DEVELOPMENTS IN BUILT-UP ROOFING 1978-1988

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There have been substantial evolutionary developments in the field of built-up roofing in the United States during the past ten years. "Revolutionary" developments are few and far between for as venerable a roofing system as the built-up roof, but some recent developments in reinforcement materials and polymer modification of asphalt for built-up roofing membranes may border on the revolutionary. While some have prognosticated the demise of the built-up roof, the concept of built-up roofing has remained amazingly resilient given the onslaught of sheet membrane systems and polymer modified bituminous membrane systems. Advancements in bitumen and built-up roofing system technology in the United States have been generally low-key, relatively unpublicized and overshadowed by development of a number of alternative roofing systems. There have been great strides made in understanding built-up bituminous roofing "systems" in recent years, which should be encouraging for those still seeking answers to roofing/waterproofing problems.

The built-up roof was generally not well understood until initiation of testing and evaluation programs, which evolved during the 1960s. Prior to that time, the built-up roofing membrane was the only type of waterproofing membrane generally available for low-sloped roofs, and it was acknowledged that the system generally "worked." Severe problems with built-up roofing membranes constructed with some types of glass fiber mats and coated organic felt plysheets in the 1960s prompted research programs by manufacturers, contractors associations, federal and private agencies intended to provide a better understanding of the mechanics of built-up roofing systems. In retrospect, the major problems besetting the built-up roofing membranes installed during that era were primarily attributable to minimizing adhesive quantities between steel roof decks and roof insulation to minimize fire damage; eliminating "plies" for economic reasons; water cooling of asphalt coated organic base and ply sheets at the time of manufacture, resulting in absorption of moisture by the organic fibers; the inclusion of asphalt coated organic sheets (with no provision for release of moisture vapor during the time of application) in the common built-up roofing membrane specification; and a general lack of understanding by the roofing mechanic of new materials and systems. Studies evaluating the thermal contraction characteristics of built-up bituminous membranes, blistering phenomena (interply and membrane/substrate) and the effects of various roof insulations on built-up roofing membrane performance resulted in better understanding of the physical properties of bituminous membranes and of the effects of "other" forces and phenomena which affected membrane performance. Developments in the past ten years have primarily been building on prior knowledge acquired during that period of extensive testing and evaluation.

Probably the most dramatic change in the built-up roofing membrane has been the transition from organic and asbestos reinforcing felts to glass fiber mat reinforcements. In 1987, Project Pinpoint (an information gathering program maintained by the National Roofing Contractors Association) indicated that 92 percent of all built-up roofing membranes reported to the program were constructed with glass fiber reinforcing mats, 5 percent were constructed using organic felts and 3 percent were constructed using polyester reinforcing materials (woven or nonwoven). In 1977, the information from Project Pinpoint indicated that approximately 55 percent of built-up roofing membranes were constructed using organic felts, 24 percent using asbestos felts and 11 percent using glass fiber mats (the balance showing only as "other"). Although there are a number of contributing reasons for the change, the primary reason for the change revolved around the generally good performance of built-up roofing membranes constructed with the latest generation of glass fiber base and ply sheets.

Glass fiber reinforcements were certainly not new to the built-up roofing business in 1977. Glass fiber reinforced built-up roofing membranes had been in general use on the Pacific coast since the early 1950s. But the overall lackluster performance of marginal "systems"—and in some instances marginal materials—in the more harsh central United States environment resulted in retrenchment of the glass fiber reinforced built-up roofing membranes from the eastern market until salient answers became available during the 1960s period of testing and evaluation. Glass fiber roofing material and systems promoted in the early 1970s exhibited substantial improvements in service characteristics of glass fiber reinforced built-up roofing membranes and precipitated an industry change during the 1970s. By the end of that decade, virtually every major supplier of built-up roofing systems offered a glass fiber reinforced built-up roofing membrane.

Recommended built-up roofing membrane physical property (preliminary) criteria were published by the National Bureau of Standards in Building Science Series 55 in 1974, setting the stage for general acceptance of the Type IV glass fiber felts listed in ASTM Specification D2178 and the 200-pounds-per-inch minimum recommended tensile strength for built-up roofing membranes at 0 F in the cross machine direction. Most glass fiber reinforced built-up roofing membranes available over the past ten years have been specified and constructed to meet these criteria, and for the most part, built-up roofing membranes constructed in accordance with these criteria have been satisfactory performers.

There have been significant changes and developments in the evaluation of asphalts used in roofing materials in the past decade. Chemical analytical techniques developed principally for identification and analysis of various types of crude oils have been helpful in evaluating crude sources for consistency, weatherability and their potential compatibility for polymer modification. The past decade has seen the introduction of polymer modified asphalts for use in built-up roofing membranes, as well as the development of catalyzed asphalts that have relatively high softening points when cool, but acceptable viscosity (EVT) at the point of application at lower application temperatures, thus improving the adhesive properties of the asphalt during normal application. These specialty asphalts must be heated and handled differently from air blown asphalts to eliminate separation of the polymer modifiers and minimize heat affectation on softening point temperatures.

The original concept of equiviscous temperature (EVT) was introduced in late 1977, as the result of a study conducted by the National Bureau of Standards (now NIST). The concept was further modified in 1988 following extensive controlled and field testing of asphalts used in construction of built-up roofing membranes. Prior to the time of the EVT concept, heating temperatures of asphalt were restricted by arbitrary "maximum" temperatures at kettles/tankers established by specifiers to eliminate "fallback" of softening point temperatures in roofing asphalts. The arbitrary "maximums" varied greatly, caused much confusion for contractors, architects and owners and resulted in many built-up roofing membranes being constructed with asphalt temperatures so low that adhesion of the asphalt to the reinforcing plies was inadequate to assure roof membrane integrity (especially with heavy, coated organic felts). It was determined that adhesive characteristics of thermoplastic bitumens were directly related to their viscosity at the point of application. It also was determined that viscosity of waterproofing bitumens could be better assessed in the field if the viscosity were related to temperature at the point of application. The concept of equiviscous temperature was the result of identifying the optimum viscosity of bitumens at the point of application and relating that viscosity to the temperature of the bitumen at the point of application. The EVT concept set the guidelines for maximum bitumen temperature at the heating device below the flash point temperature, and the minimum acceptable application temperature at 25 degrees below the EVT at the point of application, the recommended range being EVT ± 25 degrees F. The concept allowed a "window" of application temperatures which were much better guidelines than "maximum" kettle temperatures. The result of the EVT concept has been roofing membranes with better homogeneity because of more positive adhesion of the bitumen to the reinforcements used in the built-up roofing membrane.

The original concept of EVT was applicable only to asphalts, since coal tar pitches were not included in the original EVT work. In 1987, joint testing by the National Roofing Contractors Association and the Koppers Co. resulted in development of equiviscous temperature recommendations for coal tar waterproofing bitumens. A follow-up joint testing program by the National Roofing Contractors Association and the Trumbull Asphalt division of Owens-Corning Fiberglas Corp. resulted in new recommendations for EVT and roofing asphalts. By testing under controlled environmental conditions and subsequent field testing of asphalt applications, it was determined that the original recommendations for viscosity of asphalts at the point of application were too high to assure workability of asphalts from various types of application devices. The original EVT viscosity recommendation was 125 centipoise; the modified recommendations are for 75 centipoise, equating to an approximate increase in recommended EVT (at the point of application) of 25 to 40 degrees F depending on the asphalt. Higher temperatures at the point of application equate to higher temperatures at the heating device, and it is clear that some of the asphalts produced today may not fare well given the higher recommended temperatures. However, the technology is available to produce asphalts which will allow construction of built-up roofing membranes in accordance with the recommended increases in application temperature and without sacrificing waterproofing or weathering characteristics. The end result of this understanding is built-up roofing membranes, which perform better.

The last decade has seen the introduction of "economy" glass fiber felts and a move toward upgrading existing reinforcing material to "premium" glass fiber felts. There are indications that ASTM Specification D2178 may be modified to include a Type VI glass fiber felt reflecting development of "premium" grade ply sheets with higher tensile properties. The glass fiber reinforcements in use for the past decade have been proven performers, producing a dramatic reduction in split-related roofing problems. There is no "free lunch" in the roofing business, and manufacturing glass fiber mats with less glass fiber or less expensive binders has the potential to result in marginal roof membrane performance and another performance-related setback for the built-up roof. The ground of marginal materials and marginal specifications has been plowed in years past with less than satisfactory results. If the market dictates "economy" class roofs, then the market should not expect "first class" roof performance and it should be incumbent on the manufacturers of such materials to make such facts known to the consumer.

The move to upgrade already satisfactorily performing reinforcing materials to "premium" class is a cause for wonder. It is not clear why this direction is being taken by reinforcement manufacturers. Additional tensile strength of the individual plysheets probably will not result in any significantly better in-place performance of the completed built-up roofing membrane, while the additional glass fiber and asphalt contents of the "premium" plysheets may result in less than optimum installation and handling characteristics. Heavier sheets tend to be more difficult to install in cold weather; they are more "closed" with asphalt and fillers, making the finished membrane more sensitive to water in or on the felts and therefore more susceptible to interply blistering; and heavy glass fiber plysheets are more likely to be "boardy" and bridge even minor substrate irregularities, resulting in voids or unsupported areas in the finished roofing membrane. The move to Type VI felts may result in the current Type IV felts being manufactured to "minimum" properties stipulated in ASTM D2178, with the inherent risk that some of the manufactured material probably will be well below the minimum standards.

Significant advancements have been made in the use of non-woven polyester mats in hot applied built-up roofing membranes in the past few years. Development of "heat resistant" polyester mats has allowed use of polyester materials at normal thermoplastic bituminous application temperatures, and other types of polyester mats have been effectively used in cold-applied built-up roofing membrane applications. The newly recommended EVT guidelines may affect some of the more marginal nonwoven polyester materials in that the asphalt applied at the new EVT may result in shrinkage of the marginally heat sensitive materials. Each supplier of nonwoven polyester mats must evaluate the physical characteristics of individual materials to determine whether or not the mats can be effectively installed at elevated temperatures. Studies by the National Bureau of Standards on polyester reinforced built-up roofing membranes suggested that these type membranes probably should be evaluated by criteria different from glass fiber reinforced built-up roofing membranes. These studies also suggested that load-strain properties of such membranes may be the best method of performance evaluation, given the superior flexure and elongation characteristics of membranes reinforced with polyester mats. Polyester mats are relatively expensive, and the temptation by suppliers is to eliminate plies in the finished roofing membrane to make the system "competitive" in the market. Even though laboratory prepared samples constructed with two plies of reinforcement may possess sufficient physical properties to indicate good field performance, experience dictates that two-ply built-up roofing membranes constructed from any type material probably do not have enough "safety-factor" to be forgiving of common field application techniques (although additional plies in the built-up roofing membrane will not necessarily compensate for all deficiencies in application). Roofing membranes constructed using three plies of polyester reinforcing material with sufficient tensile properties to restrain the waterproofing bitumen during periods of thermal contraction will probably be admirable, but relatively expensive, performers. Polyester reinforcements were used in approximately 3 percent of the total Project Pinpoint built-up roof reports.

Some manufacturers have developed thermoplastic polymer modified asphalt which can be heated and applied similar to common blown asphalt. Polymer modified asphalts typically have better elongation characteristics than blown asphalts, and when combined with nonwoven polyester reinforcements form a waterproofing membrane with good elongation and flexural properties. Polymer modified mopping asphalts have been used to a limited extent for several years in the roofing industry with varying degrees of success. When heated in typical roofing kettles with internal flues, there has been a tendency for the polymers to degrade and separate from the bitumen and bond to the flues at elevated temperatures. To compensate for the potential degradation and separation of modifiers, all manufacturers of polymer modified thermoplastic asphalt recommend that the material be heated in double-jacket or oil-bath heating devices to eliminate the area of concentrated heat on flue surfaces. Modified blends of polymer modified asphalts have proven to be better in terms of remaining homogeneous during the heating cycle. The polymer modified asphalts are substantially more expensive than blown asphalts and will probably be confined to use in specialized, relatively expensive built-up roofing membranes for the foreseeable future.

Although commonly categorized as "single-ply" roofing membranes, the multi-layer polymer modified bituminous roofing membranes fit more into the category of bituminous built-up roofing membranes. The general recommendations for inclusion of a base sheet in torch-applied systems and the use of glass fiber or polymer modified base plies with mop-down polymer modified bituminous membrane systems much more closely resemble the construction of a bituminous built-up roofing membrane than the application of a "single-ply" roofing membrane. Combinations of polymer modified asphalt sheets reinforced with glass fibers or polyester fibers and conventional built-up roofing reinforcing material set into polymer modified thermoplastic asphalt may well constitute a common built-up roofing specification in the 1990s.

Glass fiber base sheets have almost entirely replaced coated organic base sheets in the roofing market in the past decade, and the use of base sheets in typical insulated roofing membrane specifications is essentially nonexistent at the present time. Base sheets, standard or venting type, are typically included in "nailable" type roofing membrane specifications for use over wood or lightweight insulating deck materials, primarily to provide positive separation of the roofing membrane from the substrate and to eliminate bleed-through of bitumens to the roof deck.

The removal of asbestos flashing materials from the United States roofing market in the last decade left the U.S. roofing industry at a loss for an acceptable membrane flashing material. Reinforced base flashing sheets were modified to include glass fiber mats of several different configurations, but none of the materials handled or weathered comparably to the reinforced asbestos flashing system. Fortunately, the polymer modified bituminous membranes introduced to the United States just prior to the time asbestos materials were generally withdrawn from the market proved to be acceptable substitute flashing membranes. There was a difficult period in the learning curve while manufacturers and contractors experimented with materials and methods for installing membrane base flashings. At the present time, polymer modified bituminous membranes are approved for use for membrane flashing by virtually all major suppliers of built-up roofing materials.

There is very little difference in the nature of problems presently being reported with built-up roofing membranes in Project Pinpoint from problems reported at the beginning of the decade. Splitting, blistering and ridging of built-up roofing membranes continue to be major sources of problems, accounting for an aggregate 60 percent of the total reported problems in 1987. In 1977, the same type problems accounted for 96 percent of all reported problems. Since the reporting format has been changed several times since 1977, there may be some variation in the total numbers, but performance properties of built-up roofing membranes obviously have improved in the past decade.

COMMON REPORTED BUR PROBLEMS

	1977	**1987**
Wind Damage	0%	2%
Slippage	0%	5%
Ridging	7%	15%
Splitting	40%	22%
Blistering	47%	23%

At the present time there is no way to determine the relation of glass fiber felts to organic and asbestos felts, given the aggregate information on types of problems. It is probably safe to assume that a fair percentage of the ridging and blistering problems reported in 1987 still relate to organic felt reinforced built-up roofing membranes, since these phenomena apparently occur less frequently in glass fiber reinforced built-up roofing membranes. The substantial reduction in split-related problems appear to be corollary to the use of glass fiber reinforcements and membrane specifications with adequate tensile properties to minimize membrane splitting problems.

Probably the most significant move by the industry to minimize problems with built-up roofing systems installed over steel roof decks came in early 1983, with the recommendation of the Factory Mutual System to mechanically secure all roof insulation, a major departure from previous recommendations restricting adhesive quantities used to bond roof insulation to steel deck surfaces. The current recommendations are for 100 percent mechanical attachment of any roof insulation installed over steel roof decks with fastener type, quantity and spacing clearly delineated by the Factory Mutual System. These recommendations have had a substantial impact on the performance of built-up roofing membranes installed over steel roof decks (which account for approximately 50 percent of all installations), assuring positive attachment of the roofing assembly both during and after the time of installation and minimizing roof contraction-related problems.

Educational programs in the application of built-up roofing (and other type) membranes, conducted by the roofing contractors associations and the industry-supported Roofing Industry Educational Institute over the past decade, have increased the knowledge level of the average industry participant. Such programs have created an awareness of application- and material-related problems in built-up roofing and the promulgation of methods to insure satisfactory performance of the completed system.

Indications from Project Pinpoint in 1987 are that the built-up roofing systems were regaining market share at the expense of rubber and polymer modified bituminous roofing membrane systems. In 1986, built-up roofing membranes accounted for 39 percent of the total reported roofing membrane systems. In 1987, BUR accounted for 45 percent of the total reported roofing membrane systems, indicating that a sizable share of the consumers for roofing products are apparently satisfied with the performance of the current breed of built-up roofing system.

There is definitely a future for the built-up roofing membrane, although the configuration of waterproofing bitumen and reinforcing material will probably change based on present and anticipated technology for thermoplastic bitumens and advanced composite reinforcements. Glass fiber mats are the most cost-effective reinforcements for the conventional built-up roofing membrane at the present time, but laminating technology for reinforcing materials and various methods of modifying waterproofing bitumens may lead the built-up roofing industry to combinations of materials which will outperform present bituminous roofing membranes in even more adverse service conditions. The development of catalyzed and/or polymer modified asphalts will bring new dimensions and consistency to the capabilities of waterproofing bitumens, and advanced, composite reinforcing materials will probably be designed to compliment the improved weathering and extensibility characteristics of modified waterproofing bitumens.