Into the Future: Advanced Thick-Film Spray Applied Liquid Waterproofing Membrane Systems for Bridge Deck Applications

Dudley J Primeaux II, PCS, CCI, Joseph Haydu, CEO, and Jonathan Haydu
Bridge Preservation, LLC
686 S. Adams Street, Kansas City, KS 66105 USA
www.bridgepreservation.com

Learning Objectives: Discuss new advances related to thick-film spray applied waterproofing membranes compared to traditional technologies of use. Achieve an understanding that this fast set and cure technology is: viable technology for waterproofing bridge decks, offer superior abrasion resistance and flexibility, enable faster production rates and quicker return to service even in cold installation areas. This advanced technology, equipment and application techniques offers superior advantages, and is applicable to some in robotic rehabilitation and installation work.

Abstract: It does not take one with too much intelligence to note that our infrastructure is in dire shape. Not only does this include our water & wastewater areas, but our road and bridge systems need substantial help. Deterioration due to environmental issues, water and chemicals that are used which cause for serious corrosion and erosion concerns. Over the years, a variety of methods have been employed to help with these issues, but all have individual characteristics and problems. As populations have grown in centralized areas, so does the abuse on the roads, scheduling repairs and time for those repairs, can create nightmares for local traffic. Thick-film spray applied waterproofing systems are not new to the coatings industry and have been successfully used to combat these corrosion and erosion activities. By following coating and lining industry standards; quality inspection techniques during installation; and, advancements in the product technology, these systems will provide for a high performance waterproofing membrane system for road and bridge application areas. This is a very fast set and cure technology which minimizes road work delays and offers the ability for complete wear-course applications; and, offers many advantages to waterproofing work in bridge applications. This presentation will focus on these advancements and performance properties; application and use techniques; as well as potential for robotic type installation that will carry us into the future.

INTRODUCTION:

We have all heard this before, our infrastructure is in extremely bad shape! We can look around and see many obvious problems. Some of these areas are "underground or buried," and have offered special challenges for repair. [1]

A major issue relates to our bridges, overpasses and tunnel sections. Constructed primarily of reinforce concrete, often felt to be one of the best sources of construction material, is being "attacked" by the elements. This attack comes from water, salts and chemical contamination that corrode away the reinforcing rebar and steel. This causes slight to massive spalling of the concrete, and possible collapse. It is estimated that over $400 billion US dollars will be required for repair of our bridge and road systems. [2, 3] The following Figure 1 shows some examples of this problem.



Figure 1: Concrete Bridge Deck Corrosion

The main problem seems to be the infiltration of water and/or moisture, which carries the various contaminants. The use of waterproofing membranes under the asphalt traffic bearing surface is a solution. And as a matter of fact, this is the best option. [4]

For this waterproofing method, a variety of sheet good systems, based on thermoplastic polymer systems have been used. This includes polyethylene (PE), polypropylene (PP) and polyester-based systems. Even though these "polymers" are very hydrophobic in nature, the problems arise due to the fact that these sheet good systems must be thermally sealed at the overlaps on site after laying in place. This is a mechanical process, and let just say it does not always go as planned. More importantly, they are loosely bonded to the substrate using a bitumen adhesive type system.

The best option for waterproofing of this nature, and not something new, is the use of liquid applied waterproofing membrane systems.[3,5-7] These can either be thin-film applied, typically about 10 mils (250 µm), or as thick-film elastomeric systems, typically applied at 40 to 120 mils (1 to 3 mm) or more. These are based on a variety of thermoset polymer technologies including epoxy, poly-methylmethacrylate (PMMA), polyurethane (PU) or polyurea (PUA) based technologies.

Performance Standards:

Currently, there is no real, complete industry performance standard related to bridge deck waterproofing work in North America. For this work and process, many utilize the

specific location Department of Transportation (DOT) Standard Specification for the work. Most rely on these detailed specifications that contain proposed performance requirements taken from various supplier product Technical Data Sheets.

There does seem to be one common requirement as it relates to the AREMA: American Railway Engineering and Maintenance-of-Way Association. This is a unique, specific performance test that is part of a waterproofing specification, noted as the AREMA Ballast Test. [8] For this test procedure, the liquid applied waterproofing system is applied to a steel panel, at the nominal application thickness, and then placed at the bottom end of a metal cylinder of 23.5 inches (600 mm) in diameter. Standard rail ballast is loaded into the cylinder in direct contact with the waterproofing membrane. A cyclic force of 41 to 125 kilo-Newton (kN), which is 9,000 to 28,000 lbs-force, is then applied to simulate a 25 ton axle load. This is run for 2 million cycles, and then the waterproofing membrane is inspected for damage with a "pass" or "fail" being noted.

For the European Union, where quite a bit of bridge deck waterproofing is employed, they do utilize ETAG 033 Standard. [9] This document is a Technical Approval guideline, outlining all specific requirements that apply to surface preparation, adhesion, flexibility and environmental issues related to liquid applied waterproofing membrane systems. Many of the requirements listed in this document are being compiled to prepare a similar North American standard relating specifically to performance requirements in this area of bridge deck waterproofing.

In the mean time, there are two standards that can be utilized in this bridge deck waterproofing work with liquid applied membrane systems. Those are SSPC-PA 14, a Coating Application standard, and SSPC-Paint 45, a performance based standard on plural component, thick-film elastomer systems. [10, 11]

The Chemistry or "Science Behind It":

When choosing the type of chemistry for the application use one must take into account the substrate being waterproofed; conditions of application; and, subsequent exposure of the liquid applied waterproofing membrane system. For most decks that have steel substrates, the physical demands on the waterproofing system may not be as great as that for concrete substrate decks. In concrete decks there are issues with substrate movement; cracking and uniformity in composition placement; and, then exposure to very low temperature seasons during the year; i.e. thermal cycling.

Once the waterproofing system is installed, the traffic bearing surface is then placed. This surfacing is of an asphalt or bitumen based material with installation temperatures of the product well over 350° F (175° C). The waterproofing membrane must hold up to that temperature of exposure without any detrimental effects or softening. The material must also be flexible at low temperatures as the normal road signs show (Figure 2) that bridge deck areas will freeze before the normal road.



Figure 2: Bridge Deck Road Sign, Central Texas

The following Table 1 provides a comparison of a typical thin-film waterproofing system (PMMA) to a plural component (2-K), fast set, thick-film elastomeric polyurea (PUA) waterproofing membrane system.

Table 1
Comparison of 2-K PUA Elastomer to PMMA

	2-K PUA Elastomer	PMMA
Application method	spray	spray
Ambient Conditions	< 0 to > 100° F	23 to 86° F
100% solids	yes	no
VOC content	no	yes
Flash point of component	> 250° F	53° F
Elongation, %	> 250	~ 130
Tensile strength, psi, (MPa)	2500 (17.2)	1700 (11.7)
Shore D Hardness	50	56
Tear Strength, pli, (N/mm)	~ 390 (~68)	~ 400 (~70)
Adhesion, tensile		
Concrete, psi	> cohesive strength	~ 100
Steel, psi	> 1000	~ 300
CLTE, µin / in / °F, (µm / m / °C)	2 – 6 (4 – 13)	18 – 20 (29 – 35)
AREMA Ballast Test	pass	pass

CLTE = Coefficient of Linear Thermal Expansion

Based upon the information in Table 2, the 2-K, thick-film PUA elastomeric bridge deck waterproofing systems present a viable option for a variety of bridge deck substrates. The elastomeric qualities, as well as fast set and cure, even at low temperature exposure, allows for rapid installation work.

The Process:

The steps involved in a successful installation of a thick-film, elastomeric waterproofing system involve surface preparation and repair; primer application; treatment of joint areas; application of the waterproofing membrane system; a suitable tackcoat system for the asphalt adhesion, if required; and placement of either the ballast or the traffic bearing surface. This same process is utilized whether the bridge deck is steel or concrete. Surface preparation is crucial for any coating and lining application, especially in these bridge deck waterproofing projects.

For steel substrates, the surface is prepared to an SSPC-SP 5 / NACE No. 1. [12] The typical minimum specified profile would be 3 mils (76 µm). A primer may or may not be utilized at this point, depending on overall conditions. For concrete, SSPC-SP 13 preparation is used, typically with abrasive blasting; steel shot blasting; or, industrial scarifying. [13] For concrete bridge decks, the typical resulting Concrete Surface profile (CSP) is usually CSP 4 and up to 9 – 10. [14] For this rough surface, repairs would be required to fill in for many cases adding an extra step. This demonstrates that for these type applications and surface conditions, a thick-film liquid applied system would be the preferred material of use (Figure 3).



Figure 3: Prepared Concrete Bridge Deck

Following surface preparation, a primer and then the 2-K thick-film, fast set elastomer system is spray applied. This elastomeric membrane is typically installed at a minimum average 80 to 100 mils (2 to 2.5 mm) dry film thickness (DFT). Figure 4 shows the typical work, while Figure 5 provides for field application equipment setup.



Figure 4: Spray Application of Bridge Deck Membrane



Figure 5: Bridge Deck Membrane Equipment Setup

In cases where large expansion joints are present, a prefabricated bridge deck joint system may be installed. This can be fabricated from the same type 2-K thick-film elastomer system used for waterproofing. [15] The use of this process is not new for the installation of coating lining systems over concrete floor areas. Regardless of elongation values of materials, one must also honor or respect all moving joint and treat appropriately. [16] Figure 6 shows installation of these type joints.



Figure 6: Installation of Bridge Deck Joint System

After the application of the bridge deck membrane, the installation is inspected for defects, pinholes and voids. Typical methods of inspection are employed; including, flood testing, high voltage spark testing, adhesion and applied thickness evaluations. To assist in the consistency of high voltage spark testing over concrete surfaces, the use of fluorescent pigment containing primer systems can be used.[17-18] Any pinholes can be visually seen quickly using an ultraviolet or black light source.[19]

The use of fluorescent pigmented penetrating primer systems allow for an excellent method of non-contact pinhole and holiday detection with the use of a ultraviolent (UV) or Black-Light source. This addresses the situation that often arises when trying to perform conventional spark testing of liquid applied membrane systems over concrete surfaces and being able to achieve a proper ground. Both small pinholes and large voids in complex or undercut areas are often missed with spark testing over concrete substrates. Conductive primers may help but often primer physical properties are significantly reduced, resulting in overall performance issues. Figure 7 is an illustration of the fluorescent pigment primer showing through voids in the membrane and glowing under UV light.



Figure 7: UV Light Inspection of Membrane over Fluorescent Primer

These 2-K thick-film elastomeric membrane systems are also used in a variety of high temperature exposure applications. This would include work such as lining of asphalt trucks to improve the release of the asphalt from the truck. Since the asphalt-base does not stick and releases from the membrane, to have a successful placement of the asphalt traffic bearing surface, some form of tackcoat system must be applied. The traditional method has been to apply a bitumen based tackcoat to the membrane. Figure 8 provides an illustration of this.



Figure 8: Bitumen Based Tackcoat over Bridge Deck Membrane

In some rare cases, a primer system utilizing incorporated beads of ethylvinyl acetate (EVA) will provide for adhesion of the asphalt traffic surface. [20] These beads are a thermoplastic that will soften and melt under the heat of the placed asphalt and have been shown to provide some adhesive strength.

Another option that actually proves to be viable for an actual traffic bearing surface, is to apply a slower set version of the 2-K thick-film elastomeric bridge deck membrane and then broadcast a large aggregate to rejection. This can be accomplished in 2 or 3 rapid installation lifts. Not only is there excellent adhesion and interaction with the applied asphalt, as traffic bearing surface it also performs well. Figure 9 shows the use of the imbedded aggregate system.

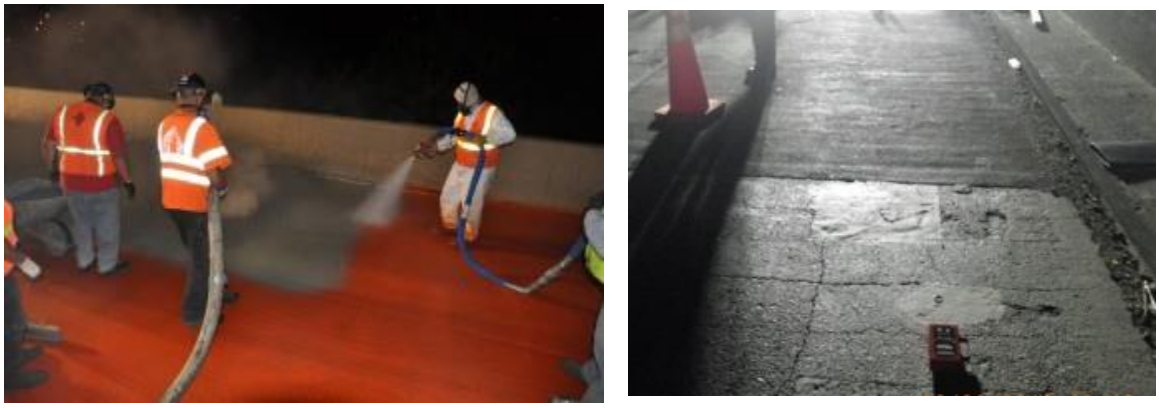


Figure 9: Use of Aggregate in Bridge Deck Membrane

Since there have been concerns on the possible slip resistance of the aggregate driving surface, a comparison of the Horizontal Slip Coefficient (HPS) of both the concrete surface and the membrane are given in Table 2. [21] As shown, the slip coefficient values of the aggregate including bridge deck membrane exceed that of the cleaned, bare concrete road surface.

Table 2

Slip Coefficient Testing Comparison*

	Concrete Road Deck	Thick-Film Elastomer with Aggregate
HPS Slip Coefficient, dry	0.68	0.93
HPS Slip Coefficient, wet	0.68	0.88

* ASTM F 609, ASM 825 Slip Meter, Panama Bridge of Americas

Recent work has shown that the use of robot systems significantly help with the uniformity of the applied bridge deck membrane, as well as speed of installation. [22] The use of a robot does not replace the highly skilled, hand spray applicators, it merely enhances and improves the installation work, see Figure 10.



Figure 10: Robotic Application of Bridge Deck Membrane System

Since the robot's movements are computer controlled, the machine performs the same movements over and over throughout the waterproofing installation process. On flat and smooth surfaces, consistent application occurs with the spray applied thick-film system noting typically a ± 5 mil (± 125 µm) DFT variance. Even highly skilled hand applicators can have DFT variances of ± 10 mils (± 250 µm) for these plural component, thick-film elastomeric systems. Also, the robots do not requires breaks or get tired, so worker fatigue can be reduced.

There are disadvantages and challenges though for the robot application. This includes application over heavily irregular surfaces, location of penetrations, drain and joint areas, as well as included vertical surface areas. This work still requires the presence of skill hand spray applicators. Also, robot application does not improve mix of the system as that is done inside the application spray gun. And a robot system is not necessarily faster, just more consistent. The speed of coverage will depend upon specified project DFT and system output capabilities and setup of the plural component application equipment.

To further illustrate the usefulness and success of these 2-K thick-film elastomer bridge deck membrane systems, one needs to evaluate the performance of the subsequent driving or wearing course. Since a Hot Mix Asphalt (HMA) is then placed, need to insure this HMA adheres to the applied waterproofing membrane. It would be a very bad sequence of events if the over-layment was not properly bonded, a heavily loaded truck slams on the breaks, and the over-layment "rolls up" like that what was seen on the Saturday cartoons.

Since there is currently no complete industry performance standard in North America related to liquid spray applied bridge deck waterproofing, a procedure has been devised to evaluate the shear bond strength of the overlay and the membrane, or base substrate. Also included in this evaluation testing procedure is the tensile bond interface after exposure to freeze-thaw cycling. [23]

For this testing, a 11,500 pound (5215 kilogram) load is applied to a 4 ft^2 (0.37 m^2) sample area of HMA applied over the various substrates. The force required to shear the HMA from the substrate is then noted. For tensile adhesion, prepared complete samples are submerged in water and exposed to 150 thermal cycles of 0º to 40º F (-10º to 4º C). This may equate to approximately 3 years of bridge deck exposure in the North Eastern United States.

The following Table 3 provides for this performance testing using the 2-K thick-film elastomeric system.

Table 3

Performance Properties of 2-K Thick-Film Elastomeric
Bridge Deck Membrane

		Thick-Film Elastomer	
	Concrete*	Membrane*	Membrane & Aggregate*
Shear Bond Strength			
Lbs-force	7230	7100	9530
Kgs-force	3280	3220	4320
Tensile Adhesion Factor (150 cycles, freeze-thaw)	4.5	4.6	4.7

* Applied HMA over asphalt based Tackcoat treated substrates

CONCLUSION:

The use of plural component, fast set, thick-film elastomeric membrane systems for waterproofing applications continues to be a growing market. These systems are generally high up to 100% solids systems, and offer superior protections of a variety of substrates. The fast set time and cure of the thick-film elastomeric waterproofing system allows for rapid application and return to service and use of the traffic areas, much to the pleasure of the commuters using the roads.

The use of the broadcast aggregate significantly improves the overall shear and adhesion performance of the applied Hot Melt Asphalt (HMA) driving course. Alternatively, the imbedded and bonded aggregate provides for alternative driving course. Robotic processing and application can provide for uniform and consistent delivery of the 2-K liquid applied waterproofing membrane. But this is no substitute for the skilled and trained human element. Bottom line, the use of thick-film, liquid applied elastomeric waterproofing membrane systems will insure the extended life and performance of our bridge decks.

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