Polymer-Modified Bitumen Roofing: Molecules, Membranes and Systems

By Steve Ratcliff

As long as bitumens—coal tar pitch and asphalt—have been used for roofing, people have tried to improve their properties. Truly effective modified bituminous materials originated in Europe in the late 1950s, when several organic chemists made the breakthrough discovery that polymers could be blended with asphalt to create materials with the waterproofing properties of asphalt and the flexibility, elongation, and recovery properties of a rubber or plastic compound.

The modified bitumen (MB) membrane revolution continued into the 1970s when these products started to gain recognition in the United States. The first systems installed in the U.S. were actually imported from Europe; however, partly as a result of the oil embargo, interest in modified bituminous materials grew, and manufacturing plants were built in the U.S., beginning in the late 1970s. The 1980s were a period of experimentation and improvement. In the 1990s performance standards were set and modified bitumens became widely accepted. Currently, as the new millennium approaches, these systems have been sufficiently tested and manufacturing processes satisfactorily improved so that reliable modified asphalt roofing systems are readily available to the roofing industry.[1]

Modified bituminous membranes are attractive for many applications, particularly in climates where roofing systems are exposed to thermal shock or freeze-thaw cycles. They offer important advantages over conventional roofing systems, including choice of application method; superior strength, durability and moisture protection with fewer plies; systems engineered for modern as well as traditional building designs; attractive, lightweight designs; and composite systems which combine the best features of MB and built-up roofing (BUR) technologies.

Cold applied modified bituminous systems, especially, are of growing importance to the roofing industry. They represent a major change in the way that bituminous roofing systems are installed and are sure to have a profound effect on the roofing industry in the years ahead. More will be said about cold applied systems later in this paper.

First, however, we present an overview of MB materials in terms of molecules, membranes, and systems. These membranes are commonplace in the roofing industry today, but specifications and systems are still evolving. Then we will examine the relation between BUR and MB systems. Newer MB materials, such as SEBS modified mopping asphalt, will be described, and how these materials can be optimized for roofing systems will be detailed. Finally, the latter part of this article will review the advantages of ambient-applied MB membranes.

OVERVIEW OF MOLECULAR COMPOUNDS

To date, the three most successful polymer compounds for modifying asphalt are styrene-butadiene-styrene (SBS), a rubber polymer compound; atactic-polypropylene (APP), a plastic polymer compound; and styrene-ethylene-butylene-styrene (SEBS), another rubber polymer compound.

In recent years, chemists also have successfully modified coal tar pitch using similar classes of polymers. The coal tar pitch is a mixture of aromatic or cyclic compounds. The basic building blocks of these aromatic compounds are ring-like molecular structures of six carbon atoms[2]. Specially formulated polymers can be blended to transform coal tar pitch. Even though only a fraction of the mixture is made of non-aromatic compounds, the effect is dramatic.

Asphalt is composed of aliphatic (fat-like) compounds, which have a string-like molecular structure, while coal tar pitch is composed of aromatic compounds, which have a ring-like molecular structure. Considering the very different molecular structures of coal tar pitch versus asphalt, it is remarkable that similar benefits can be obtained through polymer modification of either of these base materials.

The asphalt-based mixtures that are used to make the membranes for hot or cold application consist of a proper blend of SBS polymers and high-quality asphalt. The blends are manufactured into smooth or granulated membranes. Generally, the asphalt-blends are reinforced with fiberglass mat in the smooth membranes for strength and stability, and they are reinforced with a non-woven polyester mat in the granulated membranes for puncture resistance as well as tear resistance and flexibility. Reinforcements may vary, however, depending on the manufacturer and the application.

Both smooth and granulated membranes can be hot-applied, using SEBS-polymer modified asphalt or either Type III or IV asphalt. Or either of these membranes can be cold-applied using modified bituminous adhesive for the field of the roof, or mastic for flashing application.

The asphalt-based mixtures that are used to make membranes for heat welding are a blend of APP polymers and high-quality asphalt. These membranes are reinforced with a

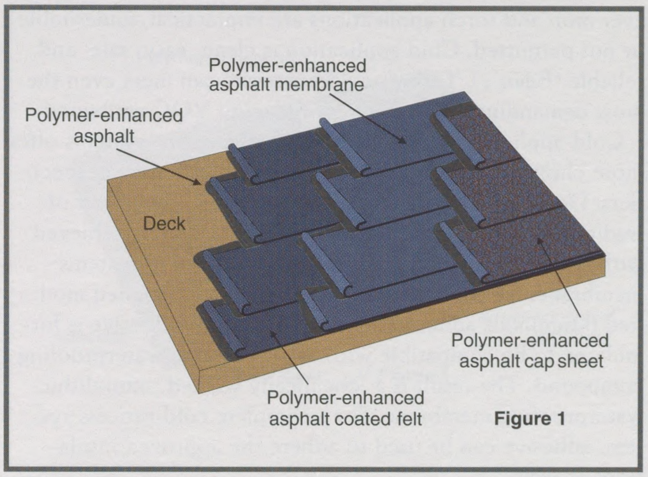


Figure 1

Hot-applied systems. *An MB system can be applied using traditional hot mop installation methods. In this case, the hot bitumen serves mainly as a bonding agent, but it also provides additional waterproofing. Although a hot-applied MB system may appear to be installed like a built-up roof, there is no need to use four or five layers. Typically, two or three plies provide sufficient strength and weatherproofing. A hot-applied MB membrane can have various surfaces, including smooth, granulated, or the conventional flood coat and gravel. Smooth and granular surfaced MB systems are lightweight, flexible, simple to apply, easy to inspect and to maintain.*

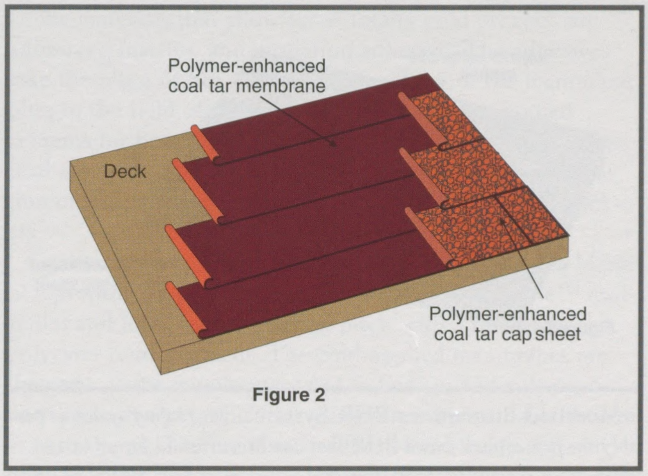


Figure 2

Heat Welded Systems. *An MB system can be applied by heat-fusing the membranes, which results in a monolithic waterproofing layer. This method is ideal for places that prohibit kettles. Logistics and economics are considerably simplified because installation is based on heat welding the membranes together. A two-ply torch system is fast and easy to install and suitable for slopes up to three inches per foot. A torch-applied system can have smooth or granulated surfacing.*

non-woven polyester mat for puncture resistance as well as tear resistance and flexibility.

Base sheets generally are reinforced with a strong fiberglass core. They can be mechanically attached or bonded to the substrate with a hot-applied bitumen or cold adhesive. Base sheets can be made with or without MB materials, particularly for the heat (torch) welded MB systems. The main purpose of the base sheets is to provide an acceptable substrate for the membranes.

Since there are so many ways to specify MB membranes, a designer can choose the application method (hot, cold or heat welding) that meets the needs of the project. *Figures 1-2* show examples of hot-applied roofing systems based on polymer-enhanced membranes. Note that both of these systems use fewer plies than traditional BUR systems.

In summary, MB combines the desirable waterproofing properties of asphalt or coal tar pitch with a strong, flexible membrane that is easy to install. MB systems typically consist of various combinations of smooth or granulated-surface membranes plus a standard or MB-coated base sheet, bonded together using hot bitumen, torch welding, or cold-applied adhesives.

MB IMPROVES BUR

Interest in MB systems is contributing to a renewal of interest in all bituminous roofing systems, including conventional BUR systems. The redundancy of the layers of a BUR system produces excellent performance that is not easily matched by other types of roofing systems. The longest-lived commercial roofing systems available today are based on the multiple-ply, built-up concept. In particular, asphalt BUR systems have long been recognized for their predictable performance and economic sense. Their availability and ease-of-use have won them a permanent place as an all-purpose system for commercial building designs.

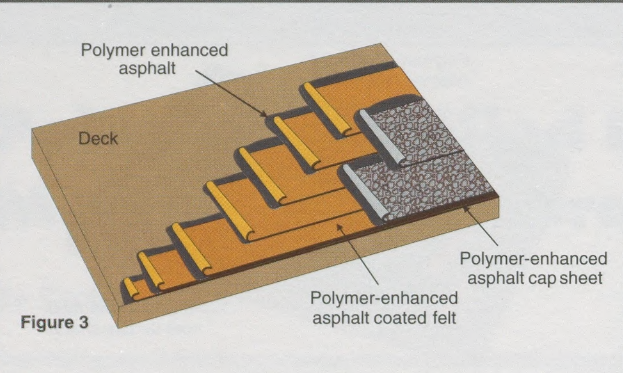
The success of any BUR system depends on all of its components working together. Ply felts provide tensile strength and flexibility as well as the foundation on which to "build-up" the waterproofing bitumen. The bitumen protects the reinforcement from deterioration. The two basic types of bitumen are coal tar pitch and asphalt. Coal tar pitch is especially well suited for low slope applications where ponded water is present, but asphalt roofing represents the overwhelming majority of higher-sloped BUR application.

The extensive use of asphaltic systems has contributed to incremental advances in technology. An important breakthrough in BUR technology was the introduction of glass fiber felt, which improved membrane strength.

The next natural step is the development of improved waterproofing compounds. Adding styrene-ethylene-butylene-styrene (SEBS) to premium grade asphalt uniquely alters the properties of roofing asphalt at the molecular level, so that the enhanced asphaltic BUR system shows a significant improvement in overall performance. SEBS polymer-modified asphalt increases the roof life and in-place performance of BUR systems.

SEBS polymer-modified asphalt is an elastomeric material with improved fatigue resistance and cohesive strength compared to conventional, non-polymerized asphalt bitumen. Its thermal stability, tensile strength and low temperature flexibility are superior to traditionally available products.

The flexibility of the bitumen at colder temperatures is a key factor in a membrane's ability to withstand the stresses



Modified Bituminous BUR System. *This roofing system is possibly the first asphalt-based BUR that can be warranted for up to 25 years. It's a composite assembly with a minimum of three plies of SEBS-polymer modified asphalt coated glass fiber felt set in SEBS-polymer modified asphalt. The capping component is a granulated membrane adhered in SEBS-polymer modified asphalt. This cap provides a lightweight surface with elongation, flexibility and puncture resistance. The overall assembly has the high tensile strength necessary to withstand stresses in both traditional and modern building designs, and the elastomeric properties required for movement.*

typically experienced in roofing applications. SEBS modified asphalt has a cold flex temperature at least 20 degrees Fahrenheit lower than that of a Type III (steep) asphalt.

The elongation of the bitumen is another important factor in the performance of a BUR system. The bitumen need only stretch as much as the reinforcement. Since fiberglass stretches less than five percent, a bitumen with 1000 percent elongation offers little advantage over one with 100 percent elongation. The quantity of SEBS polymer added to the asphalt is an important factor in determining elongation.

BUR systems using SEBS modified asphalt can be assembled using reinforcements coated with an SEBS modified compound that enhances bonding within the membrane assembly. The increased flexibility of the SEBS-modified coating improves ease of application at all temperatures. Moreover, the higher equiviscous temperature (EVT) of SEBS polymer-modified asphalt allows for proper bonding of the MB membrane. The resulting composite assembly is lightweight and easier to maintain than a traditional BUR.

Figure 3 shows a premium, modified asphalt BUR system in which the bitumen itself (the mopping asphalt) has been enhanced by SEBS-polymer modification. In this case, the bitumen functions as the membrane adhesive and provides waterproofing, flexibility, and elongation.

What is Cold Application?

The development and use of SBS polymer-modified adhesives and mastics have resulted in new cold-applied materials. Typically, a cold-applied process is one that can be performed at ambient temperatures, although the adhesive may need to be heated if the ambient temperature is below 50 degrees Fahrenheit. Cold application is recommended whenever mop and torch applications are impractical, undesirable, or not permitted. Cold application is clean, easy, safe, and reliable (*Figure 4*). Today's cold processes can meet even the most demanding regulations for reducing VOC emissions.

Cold-applied modified bituminous membrane systems offer more choices to the owners, contractors, and roofing specifiers. Depending on the configuration, the redundancy of traditional built-up roofing (BUR) systems can be achieved with a cold-applied process. In cold-applied MB systems, membranes are fused through the use of cold-applied modified bituminous adhesives and pressure. The adhesive is formulated to be compatible with the membrane waterproofing compound. The result is a "chemically welded" monolithic waterproofing membrane. For a complete cold-process system, adhesive can be used to adhere the approved insulations as well.

Cold-applied MB membranes and adhesives eliminate the need for kettles and open flames from the installation site. Worker comfort makes the cold (ambient temperature) process a preferred method among roofing contractors.

While there is still much room for improvement, current cold-applied processes address many concerns of modern building design, construction and management, such as the following.

Worker Comfort—A cold-applied process provides a better work place for roofers. It eliminates the use of hot kettles and flaming torches. The available work force and the comfort of workers are important factors to consider in choosing a roofing system. A longstanding goal of the roofing industry has been to improve worker comfort.

Logistics—Another goal of the roofing industry is to simplify the installation. The logistics of a roofing project are influenced by roof accessibility, labor availability, equipment availability, building occupancy, and the complexity of the flashing. The savings possible using a cold-applied process can be surprising. The issue of labor and equipment is especially important according to the size and accessibility of the area to be covered. Setup costs could

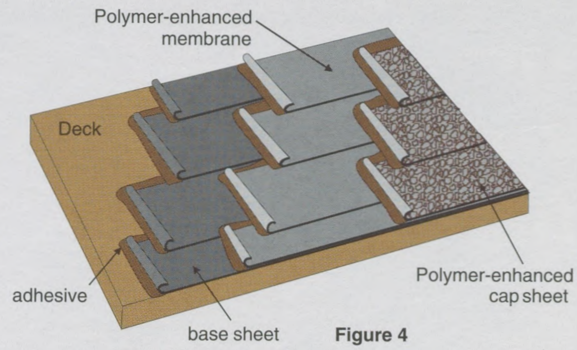
Why cold applied?

- Ideal for limited-access areas
- Clean application
- Kettles and torches not needed
- Membranes chemically welded
- Reduce installation errors

Coal tar-based cold-applied systems
- Retains elasticity through thermal extremes

Benefits of coal tar in a modified system
- Resists ponded water
- Apply on slopes up to one inch per foot

Asphalt-based cold-applied systems
- Retains elasticity through thermal shock and low temperatures
- Long-term performance in any climate
- Apply on slopes from 1/4 inch to 3 inches per foot



Cold applied system. *Cold application is recommended wherever mop and torch applications are impractical, undesirable, or not permitted. Cold application is clean, easy, safe, and reliable. Cold applied systems are available today for both polymer-enhanced asphalt membranes and polymer-enhanced coal tar membranes.*

make the overall cost much higher for a hot-applied roofing system than for a cold-applied system.

Quality Control—Cold-applied process can reduce installation errors. Blisters, voids, fishmouths, improper roll alignment and membrane slippage are common defects in traditionally-applied, built-up and modified bitumen membrane systems. These problems are usually the result of application errors, which can be reduced by using a cold-applied system.

Cold Application Reduces Installation Errors

Cold application can reduce installation errors because the modified adhesive is formulated to be compatible with modified bitumen compound. It provides a "chemical welding" of the membranes, resulting in a monolithic waterproofing membrane. This chemical welding eliminates blisters from improper application temperatures and minimizes the potential for voids and fishmouths in roll applications. With a cold process, the application timing is much less critical, thereby allowing for roll realignment during application if needed. Also, the modified bitumen compound (waterproofing) is applied to the reinforcement at the manufacturing facility under strict quality control procedures and not "on the roof." On site, there is no bitumen to overheat, which would lower the softening point (fallback), causing ply slippage and reducing weatherability of the system.

Putting Together a Cold-Applied System

Various cold-applied processes are available for forming watertight bonds between membranes in asphalt-based and coal tar-based systems. A key advantage of cold-applied membrane systems is the elastic recovery of the materials. Contemporary roof design requires that roof systems have exceptional elongation and fatigue-resistant properties.

The materials that allow for a "totally cold process" are adhesives, mastics, and insulation adhesive. The adhesives take the place of hot-mopping or torching of the membrane plies in the field of the roof. Mastics are heavy-bodied cements for bonding membrane plies in steep sloped or vertical applications. Mastics can also be used for the installation of flashings for roof drains, vent pipes and pitch pockets.

Coal tar based membranes for cold application are a blend of a proprietary polymer (i.e., AlliedSignal's Tardyne™ molecule) and high-quality coal tar pitch with a fiberglass or polyester reinforcement. The cold-applied membranes are the same as the membranes used in hot-applied systems. Both smooth and granulated membranes are available as well as base sheets. The membrane adhesive is a coal tar-based polymer-modified adhesive formulated to fuse coal tar-based, polymer-modified membranes together. Polymer modification assures the strength and flexibility needed for long-term performance and low maintenance. The roof mastic is a coal tar-based, polymer-modified cement.

Asphalt-based membranes for cold application are a blend of SBS polymer and high-quality asphalt with a fiberglass or polyester reinforcement. They are the same membranes used in hot-applied systems. Products include the smooth and granulated membranes. Modified bituminous adhesives are a blend of refined asphalts, tactifying resins, SBS polymers and selected solvents. This blend cures to a rubberized adhesive. The polymeric fortification resists bond failures caused by thermal shock and movement. Modified bituminous mastic is an SBS polymer-fortified, high-strength asphalt mastic for use with membranes and flashing systems. It resists bond failures caused by thermal shock and movement.

Cold-Applied Insulation

An insulation adhesive is typically a single-component, 100 percent solid, highly elastomeric, urethane adhesive that requires no special tools or application techniques. This insulation adhesive is designed for bonding approved roof insulations to a building's structural roof deck, base sheets, other insulation boards and smooth, built-up roof (non-graveled) surfaces for approved recover applications.

Insulation adhesive eliminates the need for hot bitumen to adhere insulation. It also eliminates the need for mechanical fasteners, which can cause damage to the roof deck and may reduce the service life of the roof.

An important advantage of cold-applied insulation adhesives is that they eliminate the need for fasteners, so there is no damage to structural decking, no fastener back-out, no noise associated with fastener installation, no fasteners through exposed decks, and no fastener corrosion. Also, the required labor is less for insulation adhesive compared to fasteners.

The one-part adhesive is easy to apply. No mixing is required. Since it is an elastomeric compound, it remains flexible and absorbs stresses. Because no solvents are required, the installation is characterized by low odors and VOC compliance. It is a 100 percent solids process.

Highly effective cold-applied processes are now available but there is room for incremental improvements in cold applied processes. The search is on for faster curing times, because errors can occur when long periods are required for complete chemical welding. The use of hot blown air to speed up curing times is being investigated. Also, new test methods and standards are sought for comparing related products, in terms of ease of installation, environmental friendliness and performance.

Continued innovation has allowed manufacturers to develop and introduce whole new families of modified bituminous products, manufactured to high standards of quality.

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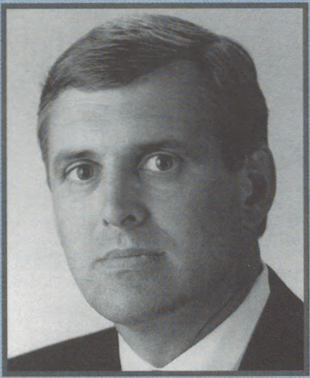

Steve Ratcliff

***Steve Ratcliff** joined AlliedSignal in 1976, and made his way up to general manager of the newly-formed Commercial Roofing Systems business unit in 1989. Ratcliff was graduated with an M.B.A. in marketing and finance from the University of Central Arkansas, as well as a B.S.B.A. in Marketing and Accounting from Hendrickson State University, Arkadelphia, Arkansas. He is currently enrolled in the M.B.A. program at the Fuqua School of Business at Duke University. Steve lives in Cary, NC with his wife and two children and is an Industry member of RCI.*

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