FIELD PERFORMANCE OF POLYMER-MODIFIED BITUMINOUS ROOFING MEMBRANES

RICHARD P. BAXTER

Carolina Roofing Service, Inc.
Monroe, N. C.

USE IN EUROPE

Polymer-modified bituminous roofing membranes were first introduced to the European market, with several countries offering various types of sheets with several different polymer modifiers. Atactic polypropylene (APP), styrene butadiene styrene (SBS), and styrene butadiene rubber (SBR) were the initial primary modifiers for asphalt, with reinforcing material varying between products. Glass fibers, polyester fibers and polyethylene film were used individually or in combination to stabilize and form a "carrier" for the polymer-modified asphalt membrane. Surfacing materials varied from glass fiber mats inherent in the membrane to mineral granules to metallic foils by individual product.

Most of the original European polymer-modified asphalt membrane roofing systems contained multiple layers of the sheet material usually applied by propane torch. Systems were changed to incorporate various sheet types and surfacing materials, but multiple layers of material appeared to be the preferred "system" approach for installation of the roofing membrane.

USE IN CANADA

Several of the European suppliers introduced their material to the Canadian market and some Canadian suppliers were licensed to manufacture polymer-modified asphalt roofing membranes locally. The materials were put into use in a similar manner as in the European market, with market penetration limited by the relatively high price of the materials. Eventually, the price reduction of the material and use of the membrane materials in the "single-ply" concept resulted in greater general exposure for the polymer-modified asphalt membranes in the Canadian market.

USE IN UNITED STATES

United States textile tariffs limited the availability of the polymer-modified bituminous roofing membranes initially available from Europe, since the materials containing cloth-type reinforcements were considered textile products by U. S. Customs. Domestic production of one SBR/polyethylene film-stabilized modified bituminous membrane resulted in more cost-effective polymer-modified asphalt membrane systems, although initial acceptance was slow. Other domestic manufacturing agreements resulted in the local manufacturing of SBS and APP modified asphalt materials, and the general acceptance of polymer-modified asphalt roofing membranes increased rapidly with the new wave of acceptance of "single-ply" roofing membranes. In 1987, polymer-modified asphalt roofing systems enjoy a significant market share with a large number of suppliers of various materials. Some 16 suppliers of polymer-modified asphalt roofing membranes are represented by the Asphalt Roofing Manufacturers Association (ARMA), with many more making the product available regionally. Unlike the original European market, most of the membranes in the United States are promoted as "single-ply", and only one layer of the material is installed for waterproofing. A minority of suppliers have remained proponents of multiple-layer applications, even in the face of significant competitive pressures.

Marketing of polymer-modified bituminous sheet membranes has generally been in the category of "single-ply" systems in the United States even though many of the "systems" are not in fact one ply, but rather two plies consisting of a base sheet and a surfacing sheet of polymer-modified bitumen.

GENERAL OBSERVATIONS ON FIELD PERFORMANCE

Roofing membranes

The initial polymer-modified asphalt membrane commonly available in the United States was an SBR modified asphalt with a polyethylene film reinforcement. Textile tariffs did not apply to plastic films used as membrane carriers, and the polymer-modified bituminous membrane material available from Spain was relatively cost effective in the United States' market. The initial material was imported, with licensing agreements for domestic manufacture eventually finalized.

The first SBR-modified asphalt membranes with polyethylene reinforcement were sold with a surface film of polyethylene or aluminum foil, the polyethylene skinned material intended for ballasted installations, and the aluminum foil surfaced material for non-ballasted installations. The material performed adequately and provided generally satisfactory service during its expected service life. Initial application problems were experienced with the new concept of torch-applied membranes and combinations of adhesives offered by the supplier. The heavy plastic film on the outer surfaces of the membrane resulted in locally incomplete lap bonding and many post-installation callbacks. Aluminum foil surfacing material available on the material generally performed adequately for membrane base flashing and on roofs with little or no surface traffic, but once the surfacing skin was damaged, significant deterioration of the waterproofing material occurred rapidly. Subsequent product modifications eliminated the surface damage and puncture problems created by the relatively soft SBR-modified asphalt, but resulted in a finished product subject to rupture and delamination of the aluminum foil facing material. The capabilities of the material to perform adequately on low-sloped roofs subject to ponded water and roofs exposed to heavy surface traffic were exceeded as marketing efforts increased and many misapplications of the material resulted. Product and in-place performance problems, along with arrangements for disposition of existing problems, resulted in eventual withdrawal of the product from the market.

Even subtle or seemingly insignificant product changes in polymer-modified bituminous membrane compounding may result in compromise of long-term system performance.

There is still one polyethylene-stabilized polymer-modified bituminous roofing membrane system available in the United States, which is a self-adhering-type system. There have been several significant roofing "system" changes made by the manufacturer, but with the exception of surfacing material the membrane material appears to be basically unchanged since its introduction to the market as a roofing material.

The overall performance of both APP- and SBS-modified asphalt roofing membranes has been acceptable, although they have not been without their problems. Product modifications to modified bituminous roofing membranes have sometimes been for the better, sometimes for the worse as manufacturers have experimented to provide satisfactory performance at competitive cost. Systems and concepts have changed since the initial introduction of most of the membrane materials. To date, no industry-accepted application criteria have been established, although the National Roofing Contractors Association has undertaken to establish such application tolerances for polymer-modified bituminous roofing membrane systems.

Base flashing membranes

Polymer-modified bituminous membranes have replaced reinforced asbestos base flashing material as the primary means of constructing membrane base flashings on both modified bituminous assemblies and built-up roofing assemblies. In general, the performance of the polymer-modified bituminous sheets has been satisfactory as a membrane base flashing material.

Most of the APP-modified asphalt membrane manufacturers have eliminated the requirement for cant (transition) strips at vertical junctures because of the fire hazard created by wood fiber insulation cant strips during torch application of modified bituminous membranes. Elimination of the cant strip has resulted in significant installation problems at horizontal/vertical membrane junctures where the membrane must be cut at the same plane to wrap around interior or exterior corners. The recent general availability of perlite insulation cant strips has greatly reduced the fire hazard associated with propane torches and wood fiber insulation cant strips, and requirements for transition strips may return in the construction of membrane base flashings with torch-applied membranes. Inclusion of a transition cant strip at vertical junctures will eliminate much of the disbonding/breaks in integrity presently possible at right angle flashing/roof membrane junctures.

SBS polymer modifiers

The general trend in the polymer-modified bituminous membrane industry has been toward the inclusion of an SBS-modified asphalt in product lines to allow flexibility in application requirements and to hedge against either shortages or increased prices of APP modifiers, and the potential limitations on the use of propane torches on roofs in some municipalities. The performance of the limited number of SBS-modified bituminous initially available in U. S. markets has been generally good, with no significant product problems other than an occasional shrinkage of polyester reinforcing material. There have been some slippage-related problems on sloped roof surfaces with some multi-layer systems caused by use of asphalt with softening point temperatures too low, or by asphalt that has been subjected to prolonged heating and suffered the resultant fall-back of softening point temperature. The currently available products have performed as intended; it remains to be seen whether or not new products from suppliers less experienced in SBS modification of asphalt will perform as well. Without some standard criteria for evaluating and/or testing these type products, it will be difficult to assess the performance of the newly introduced material and the wide selection of SBS-modified bituminous roofing membranes available in the market.

APP polymer modifiers

The dwindling supply of existing APP modifiers and the movement against rooftop torch applications are of major concern to suppliers of APP-modified bituminous roofing membranes. The present APP-modified bituminous membranes have performed with mixed reviews, with rupturing (membrane splitting) and lap delamination the most common cause of failure of the membrane assembly. Rupturing of APP-modified membranes has generally been most prevalent in extreme cold climatic conditions, with general failure of some materials installed in the Canadian Maritime Province. Modifications to membrane composition and experimentation with various combinations of reinforcing materials by suppliers have contributed to similar rupture problems in less severe climatic areas. The proliferation of APP-modified bituminous membrane suppliers has certainly contributed to the in-place exposure of APP-modified asphalt membranes and to some of the problems of delamination, rupture and splitting of APP-modified membranes, with some foreign suppliers lacking experience in assessing the climatic conditions of the U. S. market and the necessary physical properties of roofing membranes to minimize installation and performance-related problems. Overall, the performance of APP-modified bituminous sheet membranes must be considered acceptable, even though there have been localized problems with some individual materials.

Glass-fiber reinforcements

Glass-fiber reinforcement is usually used in polymer-modified bituminous membranes to provide good tensile properties to the membrane. Most glass-fiber reinforcing mats/scrims have provided sufficient tensile properties for polymer-modified bituminous sheets to minimize rupturing problems; however, there are some APP-modified asphalt membranes marketed in which the tensile strength of the glass-fiber reinforcing mat is insufficient to eliminate rupturing of the membrane even in more temperate climatic areas. Glass-fiber reinforcement is stable throughout the anticipated application temperature range for polymer-modified bituminous membranes and is not subject to degradation or shrinkage when subjected to common application temperatures. Most glass-fiber mat-reinforced polymer-modified bituminous membranes exhibit a "flatness" and "memory" common to glass-fiber reinforced built-up roofing membranes.

Glass-fiber reinforcements may contribute to poor handling qualities for polymer-modified bituminous membranes if the mat is "stiff" and retains a "memory" common to glass felts. Woven glass cloth reinforcements are not as subject to exhibiting "memory" as are glass-fiber mats, and have shown excellent handling qualities incorporated into special flashing membranes.

Polyester mat reinforcements

Polyester-reinforcing material commonly used in polymer-modified bituminous membranes is spun-bonded, spun-laced or woven scrim. In general, all have performed well individually or in combination with other type or similar type reinforcement. Polyester reinforcements used in polymer-modified bituminous roofing membranes are designed to be more heat resistant than standard polyester materials. Polyester mats/scrims are generally more heat sensitive than glass-fiber reinforcements. The major problems experienced with polyester mats have been generally attributed to overexposing the reinforcing material to heat during the time of application. Some shrinkage and wrinkling of the polyester reinforcements in polymer-modified bituminous membranes has been experienced, but these problems appear to have been rather localized and are probably attributable to defects in the manufacture of the reinforcement, or the location of the reinforcing mat in the plane of the finished membrane. Polyester-reinforcing mats can be significantly affected during the time of manufacture of the polymer-modified bituminous membrane if stresses are imposed on the reinforcement during the time of manufacture. The result of such mishandling of materials during manufacture may be wrinkling of the finished membrane subsequent to the time of installation.

Various surfacing materials

Surfacing material commonly factory-applied to polymer-modified bituminous membranes include ceramic granules and metal foil skins. Some problems have been inherent with both surfacing methods.

Ceramic granules generally provide a durable, reflective surface that protects the roofing membrane from surface abrasion and deterioration from sun exposure. Degranulation of granule surfaced sheets is common over extended periods, necessitating resurfacing, generally with liquid coatings. Membranes with granules that are "rolled" into the top surface of the membrane are much less subject to short-term degranulation than are membranes with granules that are not mechanically embedded in the membrane surface. Loose granules become an effective parting agent during the time of application of the membrane, thus contributing to problems during the time of application and eventual separation of laps formed over excessive accumulations of loose granules. If granules are not removed, or at least mechanically forced into the polymer-modified bituminous membrane surface prior to bonding of laps, especially end laps, the potential for fusion between the two adjacent membrane layers is significantly reduced. Separation (alligatoring) of the mineral granule surfacing has also occurred, generally in roof areas that pond significant quantities of water.

The successful manufacture of metal foil-surfaced polymer-modified bituminous membranes requires specialized technology and special materials. Long-term bonding of the metal skins to the membrane surface is the challenge to the manufacturer of these type of materials. Metal surfacing on polymer-modified bituminous membranes has never proven to be totally acceptable for low-sloped roof installations., especially those with any anticipated surface traffic, and the metal-surfaced materials presently available have been recognized as having limited, special applications for steep roofs and/or membrane flashings.

The first metal-surfaced polymer-modified bituminous membrane commonly available in the United States had an embossed aluminum foil surface that generally performed adequately on the original formulation of the membrane. Product changes resulted in the tendency for the metal skin to delaminate from the membrane surface, leaving the polymer-modified asphalt exposed to allow ultraviolet degradation (which was relatively rapid). Metal foil surfacing is presently available from a limited number of suppliers. The presently available metal-surfaced membranes are still relatively easily damaged by mechanical abuse, but general delamination of the metal-surfacing skins from currently available membranes has to this time not been a significant problem.

MAJOR FIELD PROBLEMS

Rupturing

Rupturing (splitting) experienced in polymer-modified bituminous roofing membranes appears to be primarily attributable to use of reinforcements that are inherently too weak to accommodate anticipated thermal loads or mechanical stresses imposed on the roofing membranes. Some ruptures are probably the result of reinforcements weakened during the manufacturing process of the polymer-modified bituminous membrane, however, aging of polymer-modified bitumen results in a reduction of ductility and its general ability to resist strain, which may also contribute to rupturing induced by thermal load.

If glass-fiber reinforcement used in polymer-modified bituminous roofing membranes is inherently too weak to prevent rupture of the roofing membrane during periods of thermal loading or mechanical stress on the roof assembly, rupturing of the roofing membrane is the anticipated result. Tensile characteristics of glass-fiber mats for roofing reinforcement vary with the type glass, the type mat and the binders used in the mat manufacturing process. Simply because the membrane contains "glass-fiber" reinforcing material is no assurance that the tensile properties of the membrane will be acceptable.

Membrane splitting/rupturing has been more common in APP-modified bituminous membranes. APP does not in itself provide elasticity to the asphalt, and the tensile properties of the reinforcement used in APP-modified bituminous membranes must be sufficient to resist anticipated thermal and mechanical loading without rupture. The cold weather characteristics of APP-modified bituminous membranes, in general, have not been totally satisfactory, although minimal problems have been reported with some of the APP-modified bituminous membranes even in severe climatic areas. The elastic properties of the reinforcing material incorporated into APP-modified bituminous membranes must be matched to the viscous properties of the APP compound to yield the optimum quasi-viscoelastic properties of the finished membrane. Sufficient tensile strength of the reinforcing material is necessary to minimize the tendency of the APP-modified bitumen membranes to separate under normal thermal load conditions.

The rupturing of polymer-modified bituminous membranes takes on the same characteristics as rupturing problems associated with built-up roofing, with ruptures usually coincident to continuous roof insulation joints or at membrane junctures. As with built-up roofing membranes, rupturing is rarely caused by only one factor; there are usually other factors—aging, lack of proper securement of the roofing assembly, structural movement/settlement, etc. contributing to the separation of the roofing membrane than just the lack of tensile properties of the membrane itself.

Because some of the reinforcements used in polymer-modified bituminous membranes have significant, inherent extensibility, there is justifiable concern that the polymer-modified asphalt may fracture (especially at low temperatures), but the reinforcement remain intact. When the continuity of the waterproofing medium (the bitumen) is interrupted, the purpose of the membrane is compromised as water enters through cracks in the waterproofing bitumen. The National Bureau of Standards has proposed concurrent evaluation of "watertightness" following tests for tensile and/or load-strain properties on polymer-modified bituminous roofing membranes to determine whether or not the membrane is capable of performing its intended function (waterproofing) after exposure to environmental or mechanically imposed elongation. The concept of additional testing/evaluation is certainly warranted, given the potentially unconventional behavior of some of the polymer-modified bituminous membranes.

Blistering
Blistering-related problems occur in polymer-modified bituminous membrane assemblies for the same reasons blisters occur in built-up roofing membranes; some moisture has been trapped in the system during the time of application. Since the polymer-modified bituminous membranes and/or their reinforcements have no particular affinity for water (as did the asphalt-coated organic felts), moisture release from the roofing material itself is unlikely. Moisture held in surface tension on the sheets or moisture on the substrate over which the membrane is directly applied would certainly result in the introduction or entrapment of moisture into the roofing assembly and membrane separation as vaporization of the moisture occurs. Torch applications tend to vaporize moisture on the substrate and minimize accumulation of moisture that might contribute to eventual separation of the membrane from the substrate. However, voids left between the roofing membrane and a solid, irregular substrate surface may result in enough entrapped moisture-laden air to result in some separation of the roofing membrane from the substrate surface subsequent to the time of application. Since virtually all of the polymer-modified bituminous membranes are essentially "waterproof," there are no avenues of escape for any moisture trapped beneath the membrane, making these membranes susceptible to blistering if care is not taken during the time of application. The SBS-modified bituminous membranes installed in hot asphalt have shown the largest propensity toward blistering of the membrane, although even torch-applied APP-modified bituminous membranes have blistered away from structural concrete decks over which they are directly applied.

The rules for minimizing tendencies for blistering do not change with the product. Inherently waterproof membranes should not be applied directly over substrates that retain moisture, but rather should be separated from such substances by mechanically attached venting base sheets or a layer of roof insulation capable of diffusing the moisture as it is released from the substrate material. Care should be taken in the storage of the rolls of material to insure that no moisture accumulates on the roll surfaces. Substrates over which the membranes are to be installed must be protected from accumulating moisture prior to the time of application, or must be thoroughly dried before application of the polymer-modified bituminous membrane.

Slippage
Roofing membrane slippage Slippage of the polymer-modified bituminous membrane systems has been primarily isolated to the SBS-modified bituminous membrane systems installed in hot asphalt on roofs with significant slope. Most slippage has been experienced when the roofing material has been "shingled" from the low roof areas to the high roof areas (ridges, etc.).

Membrane flashing slippage Slippage of membrane base flashing has been experienced primarily when SBS-modified bituminous membrane flashing sheets have been installed in hot asphalt to the vertical substrates. Torch application of polymer-modified bituminous membranes generally results in sufficient bond fusion to retain the material on the vertical substrate whether APP- or SBS- base membrane is used.

Causes for slippage
Slopes of roof decks When slopes of roof decks exceed 1 1/2 inches in 12 inches, slippage of membranes installed in hot asphalt becomes a potential problem. Most of the slope/slippage-related problems with polymer-modified bituminous membranes have occurred with SBS-modified bituminous roofing systems installed in hot asphalt. Other related problems are discussed below, but when the slope of the roof deck is greater than 1/2 inch in 12 inches, the potential for slippage increases from all other related factors.

Elimination of slippage-related problems on polymer-modified bituminous membrane systems should be approached on the same basis used to eliminate slippage of built-up roofing membrane systems. Prudent use of wood nailers on the roof deck allows mechanical securement of the roofing membrane in the field areas. Use of appropriate type asphalt for the slope of the deck is essential. "Strapping" of the membrane materials with the slope of the deck minimizes the tendency for the surfacing sheet to slide off of the base ply or substrate and allows positive attachment at the top side by mechanical means.

Some of the SBS-modified bituminous membrane systems contain a base ply and a surfacing sheet, necessitating a "phased" type construction. Some recommendations for installation of the membrane are application of the base ply over the entire roof area followed by application of the surfacing sheet, with both sheets installed by "shingling" the membrane components from the low areas to high areas. Installation of the membrane components in this manner increases the potential for slippage, since the surfacing sheet is applied over a continuous layer of asphalt with no contact with the substrate. If the softening point of the asphalt is not extremely high, some displacement of surfacing sheets may be anticipated under the weight of the surfacing sheet itself. "Strapping" of the membrane materials and use of wood nailers for mechanical securement of the base ply (and even the surfacing sheet on extreme slope conditions) would minimize slippage problems in these instances.

Lack of mechanical attachment The lack of mechanical attachment of the roofing membranes installed on steep slopes, and failure to mechanically secure tops of membrane base flashings generally contributes to the slippage related problems with polymer-modified bituminous membranes. Mechanical securement of the tops of membrane base flashings appears to be especially essential when the flashing membrane is set in hot asphalt. Even when the membrane flashings are torched into place, release of the membrane flashing caused by moisture accumulation behind the flashing membrane on masonry walls necessitates positive mechanical attachment of membrane flashing at the top edges.

Low softening points of mopping asphalt Asphalt available in some locations in the United States has contributed to slippage-related problems, again, principally on SBS-modified bituminous membrane systems installed in hot asphalt. The initial softening points of the asphalt may be lower than the certified ASTM Type, or the asphalt may be more subject to "fall-back" during the heating process in some geographic locations. Pacific Coast and Alaskan crude oils are less stable than mid-continent (U. S.) or Venezuelan crude oils and can be relatively quickly affected by even short periods of storage at temperatures approaching the Finished Blowing Temperature of the asphalt. It appears that some suppliers may "mix" asphalts blown to elevated softening points with asphalts of lesser softening points, creating a relatively unstable, or temperature-sensitive, asphalt.

Whatever the cause of instability or temperature sensitivity of the asphalt, polymer-modified bituminous roofing membranes installed on any significant slope (1/2 inch in 12 inches or greater) in hot asphalt may be subject to slippage. One domestic roofing membrane supplier has stipulated the use of Type IV asphalt to insure sufficient softening point of the asphalt to minimize slippage-related problems, since slippage of its system has been experienced with roofing membranes constructed with Type III asphalt on roof deck slopes that normally would require only Type III asphalt. The use of high-softening point asphalts in construction of the roofing membrane creates other application-related problems in maintaining sufficient temperature of the asphalt at the point of application to insure "fusion" of the mopping asphalt and the polymer modified asphalt.

Incompatibility of mopping asphalt with polymer-modified asphalt There are some legitimate concerns about the compatibility of mopping asphalts and polymer-modified asphalts. Incompatibility of the mopping asphalt with the polymer-modified asphalts may result in exudatiion between the two bituminous materials causing slippage of the membrane components on any significant slope and perhaps resulting in a shorter service life of the membrane.

Asphalts manufactured from mid-continent crudes modified with polymeric additives may provide satisfactory end-product performance, while use of the same polymer modifier used in similar quantities with asphalt manufactured from Pacific Coast crudes may result in an unsatisfactory performance of the end product. Such incompatibility problems apparently have the potential to more severely affect the performance of SBS-modified bituminous membranes since SBS membrane assemblies are more often installed in hot, mopping asphalt and depend on "fusion" between the mopping asphalt and the polymer-modified asphalt in the roofing membrane.

Although to date, asphalt compatibility problems have apparently been minimal, expansion of production facilities by some suppliers into other geographic locations may result in use of local asphalts that may not perform as expected when modified by polymeric additives. Suppliers basic in APP-modified bituminous membanes attempting to extend product lines by use of SBS modifiers may experience some initial unexpected problems in attempting to use locally available asphalts in the production of SBS-modified bituminous membranes. Current suppliers of SBS modified bituminous membranes with systems that may be installed in hot asphalt have been particularly sensitive to the problems of incompatibility with local asphalts. The limited experience with potential incompatibility of polymer modifiers and locally available asphalts dictates the need for evaluative test criteria and/or standards to minimize future compatibility related problems.

Separation at membrane flashing junctures

Flashing without cant strips Elimination of the transitions (cants) at vertical junctures results in having to fit the flashing membrane around corners of vertical junctures without any overlap at the critical bottom corners. Some suppliers have advocated sealing the corner area with small amounts of modified bitumen scraped from the back of another sheet, while some have advocated application of a "bow tie" or a small piece of membrane cut in the shape of a bow tie and installed over the bottom corner juncture.

Separation of the membrane at the bottom corners at vertical junctures has been a source of water infiltration at penetrations through the roof and at elevation walls. The separation is apparently caused by movement of roof system components or vibration of equipment curbs. Sealing of the juncture with additional modified bitumen does not generally provide a long-term solution to the juncture problem. Installation of the "bow-tie" at corner junctures appears to have resulted in a more acceptable long-term seal.

Flashing with cant strips General availability of perlite insulation cant strips has greatly reduced the potential torch-fire problem common when wood-fiber insulation cant strips are used for transitions. Perlite insulation does not "punk" like wood-fiber insulation and can be relatively safely installed beneath torch-applied flashing membrane.

Construction of the polymer-modified bituminous membrane assembly using perlite-type cant strips should be the same as construction of a built-up roofing membrane at vertical junctures, i.e., the roofing membrane is extended to the top of the cant strip, lapped at the corners and cut so that cuts in the membrane are not coincident and the corners at roof level sealed. The flashing membrane can then be installed from the top termination point to a point on the roofing membrane approximately 3 inches to 4 inches beyond the base of the cant strip with corners lapped and sealed by the overlap of flashing membrane. Some attention must be paid to cutting and lapping of the membrane, but this method does not rely on "caulking" or small, unmanageable pieces of material to provide the only seal against water entry to the system.

Lap separation and delamination

SBS-modified membranes Most lap separation problems associated with SBS-modified bituminous membrane assemblies have occurred on membrane systems constructed with hot asphalt. The major cause of the separation appears to be the lack of "fusion" of the polymer-modified bitumen to the hot mopping asphalt, or residual plastic film (parting agent) remaining between membrane layers at laps. Mopping asphalts must be maintained at relatively high temperatures (425°F) at the point of application to assure fusion of the polymer-modified bituminous materials at the laps. Failure to maintain the mopping asphalt temperatures results in no fusion of the membrane components and the asphalt becomes only an adhesive that is affected by thermal loading on the roofing or flashing membrane. The general result is separation at the overlap areas, especially at junctures of adjacent sheets.

Separation of the SBS-modified bituminous membrane systems has also occurred at endlaps of mineral-granule-surfaced sheets when an excess of granules has prevented adequate contact of the two membrane surfaces at overlap areas. The most foolproof way to correct this problem is to remove the granules or "work" them into the modified bitumen at the overlap area prior to attempting the lap at sheet ends. Mineral-granule-surfaced SBS-modified bituminous membranes without a factory selvage edge are extremely difficult to handle in the field and should be avoided for most general use.

APP-modified membranes Separation of the laps in APP-modified bituminous membranes has occurred under two separate conditions: 1) Lack of fusion of the material at the time of initial application or lack of contact of the material at endlap junctures, and 2) delamination of the membrane at the reinforcement interface.

Lack of fusion of the membrane at the overlap area is directly attributable to insufficient heat applied at the time of application, and can be relatively easily corrected during the time of installation if laps are checked and open areas resealed, although residual plastic film (parting agent) may still cause disbonding of laps even after prolonged heat application.

Polymer-modified bituminous membranes reinforced with glass-fiber mats may be affected by the "memory" of the glass-fiber material in that the membrane may "bridge" over irregular surfaces, which include endlap juncture areas. Unless special attention is paid to areas where individual sheets join at endlaps/junctures, it is possible to leave a significant void between the overlapping membrane layers at endlap joints at adjacent sheets.

Some delamination of APP-modified bituminous membranes has occurred at the reinforcement plane in the membrane during the time of application. The apparent causes for such delamination may have been a combination of overheating material at the laps (end and side) during installation and a breaking down of the bond between the reinforcing material layers and the polymer-modified bitumen in the membrane.

Some general delamination of APP-modified bituminous membranes has been experienced, primarily on membrane materials where the reinforcement is very close to or at the top surface of the membrane. General delamination of the membrane-reinforcing material may occur between two layers of reinforcing mat or between the polymer-modified bitumen and the reinforcing mat itself. Both problems are manufacturing-related and are probably the result of difficulties in introducing two separate reinforcing layers into the membrane manufacturing process, or an incompatibility and the resultant lack of bond between the polymer-modified bitumen and the binders or surface treatment of the reinforcing material.

INDUSTRY REACTION TO PROBLEMS

In general, new lessons had to be learned as polymer-modified bituminous membrane materials were moved from Europe to the United States. Application techniques are vastly different between the two geographical areas, with U. S. contractors being more "production" conscious than their European counterparts, and the field-talent "experience factor" varies dramatically in the United States from region to region because of lack of , or more experience with, these materials, depending on the acceptance of the concept in different areas.

Manufacturers/suppliers of polymer-modified bituminous membranes have been generally quick to respond to application-related problems with new information or formal training in the application of their individual systems. Mistakes have been made and generally rectified. New recommendations for application have followed realization that original recommendations did not always provide enough redundancy in the systems to make them relatively foolproof.

Moving manufacturing facilities from Europe to the United States has meant new searches for raw materials and for suppliers of essential components for the polymer-modified bituminous membranes, and adjustments in the manufacturing processes to accommodate various differences in asphalt and reinforcements. Materials that performed well in relatively moderate climatic areas of Europe did not necessarily fair well in the harsher Canadian or north-central United States' climates, and adjustments in the product physical properties were necessary to minimize product-related problems.

The industry is still in the process of "discovery" in some sectors, with manufacturers marketing polymer-modified bituminous membranes with various-weight reinforcing mats and varying combinations of reinforcing materials in an attempt to remain competitive or to better fill a niche in the market for roofing materials.

PROGNOSIS FOR THE FUTURE USE OF POLYMER-MODIFIED ASPHALT MEMBRANES

Polymer-modified bituminous membranes have been generally well accepted in the United States market, and the concensus in the industry is that the market share will continue to grow, probably at the expense of both built-up and sheet-membrane systems.

There will probably be a shakeout of the participants in the polymer-modified bituminous membrane industry, since the market appears to be saturated with participants at the present time. The *Roofing Materials Guide,* published by the National Roofing Contractors Association semi-annually, listed some 140 modified bituminous membranes in the August 1986 issue. The market surely will not find a place for all of the membranes presently available.

SUMMARY

Polymer-modified bituminous roofing membranes have generally performed as represented by their proponents and as expected by the industry—not perfectly, but perfectly acceptably. Domestic manufacturers/suppliers of polymer-modified bituminous roofing systems are generally becoming more sophisticated in the manufacture of the products and have good experience factors with their systems under differing environmental and service conditions. Some further adjustments will no doubt be required in both product and systems, but the overall performance in the United States to date has been promising.