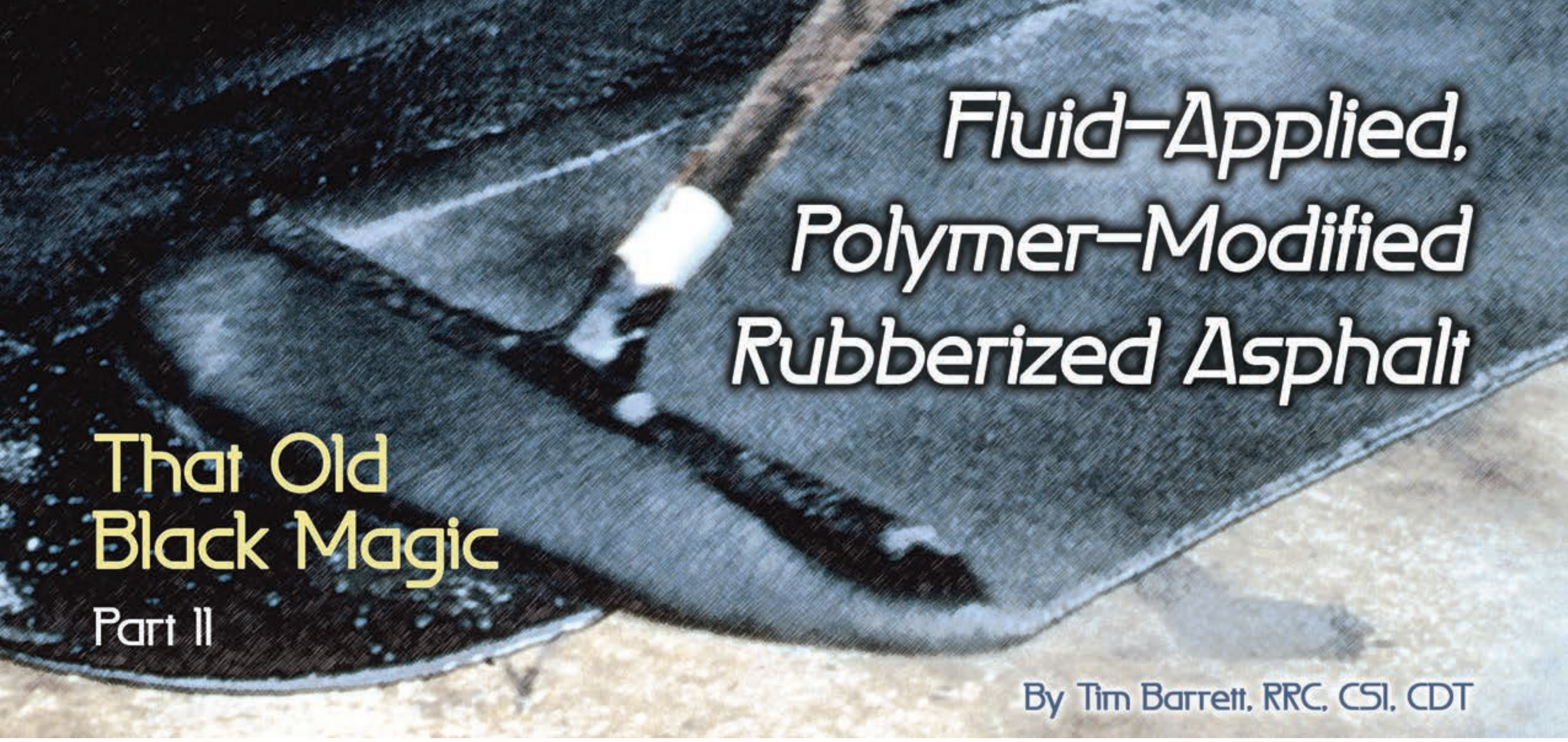

Fluid-Applied, Polymer-Modified Rubberized Asphalt

That Old Black Magic

Part II

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HISTORY

Commonly referred to as "hot rubberized asphalt," fluid-applied, polymer-modified asphalt bitumen is also known by a number of monikers, including fluid-applied, hot-melt waterproofing; fluid-applied, monolithic membrane; rubberized asphalt membrane; and different combinations of these descriptive words, as well as various acronyms.

The two primary components of early polymer-modified rubberized asphalt—unoxidized asphalt flux and styrene butadiene rubber (SBR, a synthetic rubber)—were considered to be incompatible with each other prior to innovative molecular engineering by a number of early pioneers. When asphalt flux and synthetic rubber are put in intimate contact, the light ends of the asphalt flux molecularly migrate into the rubber, causing it to swell and disfigure to a large, variable multitude of its original size, a classic incompatible response, as the minor constituent—rubber—becomes the major constituent of the mix.

The first usable rubberized asphalt material was developed in the early 1950s and reported as such in "Highway Research Report No. 25," published by the University of Michigan in 1955, with a second paper published in 1957. The next generation of rubber polymer, styrene butadiene styrene (SBS), was invented in the U.S. in the late 1960s at Shell's West Hollow Research Center in Texas. Nevertheless, most development and material engineering refinements were made in Europe by, among others, Shell's French subsidiary, Shell France Bitumen Corp., starting around 1972.

As product development continued in the 1950s, chemical engineers learned how to use high-shear mixers in such a manner that the absorption and expansion of the rubber component molecules could be engineered and controlled, resulting in an end product that was a stable, rubber-like, elastomeric-thermoplastic asphaltic material. At that time, the chemical engineers imagined an unlimited number of applications in highway construction—the 800-pound gorilla of asphalt consumption that it still is today. Subsequently, their vision grew to include roofing, and their primary focus became preformed SBS sheet roofing. SBS modified-bitumen sheet roofing was introduced into both the American and Canadian markets around 1977. Fluid-applied waterproofing incorporating SBS was not given much thought at that time.

Photo 1 – Fluid material withdrawn from double-jacketed melter.

Photo 2 – Fluid material being spread with a squeegee.

Backtracking a bit, sometime around 1963, Uniroyal Ltd. (then the Canadian subsidiary of Uniroyal, Inc.) started to use an SBR-asphalt compound experimentally on some of its own roofs. After a few years of observation, Uniroyal Ltd. started marketing the material in Canada as a fluid-applied waterproofing material suitable for roofing.

One of the unique properties of rubberized asphalt is the amazing cold-temperature flexibility of the material, typically -20°F (-29°C) and even lower, when compared with oxidized roofing asphalt, which commonly has a glass transition temperature of 38° to 40°F (3 to 4°C).

Not surprisingly, the hot-rubberized market found reasonable acceptance in the cold Canadian climates. Uniroyal Canada, Ltd. soon had competition from Flintkote of Canada. By the 1970s, there were at least five more significant suppliers of rubberized asphalt in Canada: Bakelite Thermoset; Bitumar; PennKote Ltd.; Tremco Canada, Ltd.; and Koch Materials Co. At least three of the companies (most noticeably, Uniroyal, Ltd.) also sold nominal amounts of rubberized asphalt material in the U.S. market.

Rubberized asphalt did not start to develop any significant market share or market acceptance in the U.S. until the late 1970s. By the early 1980s, there were four notable rubberized asphalt suppliers in the U.S. market, enjoying a nominal but expanding market share of the commercial roofing and waterproofing industry, with most of the rubberized asphalt being imported from Canadian blending plants.

Today there are 12 suppliers of rubberized asphalt in the American market and several more serving the Canadian market. More than half of the polymer-modified rubberized asphalt used in the U.S. today is still imported from Canada. The value of the increased competition to the industry stakeholders is debatable but certainly follows the pattern of a normal product life cycle and the basic laws of economics.

AN ENGINEERED MATERIAL

The chemical makeup of polymer-modified rubberized asphalt can vary significantly from producer to producer. The variables include:

- The compatibility of the raw, unoxidized asphalt flux with the polymerization process
- The specific polymer used
- The amount of polymer used
- The type and amount of filler material (if any)
- Any other additives employed to impart particular properties or characteristics

It is widely estimated that only 50-60% of all asphalt flux is compatible with the polymerization process; and within the compatible fluxes, the degree of compatibility ranges from slightly compatible "harder" asphalts to highly compatible "softer" asphalts. The highly compatible asphalts constitute about 10% of all asphalt and tend to be more expensive, originating from "sweet crude" petroleum.

Only one producer is known to have used oxidized "blown" ASTM D312–type roofing asphalt to make a rubberized asphalt. The roofing asphalt oxidiz-

Photos 3A-3C — Installing and overcoating polyester reinforcement.

ing process is essentially accelerated aging of asphalt flux for roofing applications by raising its softening point with steam and heat so it does not flow off roofs as raw asphalt flux would. Using unblown asphalt flux to make rubberized asphalt theoretically provides a longer lifespan for the material and, compared with oxidized roofing asphalt flux, is significantly more compatible with the polymerization process.

The polymer component is at least equally as important as the flux compatibility. In the early days of rubberized asphalt, there was SBR, the first synthetic rubber polymer derived from crude oil. SBR is an engineered chain of molecules that can be manipulated in many different configurations that impart different properties. When the polymer is mixed in sufficient quantity with compatible asphalt flux in a high-shear mixer, a polymerized rubber network is created. During the process, the rubber polymer components absorb the light ends of the asphalt, swelling or expanding in volume by more than 800% and creating the polymerized network of rubberized bitumen. The overall volume of the composite material does not change; but in absorbing the light fractions of the asphalt, the minor constituent rubber polymer becomes the major constituent with a phase change. Under a microscope, a cross section of this material would resemble a sponge, with the sponge's air spaces filled with asphaltic fractions and the structure of the sponge represented by the tumescent rubber polymer network that has swelled up after absorbing the light ends. A simple visualization example would be imagining 10% polymer mixed with 90% bitumen, resulting in a 80-90% rubber network with 10-20% bitumen infill.

As previously mentioned, in the early 1970s, Shell Oil's Kraton® Group introduced SBS polymer to Shell France Bitumen Corp., which, in turn,

Photo 4 – Column detailing.

Photo 5 – Completed view of column detailing at Soldier Field.

working with the European roofing industry, produced an entirely new class of roofing materials: SBS “mod-bit” sheet roll roofing. Subsequently, most manufacturers of rubberized asphalt roll roofing slowly replaced SBR polymer with SBS. Rather than offering the SBR “chain” of styrene-butadiene rubber configurations, SBS provides a block formation of styrene-butadiene-styrene molecules that can also be engineered and manipulated into a wider variety of different configurations than SBR. The new SBS polymer material offered greater strength, improved elastomeric properties, and easier material compounding to reach a polymer phase than SBR. Not surprisingly, SBS also came with some increased polymer costs.

Shell’s Kraton® Group also introduced styrene ethylene butylene styrene (SEBS) in the late ’70s, billing it as the next generation of rubber polymer suitable for mixing with asphalt. The product provided greater resistance to manufacturing-process heat damage and also offered high resistance to ultraviolet degradation, two areas to which SBS is less resistant. Given the significantly higher cost of the SEBS polymer (about three times as much as SBS), it never found its way into the rubberized asphalt market. It has, however, developed a niche market as an upgraded polymer-modified mopping bitumen in elastomeric built-up systems and as an SBS-modified-bitumen sheet adhesive providing 100% modified membrane assemblies. Possibly incompatible oxidized Type-III asphalt—a condition that can be problematic in the top ply of a multi-ply system due to its difference in performance at varying temperatures—is thus eliminated from such assemblies.

Worth noting is another recent market digression by one manufacturer of rubberized asphalt: the elimination of all polymers from its product, replacing them with cryogenically ground crumb rubber derived from automobile tires. This concept is ecologically very beneficial. The cryogenic crumb imparts a number of desirable rubberlike properties; however, there is no polymerization or a cross-linking polymer network—only swollen rubber particulates suspended in asphalt. Within the industry, this type of product is referred to as “asphalt-rubber,” as distinguished from (polymer-modified) rubberized asphalt. The loss of the polymer network really makes it an entirely different material from a polymer-modified rubberized asphalt, and it is a material that does not come close to meeting CAN/CGSB-37.51-M90 specifications, the only recognized standard of quality for polymer-modified rubberized asphalt as cited in ASTM D6622. “Asphalt-rubber” has found wide acceptance as a low-cost highway crack sealant; however, it has not been used very much for waterproofing or roofing.

After considering rubberized asphalt’s two primary components of bitumen and polymer, the next element in rubberized asphalt is filler materials. It seems each supplier has its own ideas of the best mix of filler material. At least one uses clay, several use calcium carbonate or crushed limestone rock, several use talc and slag, at least one uses black marble dust, one uses slate dust, many use recycled tire crumb rubber as a second filler material, and at least one doesn’t use any filler at all.

The primary technical value of filler material in rubberized asphalt is that it increases rubberized asphalt’s viscosity, resulting in a thickness build during application that is not obtained without the filler. The thicker viscosity results in thicker buildup of membrane during application, which results in superior crack-bridging and self-healing properties, increasing the abuse resistance of the membrane to mechanical damage and construction

Photo 6 – Installing protection course.

activity. Fillers can also improve uniformity, reduce flow characteristics, and some can even impart additional strength to the material. The ecological benefit of using tire crumb as a second filler is self-evident. Not as evident is the fact that the right size of crumb rubber can act as little "ball bearings," helping to regulate application thickness. Since most fillers are inert and the filler particulates are coated with the rubberized asphalt during the mixing process, the net difference between one inert filler and another is not considered significant. Also, fillers cost less than asphalt flux and a lot less than polymer. The value of not using any filler (all other things being equal) is that the rubberized asphalt material has increased tensile strength and increased cohesive strength, and it will be installed in thinner layers, which may be desirable in certain applications.

While these two to four components are blended with the high-shear mixer, there are a number of proprietary additives that can be employed to compensate for lower asphalt-flux compatibility, change the finished material's surface tension, increase the material's adhesion, make the material harder or softer, change softening points, increase fire resistance, and other modifications that might be desired or dictated by quality assurance (QA) testing before packaging.

Most manufacturers will have a battery of quality control tests run on the raw-asphalt flux coming into their plants, as well as testing of the completed mixed material in on-site labs before the material is packaged. In the event the material mix does not meet specifications, it can often be modified with additives right in the mixer to obtain compliance with the producer's specifications, which are generally represented as meeting CAN/CGSB-37.51-M90 specifications.

Amazingly, over the last 30 years, neither ASTM C24, Committee on Building Seals and Sealants; nor ASTM D-08, Committee on Roofing and Waterproofing, has been able to develop a consensus standard for fluid-applied polymer-modified rubberized asphalt, leaving CAN/CGSB-37.51-M90 as a default standard for minimum levels of performance for fluid-applied polymer-modified rubberized asphalt. The CAN/CGSB standard is cited as such in ASTM D6622, *Standard Guide for Application of Fully Adhered Hot-Applied Reinforced Waterproofing Systems.*

Photo 7 – Installing rubberized asphalt wall flashings (McCormick Convention Center, Chicago).

CAN/CGSB-37-GP-51M was first published in 1979 and superseded in 1990 by CAN/CGSB 37.51-M90 by the Canadian General Standards Board. The standard set minimal-performance standards for rubberized asphalt currently include:

- Flashpoint – ASTM D92
- Penetration (cone) – ASTM D1191 or D3407 test procedure
- Flow – ASTM D1191 or D3407 test procedure

Photo 8 – Typical plaza assembly: pavers, pedestals, XPS, protection course, and rubberized asphalt.

- Toughness – CGSB procedure
- Ratio of toughness to peak load – CGSB procedure
- Adhesion rating CGSB procedure
- Water vapor permeance – ASTM E96 (Procedure E)
- Water absorption – CGSB procedure
- Pinholing – CGSB procedure
- Low-temperature flexibility – CGSB procedure
- Crack bridging capability – CGSB procedure
- Heat stability – CGSB procedure
- Viscosity test – CGSB procedure

Only a limited number of laboratories have the capability to run the full battery of CAN/CGSB- 37-GP-51M tests, generally at a cost of $10,000 to $15,000. Unfortunately, somewhere between very few and no jobsite samples are actually tested for complete specification compliance.

UTILIZATION

The initial adoption of polymer-modified rubberized asphalt by the Canadian market was slowly followed in the U.S. by several large, innovative architectural firms such as Skidmore-Owings and Merrill, I.M. Pei and Partners, Philip Johnson, Charles Luckman Associates, Gwathmey-Siegel, Perkins and Will, HOK, Michael Graves, WDG, TAC, and similarly noted "starchitects," usually specifying rubberized-asphalt systems in inverted or protected membrane assemblies on monumental projects and significant architecture. Almost consistently, these projects had structural concrete decks, including roof decks, plaza decks, parking decks, bridge decks, mud slabs, and tunnels. A small percentage of applications were on wood decks, and practically no applications were made over steel decks until the advent of the Type-X, moisture-resistant gypsum and concrete underlayment boards. Roof insulation boards remain universally considered as inappropriate substrates for polymer-modified rubberized asphalt due to the low compressive and cohesive strength and dimensional instability of most boards. Lightweight insulating concrete decks are also universally considered as inappropriate substrates.

Early applications of fluid-applied rubberized asphalt were generally unreinforced, single-pass applications of rubberized asphalt with a 180-mil-average thickness specified. Flashings were usually a composite butyl-EPDM sheet set in rubberized asphalt, butyl side down. Today, most flashings are 60-mil-thick, uncured neoprene

Photo 9 – Completed Prudential Plaza, Chicago, 1986.

sheet or reinforced SBS modified-bitumen sheet set with either cold bonding adhesive or rubberized asphalt, with one supplier recommending torched-on modified-bitumen sheet.

The early attraction to rubberized asphalt by the elite of the U.S. architectural community was due to perceptions of ease of installation, self-healing and self-flashing characteristics, elimination of moisture migration below the membrane, conformability to irregular substrate conditions, extra thickness compared to other waterproofing materials, limited approved applicator network, wintertime subfreezing application, no cure time, and thermoplastic characteristics, among other features. The benefits of all these perceived features were supported by the continual process of successful installations with few leak complaints and near-zero systemic failures.

WORKMANSHIP—THE FORGOTTEN ELEMENT

As previously mentioned, one of the factors in rubberized asphalt's earlier success was the limited network of installers. The old adage, "The problem with roofing contractors is 80% of them give the other 20% a bad name," is probably more true than false, and the early network of rubberized asphalt installers was mostly drawn from the 20% "crème de la crème" of the roof contracting community.

Workmanship—the forgotten element in many a specifier's consideration—is almost universally agreed upon to be the source of most roofing and waterproofing problems with all types of moisture

Photo 10 – Typical construction abuse after installation.

protection systems. Polymer-modified rubberized asphalt is no exception to that notion, notwithstanding its higher degree of workmanship forgiveness. The growing awareness of the shortages of qualified craft workers recently documented by Associated General Contractors (AGC) comes with the prediction that construction labor shortages will only get worse.

Addressing the issue of workmanship forgiveness, in the latter 1980s, most rubberized asphalt specifications increased fluid-applied rubberized asphalt thickness specifications from a 180-mil single pass to a 90-mil and 125-mil thickness, two-pass application with a spun-bond polyester reinforcement fabric laid in between the two passes. This provided a level of redundancy and a measure of additional strength, decreasing the chances of workmanship error by a significant margin. The improved specification resulted in a minimum 215-mil membrane thickness, which (with SBS-protection course included) provided over 300 mils' thickness of self-healing waterproofing mass.

The most common workmanship problems and issues that still arise with rubberized asphalt start with proper deck and substrate preparation, ensuring that concrete has properly cured out; all substrates (walls, pipes, drains, etc.) are clean and free of contaminants; all projections are installed; drains are operative; adjoining walls are constructed; deck surfaces are free of unapproved curing compounds, ridges, and pockmarks; and other substrate irregularities are properly addressed.

The definitive guide for concrete surface preparation is found in ASTM D5295, *Standard Guide for Preparation of Concrete Surfaces for Adhered (Bonded) Membrane Waterproofing Systems*. From a practical point of view, a roofing or waterproofing subcontractor often does not want to upset his customer, the general contractor, with complaints about the deck not being ready for any of the foregoing reasons, only to be perceived as a troublemaker, delaying job progress. Also, there are often disputes as to who bears the expense of proper substrate preparation. This reluctance to complain leaves it to the manufacturers and QA observers to diligently supplement the waterproofing or roofing contractor's efforts in this area.

The second most common problem regarding workmanship (besides lack of experience) is the installation of flashing materials. The specific problem is flashings' not being completely adhered to their substrate, creating unsupported "bridges" and open laps. Flashing installation is rarely a problem with an experienced roofing mechanic with a modicum of pride in his workmanship. The ignorance/apathy mindset of the "I-don't-know" or "I-don't-care" worker is what manifests into problems with the installation of flashings. All flashing installations should be closely inspected by QA observers and the manufacturer's inspections.

Other less common workmanship problems are contamination of the primed substrate surfaces with construction dust; prolonged overheating of material, resulting in permanent cross-linking or vulcanization of the product in the rubber melter; and lack of material agitation in the rubber melter, causing polymer segregation and resulting in polymer-rich and polymer-lean materials' being withdrawn from the rubber melter. Inadequate application thickness is rarely a

Photos 11A-11B – Waterproofing a high-rise swimming pool and plaza.

problem except with polymer-modified bitumens lacking any filler content or resulting from overheated materials, which decreases viscosity.

With just shy of 40 years of extensive experience with this type of material, that is about all the author has seen that can go wrong on the workmanship side of the equation, with the significant exception of damage by other trades, especially after the work is completed. While this is a forgiving material, there is still plenty to keep Registered Roof Observers busy.

On the design side of the equation, it is the author's experience that the most common problem is lack of sufficient base-flashing height. Architects' tendency to value aesthetic form over function often means base flashings have to be invisible. This is often possible to do by burying or cladding the base flashings, but if it is not considered during the design phase, it results in the dreaded "change order," which more often than not means the base flashings will be constructed too low, potentially allowing leakage from above the flashings and then travelling behind the flashings through the substrate. If base flashings are not at least 8 in. above the highest expected waterline and counterflashed, they are susceptible to water entry and leakage. The battle over this one detail, in the author's experience, seems to be neverending. Other minor details, such as railing penetrations, safety tie-off devices, door thresholds, and low window-wall and curtain-wall intersections with the deck are also sometimes inadequately detailed and left as "field conditions" for the contractor to improvise.

At the end of the day, fluid-applied, polymer-modified rubberized asphalt offers perhaps the simplest installation possible for semiskilled workers. The thick fluid-applied membrane is a very forgiving, redundant, seamless, fully adhered, self-healing waterproofing membrane. The proven long-term performance of polymer-modified rubberized asphalt compares very favorably with the performance and history of old-style coal-tar pitch without any of pitch's drawbacks—literally a space-age engineered material installed with caveman techniques.

COMMODITIZATION

As the U.S. market for rubberized asphalt continued to grow, the number of material suppliers increased faster than the market growth. The net effect of the increased competition over the last ten years or so has been the commoditization of what was formerly a specialty, following the normal growth curve of most successful products.

Commoditization is a double-edged sword. Increased competition invariably leads to greater efficiencies, promotes innovation, and reduces costs for the building owner.

The flip side, which is especially true of construction materials, is it also encourages "value engineering" and reverse engineering, diminishing the quality of the product and installation details and encouraging undesirable installation compromises to which manufacturers are susceptible in order to stay competitive in a commodity market.

This value-engineering competition becomes quite apparent when currently marketed rubberized-asphalt materials are tested for strict compliance with current CGSB specifications. Few pass with perfect marks, some come very close, most come close, and a few are clearly inferior. The deficiencies are mostly driven by the desire to reduce costs, typically by lowering the polymer content, adding less volume of a needed additive, or using a few extra pounds of filler in lieu of asphalt—all to save a few pennies per pound. Almost all of the rubberized asphalts sold these days are still good or very good products, but too many do not meet the CAN/CGSB-37.51-M90 standards they are represented as meeting.

In normal business/economic product cycles, a race to the bottom usually ends when the generic product is reverse-engineered to a failure point and then kicked back up a notch or two or displaced by new technology. Many "newbie" marketers selling rubberized asphalt today are leveraging the successful history of the last five decades of polymer-modified, rubberized-asphalt with products and details that bear only a resemblance to the products and details that created the history of success. As anyone who has been in the rubberized asphalt business for more than ten years will attest, the learning curve is a steep one.

THE FUTURE

Predicting the future of polymer-modified rubberized asphalt is as fraught with ambiguity as any other prediction of what the future portends.

One- or two-component fluid-applied elastomeric membranes that are applied cold are making some inroads in the mar-

ketplace and offer a number of the same features as polymer-modified rubberized asphalt, but until they have established a decade or two of proven success in the North American market, they are unlikely to replace much of the polymer-modified, rubberized-asphalt market any time soon.

It is hard to imagine a cold-process SBS rubberized asphalt becoming popular, as that would require a volatile organic compound (VOC) solvent base or a water-based emulsion, both of which are different compounds with significantly different properties and characteristics than hot-applied rubberized asphalt. Some of the differences are environmentally objectionable, or, in the case of emulsions, subject to the possibility of reemulsification in certain applications.

Perhaps the most significant projected growth area that polymer-modified rubberized asphalt has been carving out is as the waterproofing for vegetated (green) roofs. De facto endorsed in the *NRCA Vegetated Roof Systems Manual* as a system of choice, with 100% adhesion to concrete decks in a protected membrane assembly, polymer-modified rubberized asphalt offers vegetated roofing systems the very unique feature of decades of long-term proven success in similar North American plaza and planter conditions that no other generic system (other than coal tar pitch) can honestly claim, notwithstanding some marketing claims to the contrary.

CONCLUSIONS

Roughly speaking, there are two generalized perceptions of rubberized asphalt. One: it is an incredibly sound, forgiving, time-proven, trouble-free waterproofing system; or two: it is a hot, smelly, dangerous, gooey, archaic waterproofing system.

As the waterproofing system safeguarding so many of North America's monumental structures, museums, data centers, bridges, and other architecturally significant structures for so many decades, the author sides with the former perception.

For those who have been the victims of poor workmanship or poor manufacturer choice and those who sell other types of competitive systems, it will always be the latter perception.

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Tim Barrett, RRC, CSI, CDT, started working with rubberized asphalt in 1975 and is the fourth-generation president of the Barrett Company, a provider of waterproofing and roofing systems. Barrett has served on the RCI Education Committee since its founding 26 years ago. He chaired the original RCI Green Roof education course development group and the new Vegetated (Green) Roof course. Barrett has also served on an RCI ethics panel and on the Document Competition Committee. He is also a member of ASTM D-08, D-24, and D-60 Committees; CSI; NRCA; and Green Roofs for Healthy Cities.