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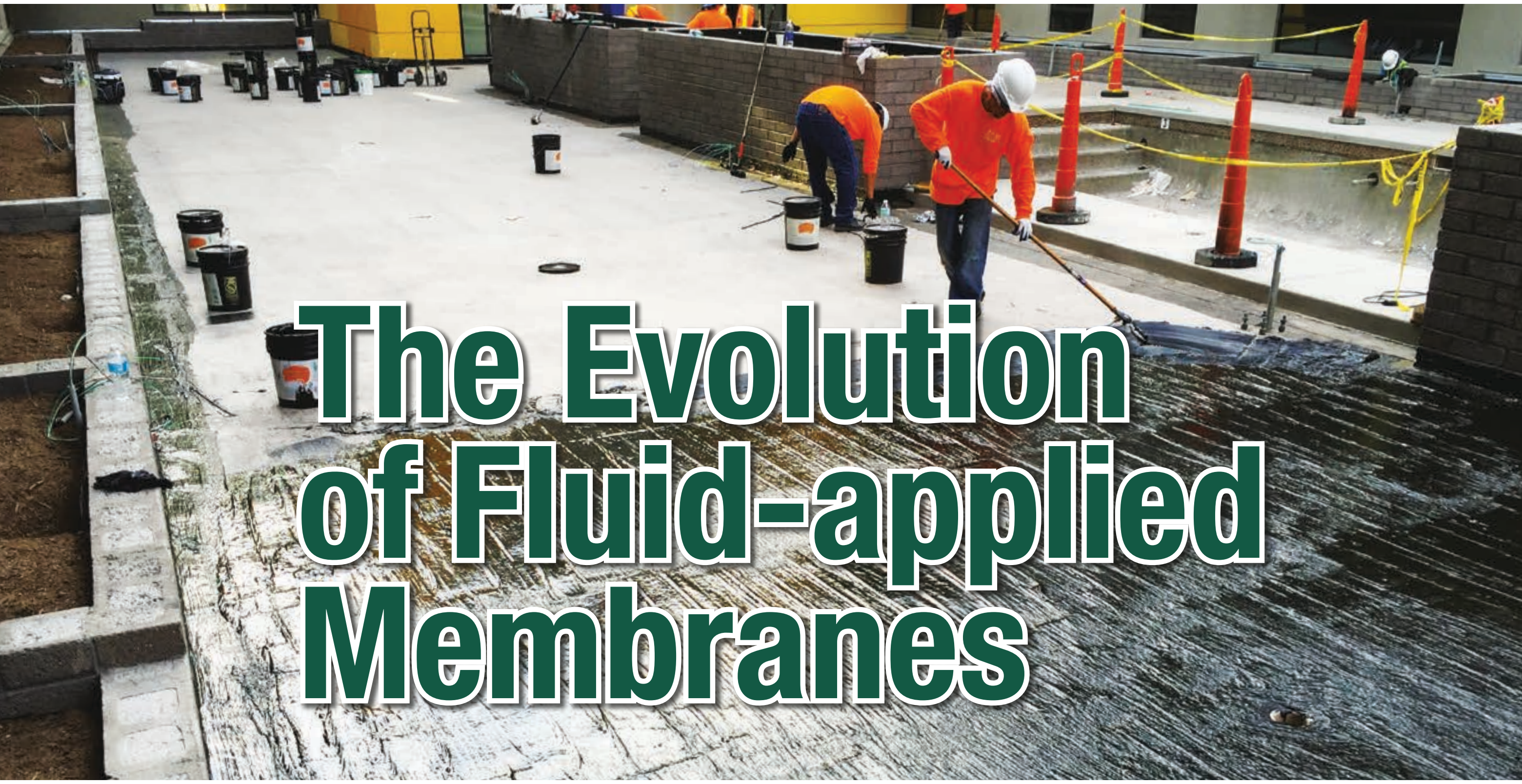

The Evolution of Fluid-applied Membranes

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Photos courtesy W.R. Meadows

AFTER CENTURIES OF USE, FLUID-APPLIED WATERPROOFING CONTINUES TO EVOLVE AS THE PRIMARY METHOD OF STRUCTURAL WATERPROOFING. ACCORDING TO GRAND VIEW RESEARCH, FLUID-APPLIED WATERPROOFING IS PREDICTED TO BE A $37-38 BILLION MARKET BY 2025. HISTORICALLY, HUMANS HAVE USED VARIATIONS OF LIQUID MEMBRANES TO WATERPROOF THEIR STRUCTURES SINCE HUNTERS AND GATHERERS USED LARGE LEAVES AND TREE SAP TO PROTECT THEIR EXCESS GRAIN FROM MOISTURE. IN THE NEOLITHIC ERA, BOATS WERE SEALED WITH BITUMEN EMULSION FROM PEAT BOGS TO PREVENT WATER FROM DETERIORATING THE WOOD. ANCIENT EGYPTIANS PERFECTED BITUMEN EMULSION TO SEAL AND PROTECT WALLS FROM THE NILE RIVER. WITH ALL THE TECHNOLOGICAL ADVANCEMENTS OVER THE YEARS, IT IS REMARKABLE THESE BASE CHEMISTRIES ARE STILL USED.

Fluid-applied waterproofing materials offer certain advantages over self-adhered sheet membranes, primarily the ease of installation, simplified detailing, and cost efficiency. Many challenges associated with sheet membrane waterproofing systems, such as 'fish mouths,' uneven seams, difficult end lapping, and complexity of installing a straight flat sheet on a polygonal structure, are eliminated in a fluid-applied system. With liquid membranes, minor substrate imperfections, small gaps, and irregularities are easily addressed. The seamless, monolithic quality of a liquid membrane reduces the concern of failures at joints, laps, seams, and changes in plane. The elastomeric properties of a fully adhered, fluid-applied system will accommodate minor settling and structural movements due to temperature and humidity changes.

Whether sprayed, rolled, or troweled on, liquid membranes reduce waterproofing installation costs by eliminating time and labor associated with substrate priming, taping, and rolling seams, and measuring and cutting large prefabricated sheets. While many variables, such as the skill of the installer and the specific site conditions, influence the final installation cost, some estimators report a labor cost reduction of up to 60 percent by using a fluid-applied membrane over a traditional sheet-applied membrane. When it comes to surface preparation, although a fluid-applied membrane is a little more forgiving with regards to surface profile, proper preparation is still The installation schedule is similarly dependent on many variables, but a sheet-applied membrane system usually requires an estimated two to three times the installation time compared to a spray-applied waterproofing membrane system. The ability of cold fluid-applied membranes to be installed over 'green' concrete is another advantage in regard to the ever-shortening construction schedule.

Installation of hot rubberized asphalt membrane.

Liquid-applied waterproofing materials

Liquid-applied waterproofing can be categorized into bituminous materials, coal tar, and polymeric materials. Bituminous binders result from the petroleum refining process and are commonly known as 'asphaltic' or 'asphalts'. The earliest discovery of bitumen dates back thousands of years to Europe and Africa. Despite being inherently combustible, bitumen is a sticky, naturally occurring and adhering, semi-solid, and innately hydrophobic material, highly suited for use in waterproofing membranes. With all of the technology for below-grade waterproofing, the use of bituminous membranes is still popular, and can be accomplished using a large array of accessory materials. It is imperative adequate research is done with regards to any materials that it will come into contact with these membranes to ensure both chemical and adhesive compatibility.

First discovered in the mid-1660s, coal tar is a byproduct of coke and coal gas production. It was commonly used in roads, sidewalks, and the preservation of railroad ties by 1865. The combination of coal tar and organic saturated felts became one of the earliest roof membranes. However, coal tar was limited to low-slope roofs due its low viscosity. Coal tar is also highly susceptible to ultraviolet (UV) degradation, often resulting in severe craze cracking in its cured form. For better UV stability, various resins, epoxies, and other materials were added as UV-resistant enhancers, including aluminum flakes. Despite the challenges, coal tar maintained a nearly 100-year popularity until the product was discovered to be carcinogenic. State and local volatile organic compound (VOC) restrictions banned its use for roofing applications and significantly reduced its use today. One other consideration is this material is also combustible, another limitation restricting its use.

Polymerics require complex formulations to cure to a solid membrane material. Most polymer technologies are highly processed and consequently more expensive than asphalt or coal tar. Polymer technologies are also less hydrophobic and have inherently lower viscosity than asphalt or coal tar. However, the installation advantages to these technologies continue to encourage their use in the field. These polymer technologies include polyurethane, acrylic (polymethyl methacrylate [PMMA]), silicone, acrylic urethane hybridization (polyurethane methacrylate [PUMA]), and silicone urethane (SPUR). As these materials are not produced from crude oil, they are deemed to be a more sustainable building material when compared with bituminous membranes.

Bituminous membranes

In the early 1900s, cold fluid-applied membranes were developed primarily for the maintenance of roadways and dust mitigation. Cold-applied membranes include cutbacks, cold-process, and emulsions, which refer to slight variations in the chemistry.

An asphalt cutback is simply heavy-grade asphalt thinned with lighter grade petroleum solvent to provide a higher viscosity and easier workability. Solvent-based cutbacks are rarely used today, and the term cutback has essentially vanished from product literature. These products are still available but limited by state and local codes due to their flammability, odor, and higher VOC content. These limitations often outweigh the benefits of cooler weather application and styrene butadiene styrene (SBS) membrane compatibility.

An asphalt emulsion replaces most of the solvent found in an

Spray installation of polymerized asphaltic emulsion.

asphalt cutback with water. Both cutbacks and emulsions contain asphalt cement, a finely ground or milled asphalt mixed with an appropriate solvent. Emulsions suspend the asphalt in the material through chemical emulsifiers and surfactants, and naturally contain very low VOC content. Standard asphalt emulsions remain viable for light-duty waterproofing in areas of low hydrostatic head pressure, commonly referred to as dampproofing. Polymer or rubber-modified asphaltic emulsions provide improved waterproofing protection against hydrostatic head pressure. These products are used primarily due to significantly lower cost compared to higher performing membranes. Applications requiring greater flexibility, improved performance, or faster setting times might be better served with alternate product types.

Modern bituminous asphalt is distilled from crude oil, oil sands, and well sources. It was first synthesized with other polymers into useable rubberized asphalt in the early 1950s. This early 'polymer-modified' asphalt contained styrene butadiene rubber (SBR), and found immediate use in the production of the nation's rapidly growing roadway networks at that time. In the late 1960s, scientific development led to the invention of SBS-rubberized asphalt with markedly higher levels of durability. The SBS asphalt formulation ages better, provides elastomeric qualities and strength while significantly improving abrasion resistance compared to its SBR predecessor.

During the early 1960s, a tire manufacturer commercially marketed SBR and later SBS-rubberized asphalt. Approximately 10 years later, a sheet version of SBS asphalt was developed into modified asphalt roofing, or 'mod-bit'. This new chemistry includes all the benefits of hot fluid-applied SBS in a polyester or glass-reinforced, factory-controlled thickness sheet good.

Hot-applied SBS membranes are unrestricted by low temperature site conditions. The Blue Cross Blue Shield Headquarters project in Egan, Minnesota, installed a majority of the 8361 m^2 (90,000 sf) application in below –18 C (0 F). Hot-applied SBS sets immediately as a fully adhered continuous membrane. In its nearly 60-year track record, hot-applied SBS membranes have one of the lowest installed costs for a waterproofing membrane. They provide robust protection for plaza decks, steam tunnels, vegetated roofing, and parking garage deck applications. Conversely, respirable emissions and unpleasant odors from the melted asphalt should be considered when working in or near densely populated areas. Additionally, the material is nearly 204 C (400 F) when installed. The high temperatures can be dangerous even to an experienced installer.

Polymeric materials

In the latter half of the 20^{th} century, the industry expanded toward new material possibilities, including polyurethanes. However, polyurethanes represent a broad category. Specifying the correct polyurethane requires precise terminology and detailed information regarding the product's physical property requirements. Subcategories include two-component, single-component, hybridized, unhybridized, modified, and unmodified. Advantages to polyurethane products in general include better elongation and flexibility. Additionally, these products adhere well to a wide variety of substrates. In restoration or maintenance applications, older surfaces may have unknown coatings or pre-existing adhesives. A polyurethane allows the contractor a greater chance of success despite any unknowns over other more substrate-specific products. At a molecular level, urethanes form a spring-like structure that allows for strength and flexibility. This molecular spring also recovers well, which creates high tensile strength, elongation, hardness, and flexibility even at extreme high and low temperatures.

Unfortunately, compatibility between polyurethanes and other waterproofing materials can be tricky. Polyurethanes are often modified with asphalt. The transfer of oils or plasticizers between adjacent asphaltic materials can negatively impact adhesion and create other compatibility challenges. Many injection grouting materials contain polyurethane technology. If injection grouting is used to repair a failing waterproofing system, the compatibly with the existing waterproofing system must be determined before installation. Likewise, transitions, detailing membranes, and protection course should always be confirmed for compatibility prior to installation. Testing information is widely available for polyurethane waterproofing, but modified or partial terminology within the testing criteria can create confusion when comparing products. Due to the various chemistries within this larger group, it can be difficult to establish true 'equals.'

Two-component polyurethane membranes were introduced in the early 1980s. These solvent-free products cure through a chemical or 'crosslinking' reaction. Two-components often have no added solvents, lower VOC levels than subsequent solvent-based, single-component products, less odor, and negligible flammability risk. While they provided a more consistent cure time than the air/moisture-cure single-components, the inconvenience of field mixing led to the development of single-component products later in the decade.

Moisture-cure single-component polyurethanes were developed in the late 1980s to eliminate the onsite mixing required by two-component membranes. Reduced site waste and improved moisture tolerance provide additional advantages over two-component polyurethane products. Single-component polyurethanes are dependent on ambient humidity to initiate the curing reaction, also known as 'moisture-cure'. The addition of solvent cutbacks assists in workability and extends the recoat time. However, moisture-cure technology presents challenges such as foaming, bubbles, and blisters if installed incorrectly or over the presence of substrate moisture. Solvent content shrinkage may also be observed. Shrinkage is directly related to solids content. The higher the solids content in the liquid membrane, the less shrinkage will occur.

Single-component polyurethanes are generally cost competitive with other waterproofing systems. The simplicity of installation, and versatility in both vertical and horizontal applications, make it an attractive option for most projects. Maintaining the proper thickness and applying multiple coats if necessary are critical to the success of these systems. Two lifts may be necessary on vertical surfaces to achieve a 1.5-mm (60-mil) thickness. For more robust horizontal waterproofing, many single-component polyurethane products can be applied at 3 mm (120 mils) with non-woven reinforcement sheets.

Another newer, single-component technology, moisture-cure, silyl-terminated polyether (STPE), materials combine the solvent-free advantages of a two-component polyurethane with the simplified installation of a one-component product. Other names for this chemistry include silyl-modified polyurethanes, polyether, silyl-terminated polymer, silicone-modified polyester (SMP), and MS polymer. There is no flammability risk or odor, and they are lower in VOCs. These products also contain significantly higher solids content, meaning little to no shrinkage as the product cures.

However, this technology is susceptible to the challenges of a moisture-cure. The membrane cures from the exposed edge inward, meaning the surface 'skins over' very quickly, while the interior remains a liquid for longer. When the concrete substrate is heated by the sun, water vapor from within the concrete will push its way through the still liquid portion of the membrane, creating bubbles and blisters on the waterproofing surface. Proper installation of these membranes includes application at the correct time of day and only over substrates that have low moisture content. Many manufacturers recommend the use of a primer in situations likely to produce blistering. This recommendation may be written into the specifications, if necessary.

One response to the bubbling challenges of moisture-cure membranes is the recent development of polyurethane water-cure technology. These products are only applicable for horizontal surfaces and must be water-saturated to cure. Moisture-cures set slower in comparison because the required moisture absorption from the air is gradual, curing from the edge-inward. With water-cure technology, the entire membrane cures simultaneously. Water-cure membranes set extremely quickly, some in as little as two hours, before escaping water vapor can create blisters or bubbles in the membrane.

Acrylic resins

PMMAs are two-part acrylic resins offering quick cure times through use of a catalyst. First synthesized in the 1930s, PMMAs did not become a viable waterproofing product until the early 1970s. When compared to asphaltic polyurethane membranes, these resins exhibit tremendous hardness as noted in their Shore Hardness data. The high-achieving abrasion and impact resistance of PMMA resins can be found in the manufacturing of aircraft windshields, safety glasses, dental fillings, and even contact lenses. Additionally, their water and chemical resistance and tolerance to heat and cold make these membranes applicable to a wide-range of construction applications. PMMAs provide the base to most traffic coatings, although polyurethanes can also be used for this purpose.

Around the turn of the millennium, a variant of PMMA was developed with the addition of polyurethane. PUMA couples the elastomeric properties of polyurethane with the durability of PMMA. The resulting PUMA membrane adds three to four times the elongation over a typical PMMA membrane. This is particularly important in northern climates where temperature extremes are greater than southern climates. Reinforcement material may be required at penetrations and transitions to ensure the material is applied at the specified thickness, but PUMA membranes are strong enough to forgo fleece reinforcement fabric that is common among PMMA membrane systems.

With the use of an epoxy primer, both resin versions feature the advantage of green concrete application approximately 72 hours after form removal. Substrate and ambient application temperatures are accommodated as low as –6 C (20 F). PUMA membranes require careful understanding of ambient conditions. Application must take place at not less than –15 C (5 F) above the dewpoint. Installers are advised to be trained and authorized by the manufacturer. These waterproofing systems are generally designed for horizontal applications such as split-slab, paver systems, planters, and vegetated roofs.

While these technologies are extremely effective, PMMA/PUMA systems are estimated at up to twice the cost of an SBS, hot-fluid-applied rubberized asphalt system. However, quick production times and the elimination of protection course, termination bars, and other accessories are to be considered.

Conclusion

While fluid-applied waterproofing products have recently surged in popularity, fluid-applied materials have existed in various forms for centuries. Instead of new technologies replacing previous products, new fluid-applied technologies are added to an expanding portfolio of waterproofing chemistries. Almost all fluid-applied waterproofing technologies that were ever developed are still offered in some form today. With numerous options available, selecting the right system can be confusing. Balancing durability, material cost, and difficulty of installation, as well as construction schedules and budgets can seem overwhelming. However, the best waterproofing material is a well-installed one. No matter which product is selected, a knowledgeable installer will have the greatest impact on the success or failure of the waterproofing system. Concise specifications to communicate product information and quality standards, along with comprehensive detailing to provide explicit installation guides to the installer, will set the groundwork for a quality installation of any fluid-applied waterproofing system. **CS**

ADDITIONAL **INFORMATION**

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Key Takeaways

Fluid-applied waterproofing materials have been used for centuries. Over the years, there have been many advances in material chemistry and technology. Dating back to the mid-1800s, bitumen has been a part of major developments in hot and cold applied waterproofing. The 1960s introduced acrylics, styrene butadienes, and other waterproofing materials that provide better quality and durability. The 1980's saw a movement toward various resin technologies with the introduction of two-component polyurethanes providing greater ultraviolet (UV) resistance. The latter part of the decade advanced to single-component, moisture-cured polyurethanes. Today, polyurethane chemistry seems to be the majority of fluid-applied materials used. However, with all of this development, proven performance in previous technologies still warrant their use around the world.

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