Long-Term Bridge Performance Program

SUMMARY REPORT

FHWA LTBP Summary—Current Information on the Use of Overlays and Sealers

FHWA Publication No.: FHWA-HRT-16-079

Author: Susan Lane, P.E.

FHWA Contact: Frank Jalinoos, HRDI-30, (202) 493-3082, frank.jalinoos@dot.gov

About LTBP

This research was conducted as part of the Federal Highway Administration's Long-Term Bridge Performance (LTBP) Program. The LTBP Program is a comprehensive research effort to collect scientific performance field data, from a representative sample of bridges nationwide, that will help the bridge community better understand bridge deterioration and performance. The products from this program will be a collection of data-driven tools including predictive and forecasting models that will enhance the abilities of bridge owners to optimize their management of bridges.

Introduction

The Federal Highway Administration's (FHWA's) Long-Term Bridge Performance (LTBP) Program is a long-term research effort, authorized by the U.S. Congress under the *Safe, Accountable, Flexible, Efficient Transportation Equity Act* legislation, to collect high-quality bridge data from a representative sample of highway bridges nationwide that will help the bridge community better understand bridge performance. The products from this program will be a collection of data-driven tools, including predictive and forecasting models that will enhance the abilities of bridge owners to optimize their management of bridges.

Bridge performance is defined by the LTBP Program in its *LTBP Bridge Performance Primer* as follows:

> "Bridge performance encompasses how bridges function and behave under the complex and interrelated factors they are subjected to day in and day out—traffic volumes, loads, deicing chemicals, freeze-thaw cycles, rains, or high winds. Bridge design, construction, materials, age, and maintenance history also play roles in performance."(1)

The LTBP Bridge Performance Primer further states, "Performance is usually associated with some set of standards, whether absolute or relative, and performance can be measured against those standards."(1)

To better define the most important issues to investigate in the LTBP Program, the LTBP Program team conducted in-depth interviews with representatives of 16 States in 2008 and 2009 and discussed the bridge issues most vexing to State transportation departments. The LTBP Program also convened a special workshop to identify bridge substructure issues. These processes are described in two FHWA publications, *Long-Term Bridge Performance High Priority Bridge Performance Issues* (Report No. FHWA-HRT-14-052) and *TechBrief: FHWA*

LTBP Workshop to Identify Bridge Substructure Performance Issues (Report No. FHWA-HRT-13-049).[2,3] These discussions resulted in the identification of more than 20 important bridge issues, including the following 6 deemed by the LTBP Program as high priority:

- Untreated decks (no overlays).
- Treated decks (decks with overlays).
- Joints.
- Bearings.
- Coatings for structural steel girders.
- Verification of the condition of prestressing strands and tendons in prestressed concrete bridge members.

These six high-priority bridge performance issues will be investigated by collecting and evaluating field data on bridges throughout the United States. This is only possible through strong partnerships with the 52 State transportation departments (includes the District of Columbia and Puerto Rico). Each agency identified an individual who will serve as that State's coordinator with the LTBP Program.

Once a year, the LTBP Program State coordinators meet in person to receive program updates and to discuss bridge issues in their States. During this annual meeting, breakout sessions are held, during which State coordinators describe bridge practices in their States on key topics; afterward, the breakout groups report back to the group as a whole. One of the topics discussed during the August 2013 LTBP Program State coordinators' meeting was bridge overlays, and the most important trends from the meeting are presented in this publication.

Many different types of overlays have been used on bridge decks. This summary report focuses on the current use (as of August 2013) of overlays and sealers by State transportation departments. Future LTBP Program publications will focus on the historical development of overlays on a national basis, as well as the historic use of overlays by State transportation departments. In addition, this document discusses the current means (as of August 2013) of evaluating the performance and condition of the overlays and sealers.

Types of Overlays and Sealers Used by the States

The top ten overlays and sealers used in 2013 by the State transportation departments were ranked as most prevalent by the number of States that had tried each overlay type and are shown in figure 1:

1. Asphalt overlay (with or without a membrane).
2. Latex modified concrete (LMC) overlay.
3. Epoxy polymer concrete overlay.
4. Membranes (act as sealers).
5. Portland cement concrete overlay.
6. Silica fume (microsilica) concrete overlay.
7. High molecular weight methacrylate (HMWM) sealer, prime coat, or overlay.
8. Polyester polymer overlay.
9. Silane sealers.
10. Low slump/dense concrete overlay.

Note that this list includes rankings from States that had tried the overlay types even if they had stopped using them. Each of these types of overlays and sealers is discussed in the following subsections.

Asphalt Overlays

Asphalt overlays have been used across the United States, both with and without a membrane. (Membranes are discussed in detail in the subsection entitled Membranes (Used With Asphalt Overlays).) The benefits of asphalt overlays are their ease of use, relative low cost, and improvement to smoothness of ride ("rideability"). The challenges for using asphalt overlays are that they add dead load to the bridge, disbond from the concrete deck, and trap water and/or chlorides beneath them.[4]

As seen in figure 2, 38 of 52 State transportation departments have used asphalt overlays. Of these 38 States, 9 rated the use of asphalt overlays as successful, and 1 of the 38 States stopped using asphalt overlays. This likely indicates that the performance of asphalt overlays was mixed, with some good performance and some less than successful performance, within a majority of the responding States.

Figure 1. Types of overlays and sealers tried by State transportation departments as of 2013.

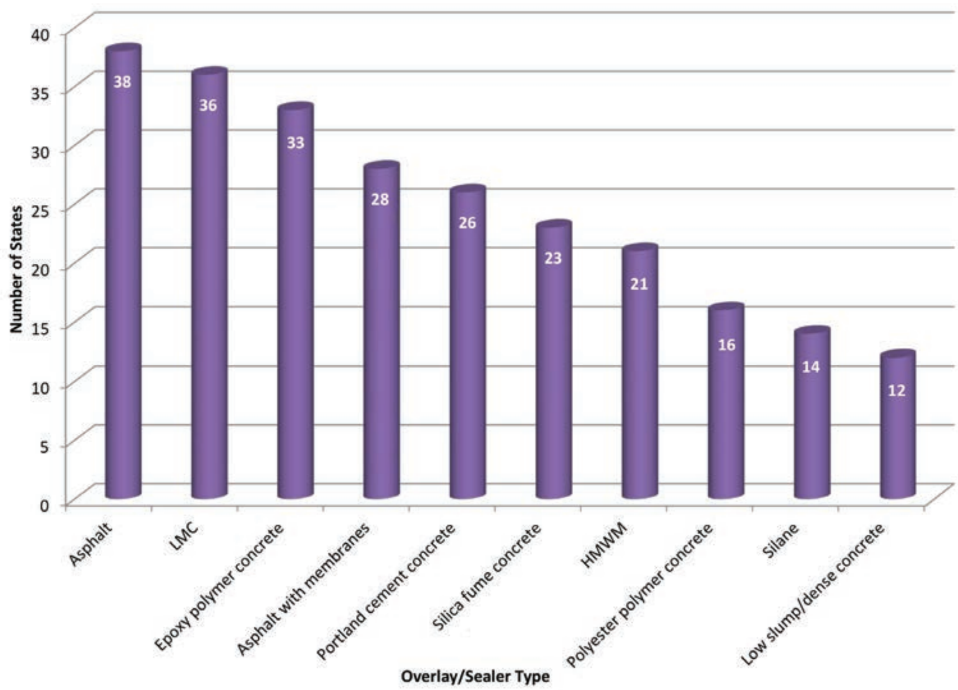
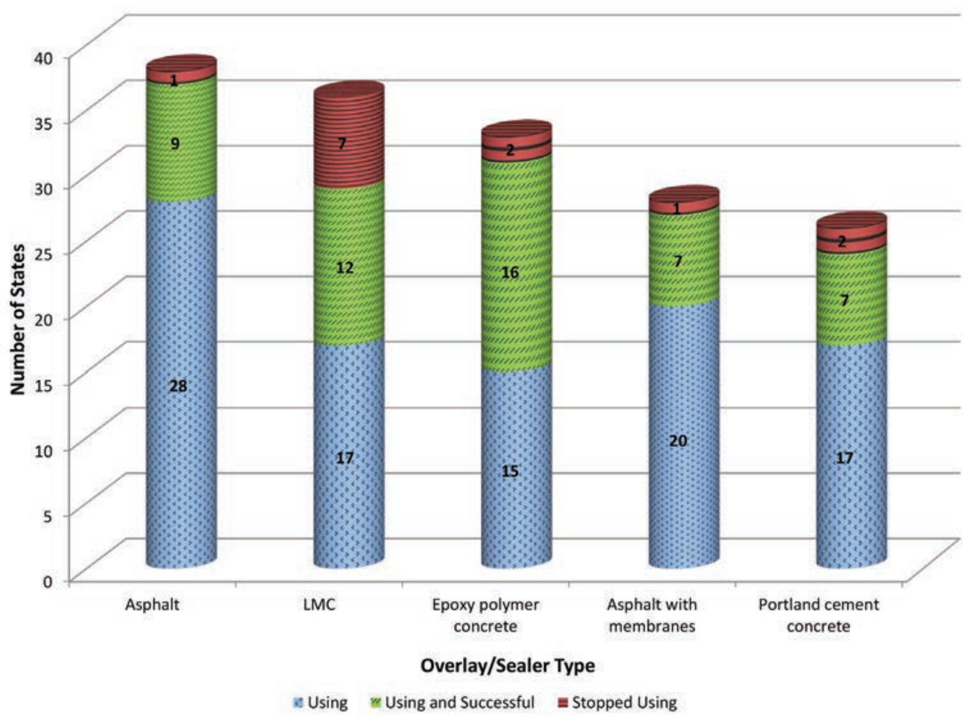


Figure 2. Usage distribution of asphalt, LMC, epoxy polymer, membranes, and portland cement by State transportation departments as of 2013.



LMC Overlays

The American Concrete Institute defines *latex* as "a dispersion of organic polymer particles in water" and further defines *LMC* as "hydraulic cement and aggregates combined at the time of mixing with organic polymers that are dispersed or redispersed in water."[5,6]

LMC overlays typically differ from conventional concrete in the following ways:

- LMC overlays contain a latex admixture, typically consisting of styrene-butadiene polymers in an emulsion.[7]
- The latex admixture has separate specifications, such as the combination of ASTM International standards ASTM C1438 and ASTM C1439, or the prequalification requirements in FHWA Report FHWA-RD-78-35.[8,9,7]
- The water content of the latex emulsion is counted as part of the water in the concrete mixture.[6,10]
- Air entraining admixtures are not typically used in LMC. "Latex loses its stability with air entrainment; hence, no air entraining admixture is used .... In fact, it is a good idea to add an anti-foamer to the latex before placing it in the mixer."[11]
- A mobile mixer is typically used for mixing the LMC.
- LMC overlays are typically moist-cured for a period of hours (such as 48 to 60 h), and then air-cured until the required concrete compressive strength is reached. Conventional concretes are typically moist-cured for the entire curing period.[6]

One major benefit of using LMC overlays is the performance. LMC overlays have much lower chloride permeability than conventional concretes.[7] However, one challenge in using an LMC overlay is the comparatively longer time that it takes for an LMC overlay to attain the required strength for opening the bridge to traffic.[4]

LMC overlays were developed prior to low slump and silica fume overlays. Both of these later overlay types are generally less costly than LMC. All three overlay types require specialized equipment. LMC overlays require mobile mixers, low slump overlays require special vibrating finishing screeds, and silica fume overlays require bagged additions of silica fume to the ready-mix concrete truck or a special storage tank at the concrete plant. Some State specifications allow the contractor to choose either LMC overlays or one of the other overlay types, and those States that allow this choice might have stopped using LMC overlays because of contractor choice of the least costly option. That could mean that LMC overlays had good performance but their use was stopped for reasons other than performance. Some of the more recent LMC overlay mixes have very rapid curing, so a resurgence of LMC overlays is possible even though the cost may be higher because the reduced curing time allows vehicles to drive on the overlay sooner and therefore may justify increased usage of LMC overlays.

As seen in figure 2, 36 of 52 State transportation departments have used LMC overlays. Of these 36 States, 12 rated the use of LMC as successful, while 7 States had stopped using LMC overlays.

Epoxy Polymer Concrete Overlays

For cast-in-place concrete decks, the binder used in the concrete mixture to hold the other ingredients together is portland cement. However, in polymer concrete overlays, portland cement is not used as the binder—polymers are used as the binder.

Polymers are substances made up of monomers chemically bonded together. A *monomer* can be defined as "an organic molecule of relatively low molecular weight that creates a solid polymer by reacting with itself or other compounds of low molecular weight or both."[12] When monomers of low molecular weight chemically react together, they form a polymer. This polymer has the same chemical makeup and proportion of constituent ingredients as the monomers, but it has high molecular weight.[12]

The molecules of polymers can react together chemically to form prepolymers. Hundreds or thousands of polymers can be linked together to form a prepolymer. Prepolymers can then be combined to form a viscous or soft solid substance known as a resin. The resin is then partnered with a particular curing agents (hardening agents) to react together to form the final polymer binder of a higher molecular weight. When aggregates are added to the binder, a polymer concrete is formed.[12,13,14]

The type of binder used to create the polymer defines the name and material properties of the resulting polymer. Four main types of binders are used in polymer concrete overlays: epoxies, polyesters, polyurethanes, and methacrylates.[13] Material properties for two types of polymer overlays, epoxy polymer concrete and polyester polymer concrete (see page 8), are provided in table 1.

The epoxy polymer forms the binder for this type of concrete overlay. The binder actually consists of two components blended together—a component with the epoxy resin and a component with the curing (or hardening) material. The aggregates are then added to form the concrete overlay. Typically, no primers are required for this type of overlay.[13]

As seen in table 1, epoxy polymer concrete overlays have short working lives (30 to 60 min) and short curing durations (about 3 h). They also provide good compressive strengths (approximately 5,000 psi). Therefore, one benefit of this type of overlay is that the roadway can be opened to traffic rather quickly after placement. Another benefit is that "cured epoxy binders are resistant to water, deicing chemicals, dilute acids, gasoline, and other petroleum products."[13] These overlays are relatively easy to place, typically using a broom and seed method, which consists of repeating layers of resin and coarse aggregate placed until the specified thickness is reached.[15] However, these overlays are thin (0.25- to 0.5-inch thickness), and their life may be limited because of high traffic volume and studded tire or tire chain use.

As seen in figure 2, 33 of 52 State transportation departments used epoxy polymer concrete overlays. Of these 33, 16 States rated the use of epoxy polymer concrete overlays as successful, and 2 States had stopped using epoxy polymer concrete overlays.

Membranes (Used With Asphalt Overlays)

Membranes are used on bridges by State transportation departments primarily for waterproofing decks, and many States use them in

Table 1. Typical properties of polymer binders and polymer concretes.[13]

Property	Epoxy Polymer Concrete	Polyester Polymer Concrete
Viscosity of binder	200 to 2,000 cP	200 to 2,000 cP
Working life (gel time)	30 to 60 min	10 to 60 min
Curing time of concrete	3 h at 70 °F	1 to 5 h
Bond strength of concrete	1,500 psi	1,500 psi
Compressive strength of concrete	5,000 psi	4,000 psi
Flexural strength of concrete	2,000 psi	2,000 psi
Modulus of elasticity of concrete, compressive	0.9 to 1.5 x 10^5 psi	n/a
Modulus of elasticity of concrete, tensile	n/a	0.9 to 1.5 x 10^5 psi

n/a = Not available at this time.
cP = centipoise.

conjunction with asphalt overlays. The typical membrane-overlay system consists of the following layers:

1. **Primer**—Primers (typically with a methacrylate, epoxy, or polyurethane resin) are used to help the membrane bond to the concrete bridge deck effectively.
2. **Membrane**—Either a sheet membrane or a liquid-applied membrane is used for waterproofing.
3. **Tack coat**—Tack coats are used to help the asphalt overlay bond to the membrane.
4. **Asphalt overlay**—The asphalt overlay serves as the wearing surface on the bridge.[16]

Primers typically are liquid and may be applied using a pump or with a squeegee. Surface preparation is necessary so that the primer is applied to a clean, dry deck.[17]

Sheet membranes are applied using either heat (torch-applied) or by using an adhesive coating on the back of the sheet. To cover the entire bridge deck, sheets overlap one another. Care must be taken to ensure that there are no pathways for leakage in the overlapping regions.[17]

Liquid membranes may use a layer of reinforcing fabric. Newer membranes are applied via hand spraying or robotic equipment. The bond of the liquid membrane to the asphalt is key to a successful installation.[16,17]

Some States employ tack coats or tack coats with aggregates spread over them on top of membranes to help achieve bond between the membrane and the asphalt. Care must be taken in both selection of the tack coat to make sure that it bonds well with the membrane and the asphalt and in allowing the tack coat to cure properly.[17]

As seen in figure 2, 28 of 52 State transportation departments used membranes. Of these 28 States, 7 rated the use of membranes as successful, and 1 State had stopped using membranes.

Portland Cement Concrete Overlays

Portland cement concrete overlays are typically the same concrete mixture that is used for the portland cement concrete deck and therefore typically use portland cement as the main binding agent for the overlay. The overlay may or may not have reinforcement in it. If the portland cement concrete overlay is placed concurrently with the deck, then the overlay is said to be "monolithic." If the overlay is placed at a later time than the deck is cast, then the overlay is said to be "integral."[18]

Advantages of using portland cement concrete overlays are that the same materials are used for the reinforced concrete deck and the overlay and that the mechanical and thermal properties of the deck and overlay will be similar. Challenges of using this type of overlay, especially for integral overlays (wearing surfaces), are that the overlay material may shrink differently from the deck itself, and if the deck concrete is providing poor performance, then the overlay of the same type of concrete may display the same poor performance.[4]

As seen in figure 2, 26 of 52 State transportation departments have used portland cement concrete overlays. Of these 26, 7 States rated the use of portland cement concrete overlays as successful, while 2 States had stopped using portland cement concrete overlays.

Silica Fume Concrete Overlays

Silica fume concrete overlays consist of a conventional concrete mixture with silica fume (microsilica) added to the mixture. The silica fume may be added as a supplement to the portland cement in the mixture, or it can be used as a replacement for part of the cement in the mixture. In addition, there may be a change in the amount of water in the mixture compared with conventional concretes. A State transportation department may keep the same amount of water for the mixture or may reduce the amount of water in the mixture—this depends on the water-to-cementitious materials ratio the State is trying to achieve and on whether or not the silica fume is added as a supplement or as a replacement for the cement. Curing of silica fume overlays may take 7 or more days.[19,20]

One primary benefit of a silica fume overlay is that it typically has a very low permeability. The challenges of using silica fume overlays are that they are a somewhat stickier mixture while mixing and placing the overlay, and they require special curing procedures to reduce shrinkage cracking of the overlay.[4] In addition, silica fume overlays require bagged additions of silica fume to the ready-mix concrete truck or a special storage tank at the concrete plant.

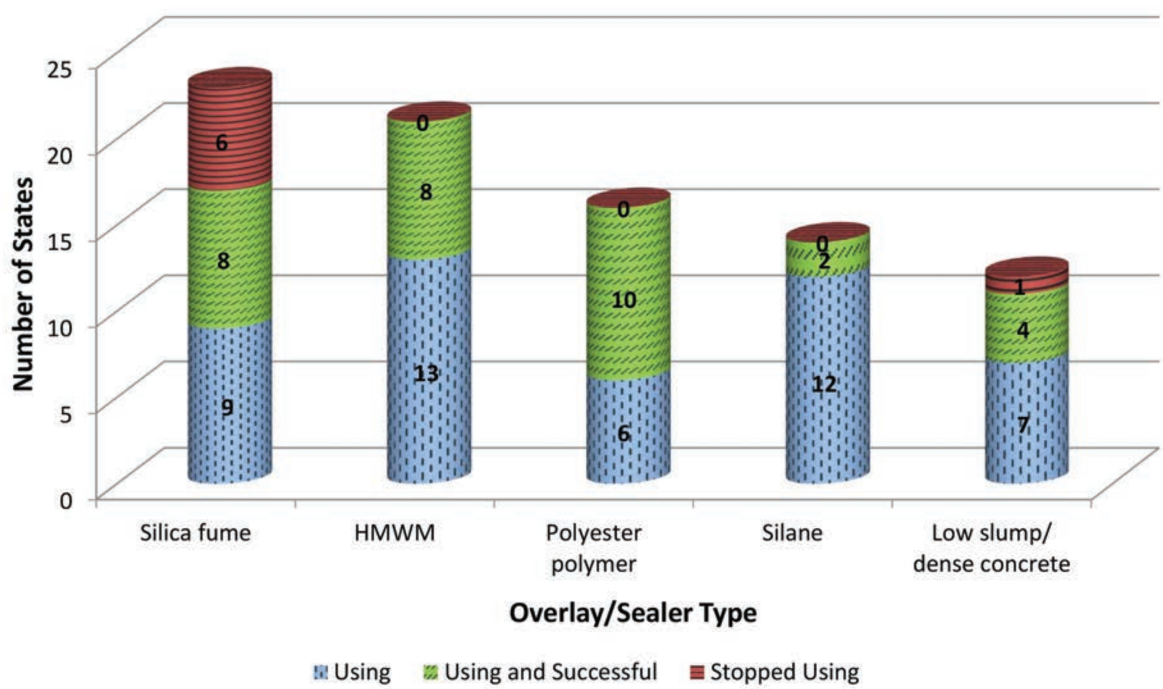
As seen in figure 3, 23 of 52 State transportation departments used silica fume overlays. Of these 23 States, 8 rated the use of silica fume overlays as successful, while 6 States had stopped using silica fume overlays. This statistic may not be reflective of poor performance but may be because of relatively long curing times for silica fume concrete overlays (days) compared with the epoxy polymer and polyester polymer overlays (hours).

HMWM Sealers, Prime Coats, and Polymer Concrete Overlays

HMWM resin is a chemical that is used by State transportation departments as a surface sealer for concrete bridge decks, as a crack sealer for concrete bridge decks, as a prime coat (bond coat) placed on a concrete bridge deck before a polyester polymer overlay is put in place, and as a polymer concrete overlay. HMWM resin systems can be "…a three component product composed of a monomer, a cumene hydroperoxide initiator and a cobalt naphthenate promoter."[21] They can also be a two-component system, with the promoter included with the resin (a promoted resin) and an initiator.[13]

In terms of benefits, "HMWM resins have been effective, when applied properly, in bonding and preventing infiltration of deicing solutions into both wide and hairline cracks."[4] In terms of cautions, HMWM is sensitive to temperature, and it produces airborne emissions.[22] At least one State required an airborne emissions monitoring plan when it was used.

Figure 3. Usage distribution of silica fume, HMWM, polyester polymer, silane, and low slump/dense concrete by State transportation departments as of 2013.



As seen in figure 3, 21 of 52 State transportation departments used methacrylate as a surface sealer, as a crack sealer, as a prime coat, or in a polymer concrete overlay. Of these 21 States, 8 rated the use of methacrylate as successful, and no States had stopped using methacrylate. Successful use as a sealer should not be inferred as successful use in a polymer concrete overlay because the product performance may differ in some States.

Polyester Polymer Concrete Overlays

The polyester polymer forms the binder for this type of concrete overlay. The binder actually consists of two components blended together—a component with the polyester resin and a component with the hardening material (also called an initiator). The aggregates are then added to form the concrete overlay.(13)

As seen in table 1, polyester polymer concrete overlays have short working lives (10 to 60 min) and short curing durations (1 to 5 h). The working life of polyester polymer concrete overlays "...can be easily adjusted to almost any range by varying the amount of initiator and promoter."(13) Temperature also plays a role in working life: "...as a general rule, polyester [polymer concrete overlays] should not be used at application temperatures below 50 °F... unless recommended by the manufacturer."(13) Polyester polymer concrete overlays also provide good compressive strengths (approximately 4,000 psi). Therefore, one benefit of this type of overlay is that the roadway can be opened to traffic rather quickly after placement. Another benefit is that "cured polyester binders are resistant to water, deicing chemicals, dilute acids, gasoline, and other petroleum products."(13)

Primers must be used for this type of overlay. In addition, care must be taken while mixing the polyester binders because both the polyester resin and the hardening agent are flammable. "Inert liquids or fillers are incorporated by the manufacturer to minimize the explosion hazard."(13) These materials are normally premixed and placed in thicker layers (0.5- to 1-inch layers) than epoxy polymer overlays and therefore have the potential to last longer.

As seen in figure 3, 16 of 52 State transportation departments used polyester polymer concrete overlays. Of these 16 States, 10 rated the use of polyester polymer concrete overlays as successful, and no States had stopped using polyester polymer concrete overlays.

Silane Sealers

Sealers for concrete bridge decks are available in two main types: penetrating sealers and film-forming sealers. The penetrating sealers travel down into the pores of the concrete surface, whereas film formers create a layer or film over the deck that prevents water and chloride ions from entering the concrete deck. The challenges with the penetrating sealer are how deep they are able to penetrate, and some have volatile organic compounds contained within them. The challenges with film formers are a potential reduction in skid resistance on the deck, and they may wear out owing to abrasion from vehicles.(23)

Silane is a penetrating sealer and is actually deemed a reactive penetrant sealer because silane reacts with the concrete and forms a layer that resists water entering the pores.(23)

In terms of performance, silane sealers have been noted as good performers. "Although silanes and siloxanes have similar water repellent abilities, silane molecules are smaller than siloxane molecules, so they penetrate deeper into the concrete. Therefore, they provide longer-lasting protection to concrete exposed to abrasion. The higher the solids content of silanes, the deeper the penetration and the better the performance."(23)

As seen in figure 3, 14 of 52 State transportation departments used silane sealers. Of these 14 States, 2 rated the use of silane sealers as successful, and none of the 14 States had stopped using silane sealers.

Low Slump Concrete Overlays

Low slump concrete overlays are also known as low slump dense concrete overlays. State transportation departments may have a specification prescribing the mix ingredients or may have a performance-based specification for the overlays. Slumps for this type of overlay are generally less than or equal to 1 inch, and a mobile mixer is frequently used.

Low slump dense concrete overlays typically have lower permeabilities than conventional concretes. However, low slump dense concrete overlays have long cure times and may be difficult to place.[4]

As seen in figure 3, 12 of 52 State transportation departments used low slump concrete overlays. Of these 12 States, 4 rated the use of low slump concrete overlays as successful, while 1 State had stopped using low slump concrete overlays.

How the States Evaluated Overlays and Sealers

While all States used visual inspection to evaluate bridge decks and bridge deck overlays, some States implemented additional measures when they suspected a problem. As seen in table 2, the predominant method of assessing bridge decks and overlays after or concurrent with a visual inspection was by chain drag and/or hammer sounding.

The following six different types of nondestructive evaluation techniques were used by the States: ground penetrating radar (GPR), infrared thermography, high-resolution imaging, electrical resistivity (ER), a nuclear density gauge, and impact echo (IE).

Conclusions

Many different types of overlays were used on bridge decks for the 52 State transportation departments. This document focuses on the current use (as of August 2013) of overlays and sealers, as well as the methods of evaluation employed by the State transportation departments. This information will be used in planning upcoming evaluations of bridges with treated decks as part of FHWA's LTBP Program.

Table 2. Methods of evaluating bridge deck overlays and sealers as of 2013.

Evaluation Method	Number of States Using This Method
Visual inspection	52
Chain drag/hammer sounding	23
GPR	13
Infrared thermography	9
Cores	9
Measurement of chloride	5
High-resolution imaging	3
Maintenance personnel's observations	3
Measurement of ER and creation of a map of values	2
Crack density	2
Nuclear density gauge	2
IE	1

References

1. Hooks, J. and Frangopol, D., *LTBP Bridge Performance Primer,* Report No. FHWA-HRT-13-051, Federal Highway Administration, Washington, DC, 2013.
2. Brown, M., Gomez, J., Hammer, M., and Hooks, J., *Long-Term Bridge Performance High Priority Bridge Performance Issues*, Report No. FHWA-HRT-14-052, Federal Highway Administration, Washington, DC, 2014.
3. Federal Highway Administration, *TechBrief: FHWA LTBP Workshop to Identify Bridge Substructure Performance Issues*, Report No. FHWA-HRT-13-049, Federal Highway Administration, Washington, DC, 2013.
4. Krauss, P., Lawler, J., and Steiner, K., *Guidelines for Selection of Bridge Deck Overlays*, Sealers and Treatments, NCHRP Project 20-07, Task 234, National Cooperative Highway Research Program, Transportation Research Board, Washington, DC, 2009.
5. American Concrete Institute, *ACI Concrete Terminology*, ACI CT-13, American Concrete Institute, Farmington Hills, MI, 2013.
6. American Concrete Institute, *Specification for Latex-Modified Concrete Overlays*, ACI 548.4-11, American Concrete Institute, Farmington Hills, MI, 2011.
7. Clear, K. and Chollar, B., *Styrene-Butadiene Latex Modifiers for Bridge Deck Overlay Concrete*, Report No. FHWA-RD-78-35, Federal Highway Administration, Washington, DC, 1978.
8. ASTM C1438-13, *Standard Specification for Latex and Powder Polymer Modifiers for Use in Hydraulic Cement Concrete and Mortar*, ASTM International, West Conshohocken, PA, 2013.
9. ASTM C1439, *Test Methods for Evaluating Latex and Powder Polymer Modifiers for Use in Hydraulic Cement Concrete and Mortar*, ASTM International, West Conshohocken, PA, 2013.
10. Sprinkel, M., *Technical Assistance Report—Very-Early-Strength Latex-Modified Concrete Overlay*, Publication Number TAR 99-TAR3, Virginia Transportation Research Council, Charlottesville, VA, 1998.
11. Concrete Construction Staff, "Latex Modified Concrete for Resurfacing," *Concrete Construction*, The Aberdeen Group, Rosemont, IL, April 1961.
12. American Concrete Institute, *Guide for the Use of Polymers in Concrete,* Publication No. ACI 548.1R-09, American Concrete Institute, Farmington Hills, MI, 2009.
13. American Concrete Institute, *Guide for Polymer Concrete Overlays*, Publication No. ACI 548.5R-94, American Concrete Institute, Farmington Hills, MI, 1994 and 1998 (Reapproved).
14. International Union of Pure and Applied Chemistry, *Compendium of Chemical Terminology*, 2d Ed. ("Gold Book"), compiled by A.D. McNaught and A. Wilkinson, Blackwell Scientific Publications, Oxford, 1997, XML online corrected version available at: http://goldbook.iupac.org (2006–), created by M. Nic, J. Jirat, B. Kosata; updates compiled by A. Jenkins, last accessed August 25, 2016.
15. Dinitz, A., "Polymer Overlays Lengthen Bridge Life," *Public Works Magazine*, 2006, obtained from: http://www.pwmag.com/roadways/bridges-culverts/polymer-overlays-lengthen-bridge-life_o, last accessed August 25, 2016.
16. Russell, H., *Waterproofing Membranes for Concrete Bridge Decks*, NCHRP Synthesis 425, National Cooperative Highway Research Program, Transportation Research Board, Washington, DC, 2012.
17. Larson, R., *Lessons Learned on Bridge Deck Membrane Failure*, presentation at Oregon Department of Transportation Annual Project Manager Meeting, 2016, https://www.oregon.gov/ODOT/HWY/CONSTRUCTION/docs/pm_meeting/2016/02C_Bridge%20Membrane_Ron.pdf, last accessed August 25, 2016.
18. Federal Highway Administration, *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges*, Report No. FHWA-PD-96-001, Federal Highway Administration, Washington, DC, 1995.

19. Ozyildirim, C., "Ensuring High Quality Silica Fume Concrete Overlays," *Proceedings of the Fifth International Conference on Fly Ash, Silica Fume, Slag, and Natural Pozzolans in Concrete*, ACI SP-153, Paper SP 153-35, American Concrete Institute, Milwaukee, WI, 1995, pp. 675–686.

20. Sprinkel, M., "Rapid Concrete Bridge Deck Overlays," *Frontiers in the Use of Polymers in Concrete*, Publication No. ACI SP-278, Paper SP 278-9, American Concrete Institute, Farmington Hills, MI, 2011.

21. Marks, V.J., *High Molecular Weight Methacrylate Sealing of a Bridge Deck*, Final Report for Iowa DOT Project HR-2013 and FHWA Project DTFH71-86-948-IA-24, Iowa Department of Transportation, Ames, IA, 1988.

22. Rahim, A., Jansen, D., Abo-Shadi, N., and Simek, J., "Overview of High-Molecular-Weight Methacrylate for Sealing Cracks in Concrete Bridge Decks," *Transportation Research Record: Journal of the Transportation Research Board No. 2202*, Transportation Research Board, Washington, DC, 2010, pp. 77–81.

23. McGovern, M., "A Clear View of Sealers," *Concrete Construction*, The Aberdeen Group, Rosemont, IL, January 2000.

Researchers—The study was performed by Federal staff of the LTBP Program in conjunction with the LTBP State coordinators in each of the 50 States, the District of Columbia, and Puerto Rico. For additional information, contact Frank Jalinoos, in the FHWA Office of Infrastructure Research and Development, located at 6300 Georgetown Pike, McLean, VA 22101-2296.

Distribution—This summary report is being distributed according to a standard distribution. Direct distribution is being made to the Divisions and Resource Center.

Availability—This summary report may be obtained from the FHWA Product Distribution Center by e-mail to report.center@dot.gov, fax to (814) 239-2156, phone to (814) 239-1160, or online at http://www.fhwa.dot.gov/research.

Key Words—LTBP Program, bridge, bridge deck, bridge preservation, bridge maintenance, overlay, sealer, wearing surface.

Notice—This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The U.S. Government assumes no liability for the use of the information contained in this document. The U.S. Government does not endorse products or manufacturers. Trademarks or manufacturers' names appear in this report only because they are considered essential to the objective of the document.

Quality Assurance Statement—The Federal Highway Administration (FHWA) provides high-quality information to serve the Government, industry, and public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. FHWA periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.

OCTOBER 2017

FHWA-HRT-16-079
HRDI-50/10-17(WEB)