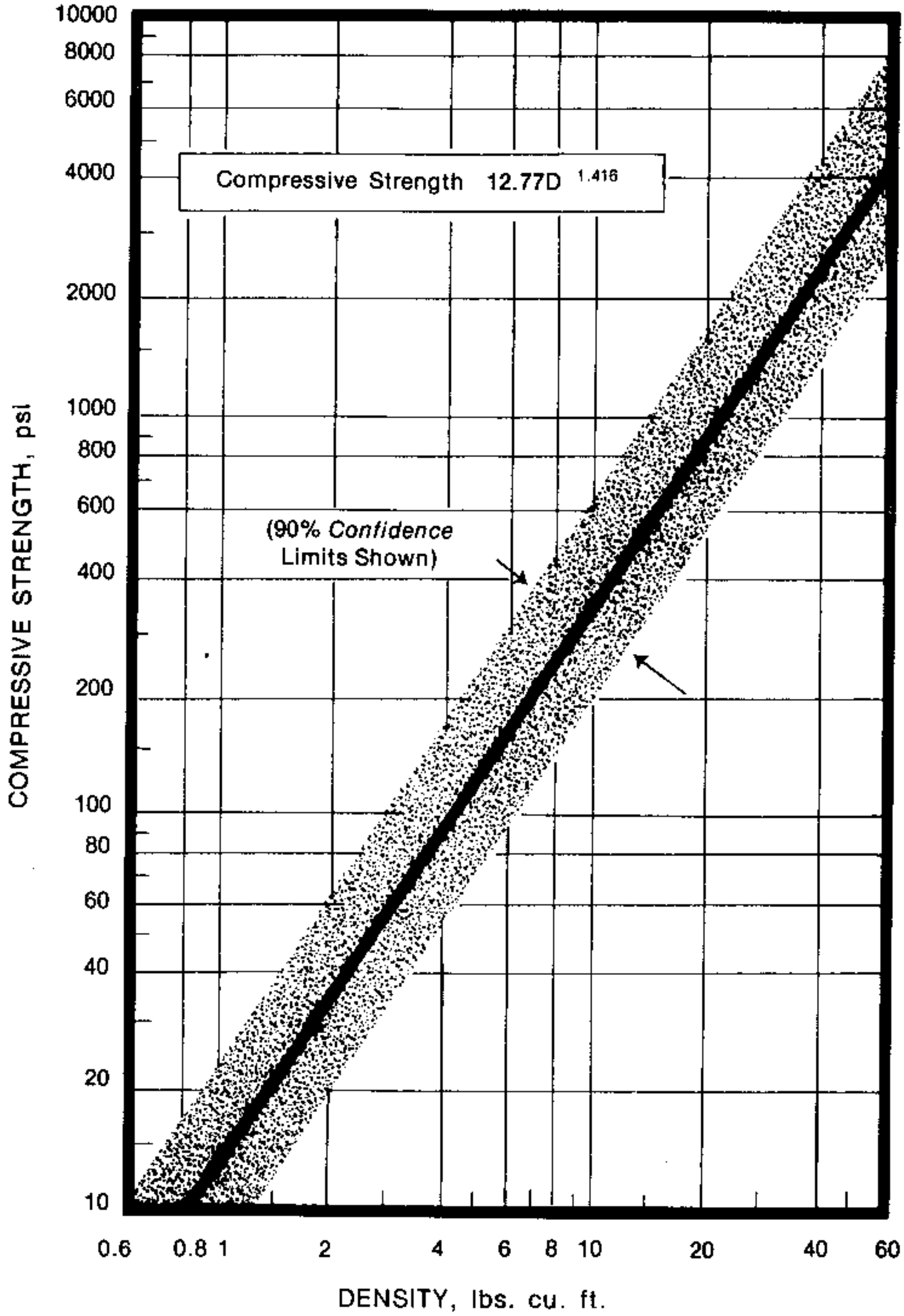

TABLE 3

DIMENSIONAL STABILITY
(Blown with FREON - 11)

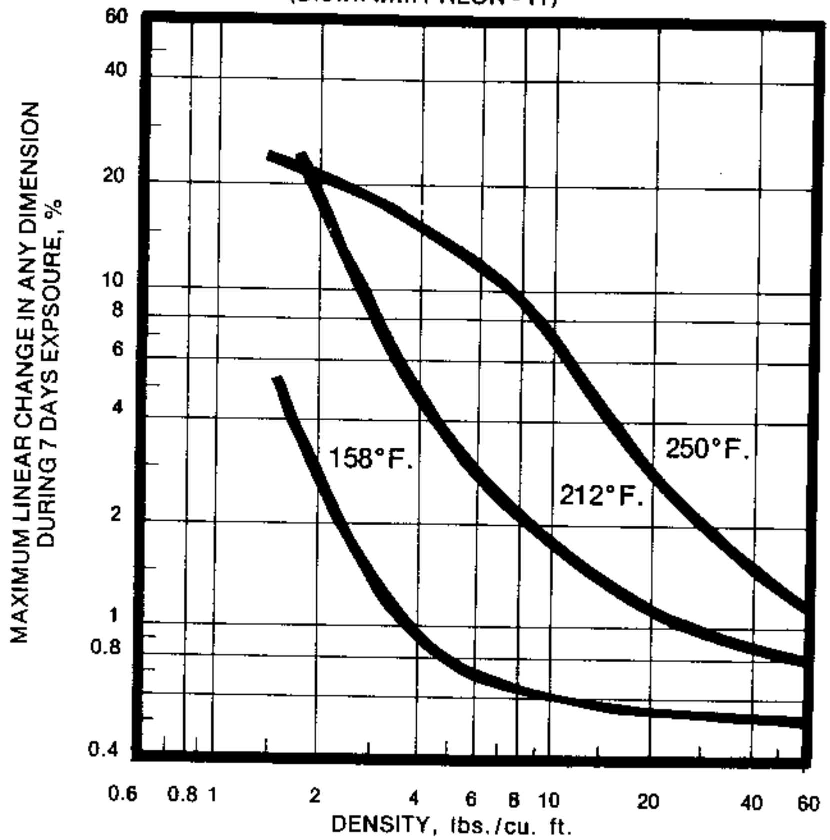

TABLE 4

EFFECT OF DENSITY ON WATER VAPOR TRANSMISSION