Keweenaw Research Center

Field Performance of Polymer Bridge Deck Overlays in Michigan

Final Report

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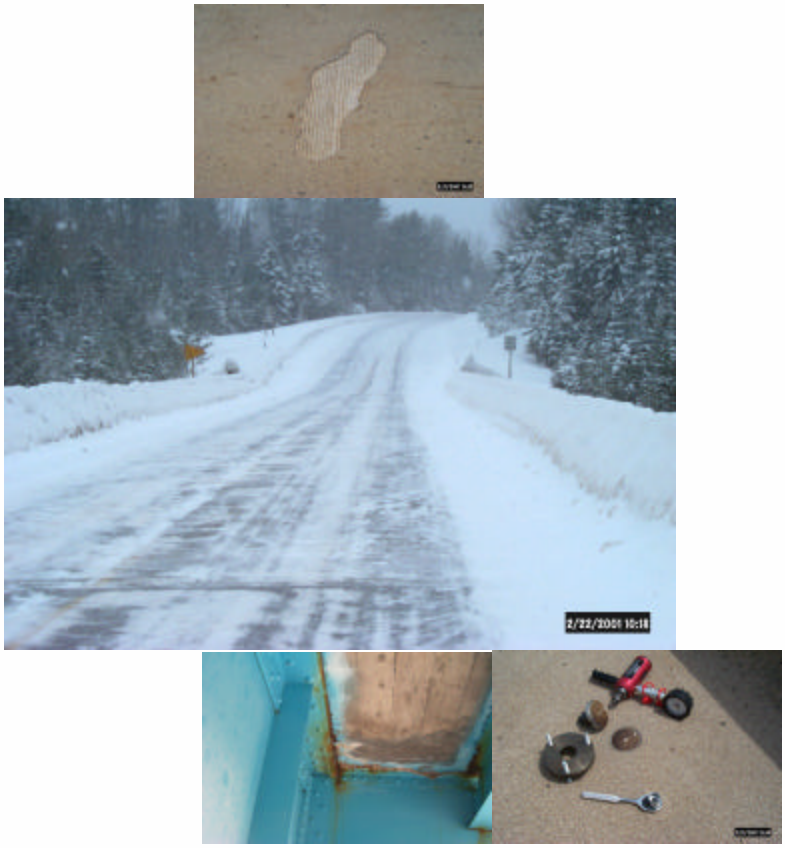

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16. Abstract

The study contained in this report is an overview of the history of elastomeric coatings, a survey of current use, and a field survey of existing coated structures. An extensive literature search is made to determine some of the past experiences and changes in the technology. A survey of existing structures in Michigan is also made prior to a field investigation of several bridges within the state to determine how well these overlays are holding up as well as an investigation of possible "anti-icing" characteristics of the coatings. Finally, an attempt to determine the cost benefits of use is made.

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Executive Summary

Over the past 5 years, the use of elastomeric overlays on bridges has become more common, especially in Michigan. During this period, there have been changes in the materials used, and the methods to apply these overlays has been fine tuned to make installation quite easy and efficient.

The study contained in this report is an overview of the history of elastomeric coatings, a survey of current use, and a field survey of existing coated structures. An extensive literature search is made to determine some of the past experiences and changes in the technology. A survey of existing structures in Michigan is also made prior to a field investigation of several bridges within the state to determine how well these overlays are holding up as well as an investigation of possible "anti-icing" characteristics of the coatings. Finally, an attempt to determine the cost benefits of use is made.

There have been numerous improvements in the materials used, both binders and aggregates, especially over the past 5 years. Pre-application conditioning of the pavement surface, as well as methods of application have also been improved. Within the scope of this study, there appears to no measurable benefit for the standard overlay for "anti-icing." If these overlay systems hold up for 15 years or more, (as expected) this technology will be very beneficial. The benefits include the potential elimination of surface spalling of concrete decks and intrusion of moisture and chlorides into the deck. The project also has the potential to be re-coated quite easily during it's service life extending the usefulness for another 15 plus year period.

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Introduction

The study of various methods to seal pavement surfaces, especially bridge decks, has been ongoing for over 25 years. Field experience and research have developed methods and materials that make these coatings quite effective for protecting and extending the service life of pavements and bridge decks. Over the years many different thin coat binders have been researched and used in an effort to maximize interfacial bonding. Numerous types of aggregate materials have also been studied to enhance surface wear and surface friction characteristics of the systems.

This report contains the results of a study of past and present experiences with thin epoxy bridge deck overlays. It is centered in Michigan, but has references from as many other states as information could be obtained. The study was carried out by the use of 3 separate methods. First, an extensive literature search was performed to determine past experiences and research. Second, a survey was sent to the regions within Michigan to obtain information on projects within the state. Third, a field survey of a representative number of coated bridge decks in Michigan was made by the authors. Coupled with the field survey, an attempt to correlate winter maintenance benefit to these coatings, was made.

Finally, in the conclusions section of this report, a discussion of cost benefits of these overlays is made.

Background

The search for methods to extend the service life of bridges has been ongoing for decades. This research has resulted in several techniques that include modified concretes, coated reinforcing bars, asphalt overlays, epoxy overlays, methacrylate sealers, and many others. This report, for the most part, will concentrate on the use of thin epoxy overlays and be focused mostly on their use of these on bridge decks. Appendix A of this report contains an MDOT special provisional for this process.

Most of the research and field testing of overlay systems has evolved for use on bridges. This stems from the fact that bridges are not only expensive to build initially, but to maintain and repair throughout their service life.

The overlays discussed here are not intended to add any structural strength integrity to the pavement system. Therefore, there is no benefit to added strength from a design sense. The mechanism for failure of PCC pavements and bridge decks is the minimization of intrusion of water and chemicals into the concrete. It is well known that if liquid water is allowed to infiltrate the system, it can collect in the pore structure of the concrete, and promote deterioration through freezing and thawing. This deterioration rapidly accelerates as more water moves in the cracks as they are formed. Chemical intrusion will degrade not only the cement paste itself, but contact with steel reinforcing bars will propagate accelerated corrosion, deterioration, and failure of the reinforced structure.

The overlays discussed in this report are designed to be impermeable to water as well as resilient to the types of chemicals that can be expected to be introduced on the surface. These can include deicers, petroleum products from vehicles, and some cleaners. The evolution of these overlays has seen improvements in the binders used to incorporate high bond strength, flexibility, and a large range of expansion and contraction without cracking. Methods to apply these systems as well as specifications for the binder and the aggregates used have also evolved.

Results of Literature Search

A detailed national and international literature search was conducted to synthesize state-of-the-practice, materials, and technologies related to polymer concrete overlays and their constituent materials. The key issues that were addressed included; (1) justifications for the overlay, (2) criteria for selecting potential candidates for overlays, and (3) appropriate timing for the overlay. The literature review was conducted through NERAC and through Michigan Technological University's Library search engines. This section contains the names of the reports and papers with pertinent information from each.

Polymer Impregnation of New Concrete Bridge Deck Surfaces. Interim User's Manual of Procedures and Specifications
AEO 76-00 7632594N NDN- 011-0028-4022-3
Smoak, W. G.
DOCUMENT TYPE- TECHNICAL REPORT
REPORT NUMBER(S)- PB-252422/1; FHWA/RD-75-72
YEAR: 1975

Overview: This report is a manual for newly constructed bridges not previously contaminated by chlorides. This is an attempt to minimize chloride intrusion into concrete resulting in corrosion of reinforcing steel. The concrete bridge deck surfaces were impregnated with Methl-methacrylate monomer (~ 1 inch depth). This included four basic steps, including; 1. Surface preparation of concrete to remove contaminants. This will include high pressure steam cleaning and sand blasting of the surface. 2. Dry the concrete to a greater depth than coating penetration, otherwise unreliable and inconsistent results occur. This can be accomplished by using an open flame, gas fired or electric IR or forced hot air and will require approximately 1100 to 1400 BTU/ Sq. ft. heater capacity to achieve approximately 1% moisture by weight which is required for good bonding. 3. Impregnate the concrete with liquid monomer at 96% MMA and 5% Trimethylolpropene Trimethacrylate (TMPTMA) by weight. Note that impregnation is sensitive to solar radiation. 4. Polymerization of monomer in concrete.

Field Evaluation of Concrete Polymerization as a Bridge Deck Seal
AEO 76-00 7622602N NDN- 011-0026-4191-3
Horn, M. W.; Stewart, C. F.
DOCUMENT TYPE- TECHNICAL REPORT
REPORT NUMBER(S)- PB-247464/1; CA-DOT-ST-4174-1-74-4
YEAR: 1974

Overview: Although the bridge deck was originally sealed with a Chipseal, which showed that tire chains and plow blades removed most of it in 2 years, the purpose of this project was to determine if a polymer type material would provide effective barrier for salt. Two monomers were chosen for the testing. The first was Styrene and the second was Methyl-methacrylate. It was found that rollers and squeegees were not a dependable method for impregnation and that oils need to be completely removed. Also, no monomers were detrimental to friction as long as sand is applied, therefore, resistance testing may not be good criteria for evaluation. It was also determined that under surface fractures are not re-bonded when monomer is applied and the flammability and biological properties of monomers require safety precautions.

Premixed Epoxy Polymer Concrete Bridge Deck Overlays
CAS 128-03 128-025998 128:025998 NDN- 127-0213-6563-0
Dimmick, Floyd E. Sr.
ABBREVIATED JOURNAL TITLE- Am. Concr. Inst., SP
VOL. SP-169
VOLUME TITLE- In-Place Performance of Polymer Concrete Overlays
YEAR: 1997

Overview: This article is an overview of methods of applications and what was found to be important to get an overlay to perform properly. The first part of the article looked at the two methods of mixing the epoxy with or without the aggregate. The first involved the use of vehicles similar to concrete trucks, which automatically mix the material. The second utilized a concrete drum mixer. Methods of placement were discussed next and included use of power, manual, and static screeding. Power screeding is defined as a self powered moveable screed. Manual screeding was accomplished using a straight edge and guides and static screeding was performed with a screed bar and guides where the aggregate was applied behind the bar utilizing the broadcast method of aggregate dispersion thus eliminates troweling.

The author defined "micro-thin overlays" as 6 to 31 mm (¼ –1¼ inches) thick. Non-broadcast mixes were found to be not self-leveling. Broadcast mixes were found to be self-leveling and could contain smaller and medium size aggregates in mixture, however, large aggregates needed to be added by broadcast. Overlays that are not of similar thermal expansion properties and static Modulus of Elasticity will move at different rates and fracture (5-10% tensile elongation at best).

A Study of Deterioration in Concrete Bridge Decks
AEO 79-00 7922343N NDN- 011-0045-8477-5
NO-AUTHOR
DOCUMENT TYPE- TECHNICAL REPORT
REPORT NUMBER(S)- PB-291937/1; MCHRP-62-1; FHWA/MO-62/1

Overview: Report done by the Missouri State Highway Department of Materials and Research. In the 1950's bridge decks exhibited scaling and fracture plane deterioration (or spalling). This was believed to be due to salt. Linseed oil was used as a sealant. Air entrained concrete was used on all pours. Epoxy resin and linseed oil verses 5 applications of Linseed oil showed no difference in preventing concrete scaling.

Experience with Epoxy Polymer Concrete Bridge Deck Thin Overlays in Service for over 10 Years
CAS 128-03 128-025996 128:025996 NDN- 127-0213-6561-6
Nabar, Shree; Mendis, Peter
ABBREVIATED JOURNAL TITLE- Am. Concr. Inst., SP
VOL. SP-169
VOLUME TITLE- In-Place Performance of Polymer Concrete Overlays
YEAR: 1997

Overview: The authors found many factors that increase the quality and service life of overlays. This included the importance of proper surface preparation and quality control during application. This was found to be critical to the success and durability. Two types of overlays were used. The first, a Polymer Concrete, is a composite formed by aggregate with polymeric binder, formed by polymerizing monomer or reacting resins and hardeners. (In this paper "binders" are defined as epoxies, polyesters, polyurethanes and methyl-methacrylate ~.375" thick). The second, a Latex-modified concrete (water causes hydration of hydraulic cement) is applied approximately 1.5-2.0" thick. The authors found aggregates with high percentage of aluminum oxide offer the best performance for friction and skid resistance and aggregates must have high compressive strength, be non-friable, non-expansive and resist polishing. In multiple layer and slurry methods of application, aggregate is broadcast. Also noted was to cure new concrete 28 days before applying coating and the preferred method of surface preparation is shot-blasting. The surface was clean enough if following ACI 503R, App. A of ACI Manual of Concrete Practice.

The authors also identified four types of failures. The first was a delamination/debonding caused by improper or inadequate surface preparation or thickness over ½ inch. The second was cracking caused by the presence of large or moving cracks in the concrete, which will cause reflective cracking in overlays. The third was increased porosity caused by voids, created by shrinkage of binder due to solvents or thinners, or pop-outs caused by wet or damp aggregates. The final one was loss of skid resistance caused by aggregate type where gradation is a major contributing factor

Overlay Materials for Bridge Decks
EIX 91-10 EIX91100121158 NDN- 017-0158-1718-4
Calvo, Luis; Meyers, Martin
DOCUMENT TYPE- JA, Journal Article
MONTHLY PUBLICATION NO.- 116901
JOURNAL NAME- Concrete International: Design and Construction
YEAR: 1991

Overview: This two page magazine article is an overview of the technology in 1991. It included information on the Slurry Method and rates and the Broadcast Method and rates.

Evaluation of Thin Lift Polymer Bridge Deck Overlays on I-57 Bridges at Clifton, IL. Construction Report.
USG 00-07 PB2000-102467/XAB NDN- 059-0210-2452-4
Pfeifer, B. A.; Kowlaski, G.
DOCUMENT TYPE- Physical research report.
REPORT NUMBER(S)- PHYSICAL/RR-132IL-PRR-132
YEAR: 1999

Overview: The authors noted chlorides in deck before application. They also used what they referred to as "broom and seed" method (same as the broadcast method) and that it seemed to work well. The report concluded that; 1. If applied correctly, polymer overlay systems can yield an impermeable and durable surface with high skid resistance to 15 years. 2. Polymer is lighter than conventional overlays and can open to traffic sooner. 3. Decreased dead loads. 4. To apply properly, contractors must be trained.

Bond Characteristics of Overlays Placed over Bridge Decks Sealed with HMWM or Epoxy.
USG 99-15 PB99-140865/XAB NDN- 059-0207-3384-9
Shahrooz, B. M.; Gillum, A. J.; Cole, J.; Turer, A.
DOCUMENT TYPE- Final report.
REPORT NUMBER(S)- UC-CII-98/02
YEAR: 1998

Overview: Study involved field and lab tests of cores under direct shear, SHRP interfacial specimens, beams and 1/3 scale bridge. Three overlays were tested including micro-silica modified concrete (MSC), super dense plasticized concrete (SDC), and latex modified concrete (LMC). The data suggests sealers at the interface reduce bond strength. This included both the epoxy resin and the high molecular weight methacrylate (HMWM) sealers. The magnitude of the strength reduction depended on the HMWM sealer manufacturer and the moisture level for both the epoxy and HMWM sealers. The Hydrodemolition provided greater bond strength than mechanical chipping (33% greater). The study recommends additional surface preparation to increase the bond strength, such as sandblasting or sand broadcasting.

Extended Evaluation of Selected Bridge Deck Protection Systems.
USG 96-07 PB96-139746/XAB NDN- 059-0188-1791-0
Hagen, M. G.
DOCUMENT TYPE- Final report. 1981-90.
REPORT NUMBER(S)- MN/RD-95/33
YEAR: 1995

Overview: Evaluation of bridge deck protective systems to reduce the amount of reinforcing steel corrosion, included;
1. Membranes (spray-on and preformed) with bituminous overlay.
2. Modified concrete (latex and low slump) overlays.
3. Coated rebars (galvanized and epoxy).
4. Cathodic protection.

Conclusions:

1. Membranes and bituminous overlays work well at preventing chloride intrusion but showed poor durability.
2. Chloride penetration resistance of latex modified concrete is good.
3. Little corrosion is apparent on new decks with latex modified concrete (LMC) after 16 years.
4. LMC appears to provide better resistance to chloride penetration then low slump dense concrete (LSDC).
5. LSDC considered satisfactory however some delaminations occurred in older decks.
6. In LSDC the half cell values varied somewhat from year to year but below corrosion threshold.
7. No sign of distress on decks with galvanized rebar or epoxy coated rebar.

Thin Polymer Bridge Deck Overlays: WSDOT's Ten Year Evaluation.
USG 95-16 PB95-220257/XAB NDN- 059-0183-1232-0
Wilson, D. L.; Henley, E. H.; Lwin, M. M.
DOCUMENT TYPE- Final report.
REPORT NUMBER(S)- WA-RD-374.1
YEAR: 1995

Overview: The data obtained from testing of WSDOT polymer overlays and information from construction records support the following comments on the performance of Epoxy and Methyl Methacrylate (MMA) overlays; 1. Chloride Permeability tests show that both Epoxy and MMA overlays are very effective in preventing chloride-ion penetration. 2. Epoxy has better initial and long term bonding compared to MMA. 3. MMA has better long term skid resistance compared to Epoxy. 4. MMA and Epoxy are comparable in cost.

WSDOT reported major observations as; 1. The same polymer used in the overlay should be used to repair spalls and delaminations. 2. A prime coat of Epoxy should be applied with an Epoxy polymer overlay. 3. An application of large aggregate (1/2 inch) should be specified. 4. Thin polymer overlays should not be applied using continuous batching machines. 5. Thin polymer overlays are sensitive to moisture before they cure.

Evaluation of Thin Epoxy Systems Overlays for Concrete Bridge Decks.
USG 93-00 PB93-127520 NDN- 059-0164-9868-0
Rasoulian, M.; Rabalais, N.
DOCUMENT TYPE- Final report. May 85-Dec 91.
REPORT NUMBER(S)- RR-243
YEAR: 1991

Overview: Report based on four sealing systems, Dural Flexogrid and basalt aggregate (Dural and Basalt), Poly-Carb Flexogrid Mark 163 with basalt aggregate (Poly-Carb), Con/Chem Cono/Crete 101 mortar system with bauxite aggregate (Cono/Crete), and Dural Flexolith and blasting sand (Dural and sand). Each system performed satisfactorily through installation and the five year evaluation, although Dural and basalt and Poly-Carb seemed to show the most

promising results in terms of bonding, crack resistance, resistance values and ease of installation. The authors recommended that the use of epoxy coated overlays be considered as an alternative to conventional methods of resurfacing deteriorating bridge decks, especially when improving skid resistance is of primary concern.

Results of Regional Surveys

With the assistance of MDOT's regional bridge engineers, a survey was conducted in an attempt to document all current bridge locations, to date, where polymer concrete overlays have been applied onto bridge deck surfaces. The product manufacturer, as well as other material and application related information is also provided in tabular format in the following section by district, but only if the information could be obtained. The items in the tables are as supplied by MDOT personnel.

Table 1. Results from Grand Region.

Bridge Number	Facility	Feature	Year Coated	Epoxy Type	Aggregate	Number of Layers	Comments
41024-S02	Kraft Ave	I-96	2001 May-June	E-Bond 526-Lo-Mod	Quartz Aggregate size 3	2	Just recently applied
54014-S09	M-20	US-131 NB	2001 May-June	Same as above	Same as above	2	Just recently applied
54014-S10	M-20	US-131 SB	2001 May-June	Same as above	Same as above	2	Just recently applied
54014-S11	Woodward Ave	US-131 NB	2001 May-June	Same as above	Same as above	2	Just recently applied
54014-S12	17 Mile Rd	US-131 NB	2001 May-June	Same as above	Same as above	2	Just recently applied
54014-S13	17 Mile Rd	US-131 SB	2001 May-June	Same as above	Same as above	2	Just recently applied
54014-S14	19 Mile Rd	US-131 NB	2001 May-June	Same as above	Same as above	2	Just recently applied
54014-S15	19 Mile Rd	US-131 SB	2001 May-June	Same as above	Same as above	2	Just recently applied
54014-S16	21 Mile Rd	US-131	2001 May-June	Same as above	Same as above	2	Just recently applied

Table 2. Results from Superior Region.

No information was received.

Table 3. Results from Metro Region.

No information was received.

Table 4. Results from University Region.

Bridge Number	Facility	Feature	Year Coated	Epoxy Type	Aggregate	Number of Layers	Comments
23061-R01	I-69 & Billwood Hwy 69	GTW RR	1997	SIKA		2	Applied by contractor. Some Peeling.
23092-B01	M-99 S BD	Skinner Drain	1998	Unitex		2	Holding up well.
23092-B04	M-99 N BD	Skinner Drain	1998	Unitex		2	Holding up well.
23063-R02	I-69 S BD	Over RR & Billwood Hwy	1998	Unitex		2	Some peeling has occurred.
23063-S17	I-69 S	M-100	1998	Unitex		2	Holding up well.
23063-S14	I-69 N BD	I-96	1998	Unitex		2	Peeling From Deck In Several Locations
23063-S15	I-69 S BD	I-96	1998	Unitex		2	Holding up well.
23063-S11	I-69 S BD	Nixon Rd	Nov-98	Akemi/Axson		2	Holding up well.
19042-S10	I-69 Ramp to M-78		1998	Unitex		2	Cracks are showing Needs to be monitered.
19042-S09	I-69 Ramp to Business I-69		1998	Unitex		2	Cracking needs to be monitered.
19033-S11	US-27 S BD	M-21	1998	Poly Carb-3 CTS	2 Apps Washington Stone	3	Holding up well - S end peeled off (driving lane).
23063-S10	I-69	Nixon	1998	Unitex		2	Holding up well.
19043-S15	I-69	Grand River Ave	Jul-99	E-Bond	#3 Quartz (?) From Flat Rock Bagging	2	Holding up well.
19043-S13	I-69 N BD	Turning Roadway	Jul-99	E-Bond	#3 Agg	2	Holding up well.
19043-S20	I-69 E BD	Turner Rd	Jul-99	E-Bond	#3 Agg	2	Holding up well.
19043-S16	I-69 S BD	I-96 E BD & W BD	Jul-99	E-Bond	#3 Agg	2	Holding up well.
19043-S14	I-69 S BD	Grand R Ave	Jul-99	E-Bond	#3 Agg	2	Holding up well.
19043-R01	I-69 S BD	RR	Jul-99	E-Bond	#3 Agg	2	Holding up well.
19042-S15	I-69 W BD	Peacock Rd	Jul-00	Unitex	Chipped Flint	2	Holding up well.
19042-S14	I-69 E BD	Peacock Rd	Jul-00	Unitex	Flint Agg	2	Cracks appearing beneath surface.
76024-S07	I-69 W BD	Bath Rd	Jul-00	Unitex	Flint Agg	2	Holding up well.
76024-S06	I-69 E BD	Bath Rd	Jul-00	Unitex	Flint Agg	2	Holding up well.
76024-S13	I-69 W BD	Shaftsburg RD	Jul-00	Unitex	Flint Agg	2	Holding up well.
76024-S05	I-69 E BD	Shaftsburg RD	Jul-00	Unitex	Flint Agg	2	Holding up well.
76024-S12	I-69 W BD	Colby Lake Rd	Jul-00	Unitex	Flint Agg	2	Holding up well.
76024-S11	I-69 E BD	Colby Lake Rd	Jul-00	Unitex	Flint Agg	2	Holding up well.
76024-B02	I-69 W BD	S. Br Looking Glass River	Jul-00	Unitex	Flint Agg	2	Holding up well.
76024-B01	I-69 E BD	S. Br Looking Glass River	Jul-00	Unitex	Flint Agg	2	Holding up well.
76024-S02	Woodbury Rd	I-69	Jul-00	Unitex	Flint Agg	2	Holding up well.
81063-R01	US-12 E BD	Conrail	Aug-00	Flexolith 216	Flint Agg	2	Holding up well.
38111-B04	US-127 S BD	Grand River	Jul-01	Unitex	Flint Agg	2	
38111-B04	US-127 N BD	Grand River	Jul-01	Unitex	Flint Agg	2	
38111-B03	US-127 S BD	S. Branch Grand River	Jul-01	Unitex	4SB Agg (Flat Rock Bagg.)	2	
38111-B03	US-127 N BD	S. Branch Grand River	Jul-01	Unitex	Flint Agg	2	
38111-R01	US-127 S BD	Conrail & M-50	Jul-01	Unitex	Flint Agg	2	
38111-R01	US-127 N BD	Conrail & M-50	Jul-01	Unitex	Flint Agg	2	

Table 5. Results from Southwest Region.

Bridge Number	Facility	Feature	Year Coated	Epoxy Type	Aggregate	Number of Layers	Comments
13082-S07	I-94	Verona Rd.	1998 Sept	E-Bond	Unknown	2	Looks Good
13082-S07	I-94	15 Mile Rd	1999 July	Unitex	silicas or basalt from Humble Sand Co	2	Looks Good
03023-B03	M-89	Kalamazoo River	1999 August	Unitex	silicas or basalt from Humble Sand Co	2	Looks Good
11057-B01	US-31 SB	St Joseph River	2000 August	Unitex	silicas or basalt from Humble Sand Co	2	Only coated one lane

Table 6. Results from Bay Region.

Bridge Number	Facility	Feature	Year Coated	Epoxy Type	Aggregate	Number of Layers	Comments
06073-B02	US-23	Au Gres R					New thin epoxy overlay in 1998,
							as of 5-'00 overlay peeling at center jt and at end jts.
06072-B03	US-23	Rilfe R					New thin epoxy overlay. 6' round spall in NB lane
09101-S05	Carter Rd	US-10					1997 W lane coated, black silica has been worn off, numerous transv crks & scaling
							w/ map crking. 1999 12SF of repaired spalls
09101-S06	11 Mile Rd	US-10					1997 W lane of span 1 has been coated. 1999 Coating worn off.
							2-10% of surface is spalled or delam.
25042-S08	I-69 EB	Linden Rd					2000 Dk has been coated. Coating has worn off slow lane
25042-S18	I-69 WB	Linden Rd					2000 Dk has been coated. Coating has worn off slow lane
25132-S37	I-475 NB	Maple Rd.					2000- Coated in the past. A few transverse cracks <2% cracking
25132-S38	I-475	Detroit St	1998				1998 New epoxy overlay. 2000 8sqft spall @ W. ref line. <2% of dk is crkd.
25132-S43	I-475 WB	Clio Rd					new epoxy overlay, 2-10% repaired w/concrete-98. 2000 Repaired areas
							+- 100 sqft. open spalls.
32091-B01	M-25	White R					Few transverse cracks. Thin epoxy overlay is wearing off. Long crack at center
44031-B02	M-53	Western Drain					1997 epoxy coat has deteriotated 8 sy ofconc. Patch. Numerous spalls in
							NB &SB lanes and shoulders
44043-B01	I-69 EB	Farmers Ck	1997				1997 Coated - most of granular material has been removed, one conc patch
							near W ref line.
44043-B02	I-69 WB	Farmers Ck	1997				1997 Coated - most of granular material has been removed, one conc patch
							near W ref line.
44043-S06	I-69 EB	M-24					Few trans cracks in deck. Epoxy coated +9 sy patch. Several spalled areas
							and delam around patches
44043-S07	I-69 WB	M-24					Many trans crks (97) Epoxy coat has loss of granular material w/ 84 sy
							conc patch. Numerous spalls, most in east span.
56044-S03	M-30	US-10	1999				1999 Coated. 2-10% of deck has repared spalls.
73021-B04	M-57	Northwood Cr	1999				1999 new coat
73051-B01	M-13	Savage Drain	1999				1999 new coat
73051-B02	M-13	Milks Drain	1999				1999 new coat
73051-B03	M-13	Koepke Drain	1999				1999 new coat
73051-B06	M-13	Cole Drain	1999				1999 new coat
73081-B01	M-81	Blumfield Cr					Recently coated
73081-B02	M-81	Cheboyganing Cr					New coat
73101-R02-1	I-675 NB	CSX RR					1997 Coat- most has wore off Large areas of conc patch before
							coat-surface in good cond. 1999-W2/3 N span patch & asst pothole. (10-25%)
73101-R02-2	I-675 SB	CSX RR					1999 Coating 1/2 complete, rated as done
73101-S07-1	I-675 NB	5TH St					1999 coat worn off, est repairs at 15%
73101-S07-2	I-675 SB	5TH St					1997 4 sy conc. Patch w/epoxy coat-surface in good condition.
							1999- coat worn off
73101-S12-1	I-675 NB	Weiss St					Larged conc patches + epoxy coated-Good Condition 1999 - @ 60 sm
							conc patches,same 2000
73101-S12-2	I-675 SB	Weiss St	1999				1997 conc patch + epoxy sealed -good condition 1999-coat being applied
							at present, rated prior to completion
73101-S13-1	I-675 NB	Schaefer St.					2SY conc patch w/epoxy coat-most of black granular mat scraped
							off by plows.
73101-S14-1	I-675 NB	Shattuck Rd	1999				1999 New coat
73101-S14-2	I-675 SB	Shattuck Rd	1999				1999 New coat
73101-S15	abawassee	I-675					Several trans crks up to 1/16' wide - 1997-Epoxy coat has failed most
							has worn off '99- under 2% concrete patch.
73101-S24	I-695	I-675 & I-75					8 sqyd of spall-shallow to steel along N gutter and some @ S curb at E& W ends.
	Ramp to						Some diagonal crks at corners and few trans crks '99-coat wearing off,
	I-75						rating continued.
73131-B03	M-83	Cheboyganing Cr	1999				1999 New coat, cracks sealed

Table 7. Results from North Region.

Bridge Number	Facility	Feature	Year Coated	Epoxy Type	Aggregate	Number of Layers	Comments
16021-B01	M-68	Sturgeon R	2000	Unitex			
16092-S04	US-31NB	I-75	2000	Unitex			
16093-B01	I-75 SB	Sturgeon R	2000	Unitex			
16093-B02	I-75 NB	Sturgeon R	2000	Unitex			
24011-B01	US-31 & M-68	Bear C	1999	Unitex			
35021-B01	M-55	Au Gres R	1998	Unitex			
35021-B02	M-55	Au Gres R	1998	Unitex			
35031-B01	US-23	Tawas R	1999	E-Bond			
51021-B03	M-55	Pine R	1999				
51031-B01	M-22	Richley C	1999				
53033-B01	US-31	S Br Lincoln R	1999				
57011-B01	M-66	Mid Br Clam R	1999				
57022-B02	M-55	Muskegon R	1999				
60022-B01	M-32	Miller C	1999	E-Bond			
65022-B02	M-55	Au Gres R	1998	Unitex			
67016-B01	US-131 NB	Johnson C	2000				
67016-B03	US-131 N BRMP	Johnson C	2000				
67016-B04	US-131 S BRMP	Johnson C	2000				
67016-R01	US-131NB	CSX RR	2000				
67016-R02	US-131 SB	CSX RR	2000				
67016-R03	US-131N B RMP	CSX RR	2000				
67016-R04	US-131S B RMP	CSX RR	2000				
67016-S09	US-131N B	US-10	2000				
67017-B02	US-131 S B	Hersey C	2000				
67022-B02	US-10	Twin C	1999				
67022-B03	US-10	Muskegon R					
67031-B02	M-66	Muskegon R	1999				
67051-B01	M-115	Muskegon R	1999				
67051-B02	M-115	Middle Branch C	1999				
69014-S06	Alexander Rd	I-75 SB	2000	Unitex			
69014-S07	Alexander Rd	I-75 NB	2000	E-Bond			
72013-S03	Snow Bowl Rd	US-27 SB	2000	Unitex			
72013-S04	Snow Bowl Rd	US-27 NB	2000	Unitex			
72014-B01	US-27 SB	Muskegon R	1998	Unitex			
72014-B02	US-27 NB	Muskegon R	1998	Unitex			
72041-B01	M-18	S Br AuSable R	1998	Unitex			

Field Evaluation

Anti-Icing Characteristics

KRC/MTU personnel conducted field evaluations of several bridge decks throughout the Upper Peninsula during the winter to document whether these polymer concrete overlay systems exhibit potential anti-icing characteristics. These field evaluations were designed to assess the current condition of the coatings, and visually interpreted the coatings potential abilities toward ease of snow removal, frost resistance, and greater winter time skid resistance. Comparisons were based on non-coated decks within the same geographic region as the control. Inspections were performed where the coatings could be seen through the snow, and were also performed as near to a storm event as possible. The note "There was no noticeable difference between the adhesion of the snow between and road and the bridge" is used several times in the following section. This simply means that the coated surface does not show any superior quality to the surrounding un-coated pavement. Additionally, interviews were conducted with respective MDOT maintenance personnel to obtain information related to their practical field experiences regarding snow removal and maintenance of these bridges.

A loop from Calumet to Iron River was traveled in February, 2001 during three different weather events. These events occurred on the 15th, 20th, and 22nd of the month. Seven coated bridges and 14 un-coated bridges were inspected during these days. Although the weather conditions varied throughout the course of the day and at different locations, snow events did exist in the northern portion of the loop. Differences in accumulation and bonding between the bridges and the adjacent road surfaces were noted and some representative photographs of the conditions are shown below. A complete set of photos from this task is contained in the Appendix A (under separate cover) and electronically on a CD named by bridge location. This is a large number of photos. A limited number of these are contained in the following write-up.

B01-66041

The B01-66041 Bridge is located on M-38 over the West Branch Firesteel River 2.7 miles east of M-26 in Ontonagon County (Bridge sign reads “Firesteel River”). This bridge was inspected on all three days. Damage was noticed in the coating in the east bound lane as shown in Figure 1. This deterioration cased by delamination at the interface.

Date: 02-15-01
The weather was cold and the sky was clear. Some packed snow existed on the road and shoulder as seen in the photographs. There was no noticeable difference between the adhesion of the snow between and road and the bridge.

Date: 02-20-01
The conditions were: -13°C (8.6°F), snow and light wind, 10:00 am. Most of the surface of the bridge and road was covered with light packed snow. See Figure 2. There was no noticeable difference between the adhesion of the snow between and road and the bridge.

Date: 02-22-01
The conditions were: -13°C (8.6°F), snow and very light wind, 10:30 am. Most of the surface of the bridge and road was covered with heavy packed snow. There was no noticeable difference between the adhesion of the snow between and road and the bridge.

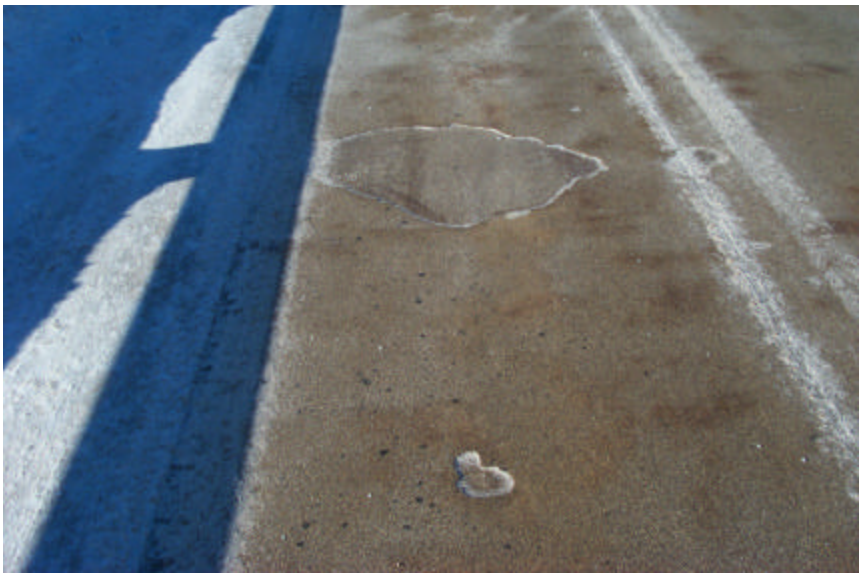

Figure 1. B01-66041 - Representative Delamination.

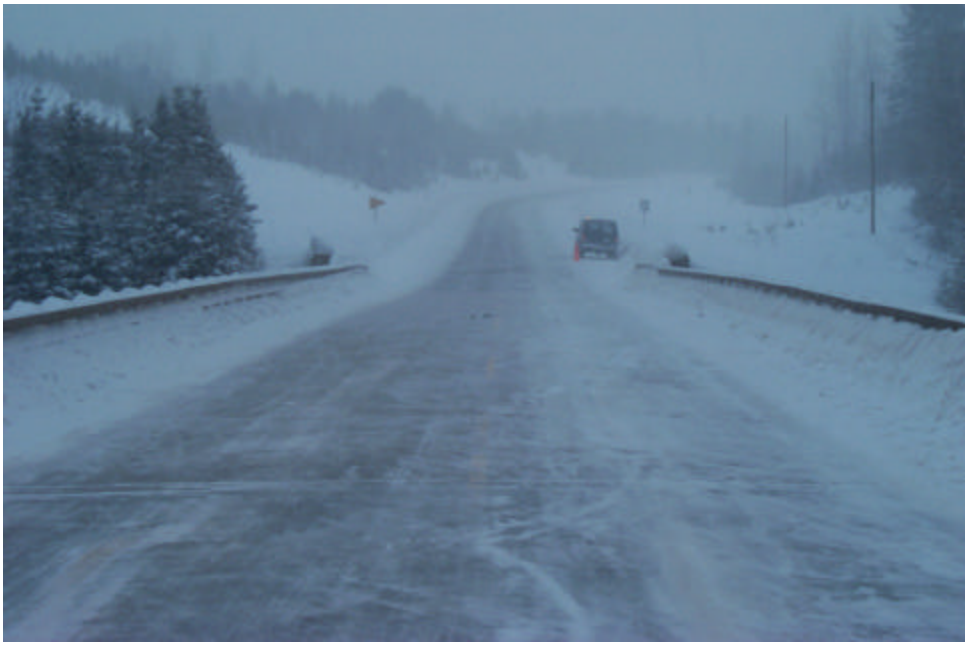

Figure 2. B01-66041 - Winter Condition.

Figure 3 shows a section of the underside of B01-66041.

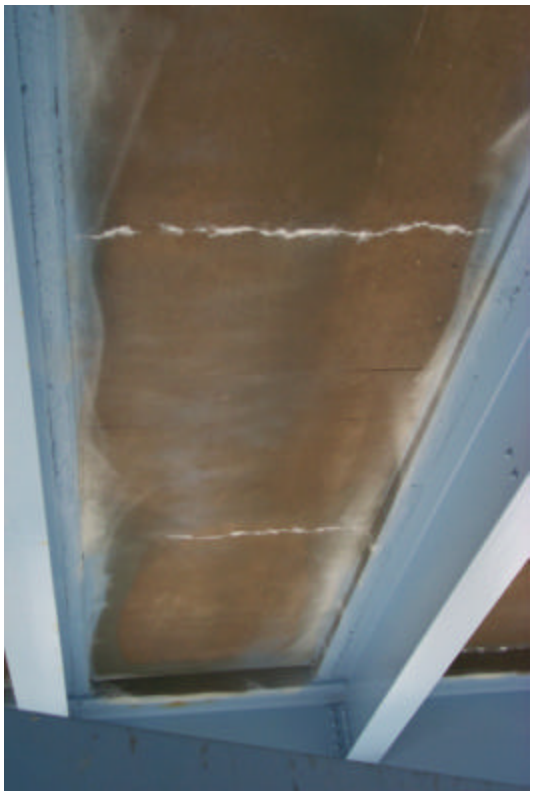

Figure 3. Underside of B01-66041.

B02-66032

The B02-66032 Bridge is located on M-45 over the East Branch Ontonagon River 2.0 miles south of M-26 in Ontonagon County (Bridge sign reads "Ontonagon River"). This bridge was inspected on all three days. No damage was found on the overlay.

Date: 02-15-01
The conditions were: -10°C (14°F), clear and calm, 9:50 am. No snow existed on the road except between lanes and on the shoulder as seen in the photographs. There was no noticeable difference in the surface condition between the adjacent road and the bridge.

Date: 02-20-01
The conditions were: -11°C (12.2°F), light flurries and windy, 10:40 am. Most of the surface of the bridge and road was sparsely covered with light packed snow. See Figure 4. There was no noticeable difference in the surface condition between the adjacent road and the bridge.

Figure 4. B02-66032 - Winter Conditions.

Date: 02-22-01
The conditions were: -10°C (14°F), overcast, light snow and calm, 11:00 am. Most of the surface of the bridge and road was covered with packed snow with the exception of the tire zones. There was no noticeable difference in the surface condition between the adjacent road and the bridge.

B03-66022

The B03-66022 Bridge is located on M-28 in Ewen over the South Branch Ontonagon River 4.7 miles west of US-45 in Ontonagon County. Slight damage was noticed in the coating. Near the center of the west end, small chunks, approximately 5" wide and 48" long were missing from the overlay. The westbound lane exhibited some transverse cracks with some delamination. See Figure 5.

Date: 02-15-01
The conditions were: -8°C (17.6°F), sunny and calm, 10:35 am. Some packed snow existed on the shoulder as seen in the photographs. There was no noticeable difference in the surface condition between the adjacent road and the bridge.

Date: 02-20-01
The conditions were: -12°C (10.4°F), sunny and windy, 11:32 am. Most of the surface of the bridge and road was covered with light packed snow. There was no noticeable difference in the surface condition between the adjacent road and the bridge, however, a little less snow appeared on the centerline of the bridge than the adjoining road surfaces.

Figure 5. B03-66022.

Date: 02-22-01
The conditions were: -10°C (14°F), light snow and overcast, 11:30 am. Most of the surface of the bridge centerline and shoulders of the road were covered with packed snow. There was no noticeable difference in the surface condition between the adjacent road and the bridge.

B02-31021

The B02-31021 Bridge is located on M-28 in Kenton over the East Branch Ontonagon River in Houghton County. This bridge was inspected on all three days. Some damage was noticed in the coating. Delamination on both inlet sides of the east and westbound lanes was recorded. See Figure 6.

Date: 02-15-01
The conditions were: -8°C (17.6°F), sunny and calm, 11:40 am. Some packed snow existed on the shoulder as seen in the photographs. There was no noticeable difference in the surface condition between the adjacent road and the bridge.

Date: 02-20-01
The conditions were: -10°C (14°F), partly sunny and some wind, 12:40 pm. Some packed snow existed on the shoulder as seen in the photographs. There was no noticeable difference in the surface condition between the adjacent road and the bridge.

Date: 02-22-01
The conditions were: -10°C (14°F), light snow and overcast, 12:15 pm. Most of the surface of the bridge centerline and shoulders of the road were covered with packed snow. There was no noticeable difference in the surface condition between the adjacent road and the bridge.

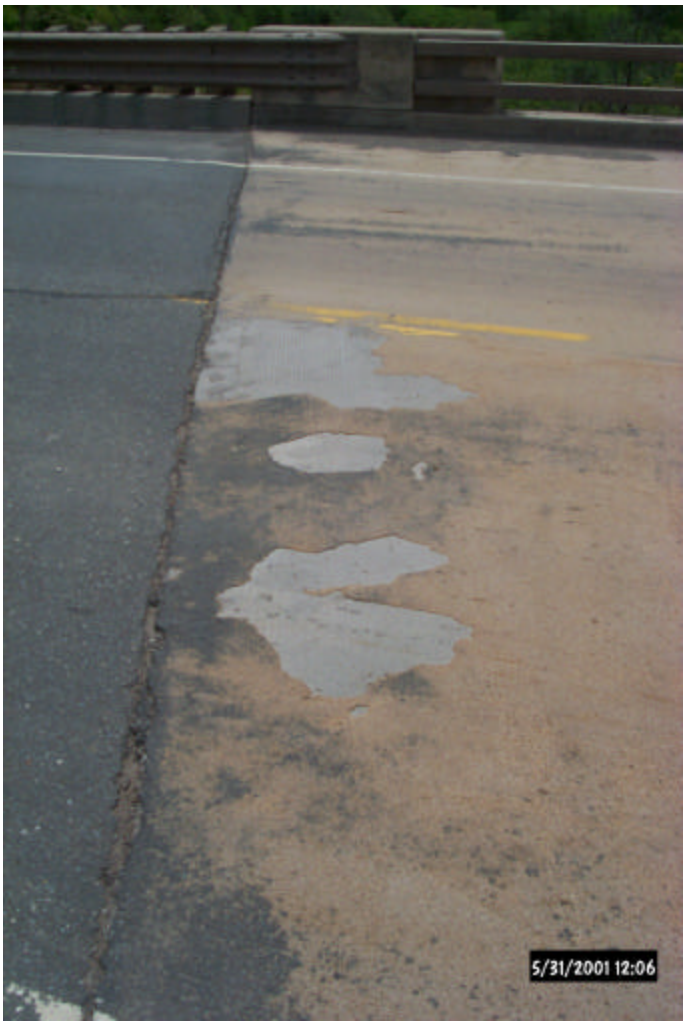

Figure 6. B02-31021

B01-36022

The B01-36022 Bridge is located on US 2 in Iron River over the Iron River in Iron County. This bridge was inspected on all three days. Damage was noticed in the coating in one area only. There were a few small spots on the surface that appeared to be poor mixing at the time of installation. See Figure 7.

Date: 02-15-01
The conditions were: -8°C (17.6°F), sunny and calm, 12:30 am. Some packed snow existed on the shoulder. There was no noticeable difference in the surface condition between the adjacent road and the bridge.

Figure 7. Surface "Pock Marks" on B01-36022.

Date: 02-20-01
The conditions were: -7°C (19.4°F), mostly sunny and some wind. Some packed snow existed on the shoulder. There was no noticeable difference in the surface condition between the adjacent road and the bridge.

Date: 02-22-01
The conditions were: -11°C (12.2°F), light snow and overcast, 1:00 pm. Most of the surface of the bridge centerline and shoulders of the road were covered with packed snow. There was no noticeable difference in the surface condition between the adjacent road and the bridge.

B04-36052

The B04-36052 Bridge is located on US 141 over the East Branch Net River 4.0 miles south of the Baraga County line in Iron County (Bridge sign reads "Net River"). This bridge was inspected on all three days. Delamination on the centerline of the bridge was recorded. See Figure 8. Damage to the expansion joints inlets was also observed.

Date: 02-15-01
The conditions were: -8°C (17.6°F), sunny and calm, 1:20 am. Some packed snow existed on the shoulder. There was no noticeable difference in the surface condition between the adjacent road and the bridge.

Figure 8. Damage along Centerline on B04-36052.

Date: 02-20-01
The conditions were: -8°C (17.6°F), mostly cloudy and windy, 2:10 pm. Some packed snow existed on the shoulders. There was no noticeable difference in the surface condition between the adjacent road and the bridge.

Date: 02-22-01
The conditions were: -6°C (21.2°F), flurries and overcast, 1:50 pm. There is no accumulation of the snow on the road or bridge deck. There was no noticeable difference in the surface condition between the adjacent road and the bridge.

B02-07012

The B02-07012 Bridge is located on US 41 south of Baraga over the Sturgeon River 1.4 miles south of Alberta in Baraga County. This bridge was inspected on two days. Delamination on the seam between adjacent applications in the middle of the bridge was evident. This was over an area of about 3" in width and over a length of 72".

Date: 02-20-01
The conditions were: -10°C (14°F), snowy and windy. More snow was noted on the southbound lane of the bridge than the road. There was no noticeable difference in the surface condition between the adjacent road and the bridge.

Date: 02-22-01
The conditions were: -8°C (17.6°F), overcast, 2:35 pm. There was packed snow on the bridge and road on the north side of the bridge and in the center of the road but no snow pack on the south side of the bridge. There was no noticeable difference in the surface condition between the adjacent road and the bridge.

Summer Bridge Deck Survey

A survey of 37 coated bridge decks located throughout Michigan was conducted by KRC/MTU. Photographic documentation of inspections included complete mapping of each deck coating for cracking, delamination, and overall surface integrity. Bond strength testing was conducted on 2 representative deck surfaces to document the in-situ bond strength of the coating systems. The bond strength measurements were made using a James Bond (James Instruments, Inc.) in-situ bond strength tester. Figure 9 is a photo of this system after a test. The results of these measurements are given in section **JB-007 Tests** on page 28 of this report. As mentioned previously, photos taken during these surveys are contained in Appendix A under separate cover.

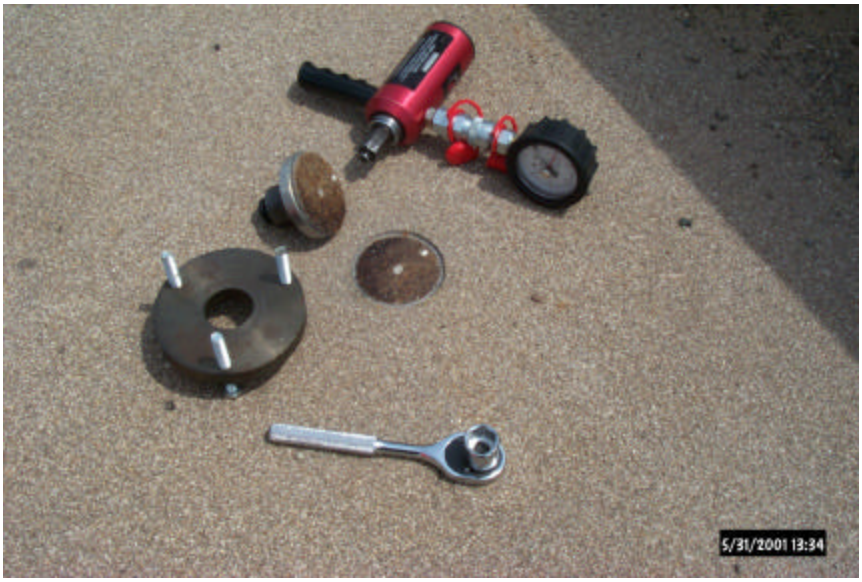

Figure 9. James Bond Test in Progress.

B01-66041

The B01-66041 Bridge is located on M-38 over the West Branch Firesteel River 2.7 miles east of M-26 in Ontonagon County (Bridge sign reads “Firesteel River”). Deterioration was noticed in the coating in the entire eastbound lane as shown previously in Figure 1. This appears to be was delamination of the coating. Pitting was also very common on this bridge possibly caused by improper mixing. The JB 007 pull tests were performed on this bridge. Both the east and westbound lanes were tested. See the results in the section titled JB-007 tests (page 28).

B02-66032

The B02-66032 Bridge is located on M-45 over the East Branch Ontonagon River 2.0 miles south of M-26 in Ontonagon County (Bridge sign reads “Ontonagon River”). Although there was no major delamination in this bridge deck coating, pitting was noticed. From looking at the pattern of the pitting it looks as though it may have been from bubbles in the epoxy. This is over an area of about 5% of the deck surface. This can be seen in Figure 10. Some plow damage in the form of chipping off the coating near the expansion joint was also noticed over a small area (3"wide over the width of the lane).

Figure 10. Bubble Pits in Coating Surface.

B03-66022

The B03-66022 Bridge is located on M-28 in Ewen over the South Branch Ontonagon River 4.7 miles west of US-45 in Ontonagon County. Slight damage was noticed in the coating. Near the center of the west side, small chucks were missing from the overlay. The westbound lane exhibited some transverse cracks with some delamination. Pitting was noticed, although the bridge was generally in very good shape. See Figure 3.

B02-31021

The B02-31021 Bridge is located on M-28 in Kenton over the East Branch Ontonagon River in Houghton County. Damage was noticed in the coating. Delamination on both inlet sides of the east and westbound lanes was recorded. Looks like this bridge only had a single coating of the overlay. Generally this bridge was in poor shape. See Figure 6.

B01-36022

The B01-36022 Bridge is located on US 2 in Iron River over the Iron River in Iron County. Damage was noticed in the coating in one area only. Delamination on the eastbound lane was recorded. The delaminations on this bridge were generally about the size of a quarter. Some pitting was also noticed. See Figure 7.

B04-36052

The B04-36052 Bridge is located on US 141 over the East Branch Net River 4.0 miles south of the Baraga County line in Iron County (Bridge sign reads "Net River"). Damage was noticed in the coating. Delamination on the centerline of the bridge was recorded. See Figure 8. Damage to the expansion joints inlets was also observed. This bridge also appeared to have only a single coating overlay.

B02-07012

The B02-07012 Bridge is located on US 41 south of Baraga over the Sturgeon River 1.4 miles south of Alberta in Baraga County. Damage was noticed in the coating. Slight delamination on the seam between adjacent applications of coating in the middle of the bridge was recorded. . This was over an area of about 3" in width and over a length of 72". This is evident in Figure 11. Some pitting was also noticed, but this is over a small area only.

B04-07012

The B04-07012 Bridge is located on US-41 across the Falls River in L'Anse in Baraga County. The only damage found on this bridge was the delamination of epoxy from the metal at the expansion joints. Some minor pitting was also noticed. Generally this deck was in very good condition.

Figure 11. B02-07012 - Damage at Deck Joint.

B01-48041

The B01-48041 Bridge is located on M-28 over the East Branch Fox River 2.8 miles east of the Schoolcraft county line in Luce County. This coating is in excellent condition.

B01-16093

The B01-16093 Bridge is located on I-75 southbound over the Sturgeon River 2.3 miles north of the Otsego County line in Cheboygan County. The only damage found was on the north side of the bridge at the expansion joint caused by plow blade chipping. Figure 12 shows this area as well as recent applications of crack sealer.

B02-16093

The B02-16093 Bridge is located on I-75 northbound over the Sturgeon River 2.3 miles north of the Otsego County line in Cheboygan County. The only deterioration found was on the south side of the bridge at the expansion joint. This was delamination of the epoxy from the metal joint.

B04-09035

The B04-09035 Bridge is located on I-75 southbound over the Saganing River 3.5 miles northwest of Pinconning in Bay County. The only deterioration found was on the south side of the bridge at the expansion joint. This was delamination of the epoxy from the metal joint.

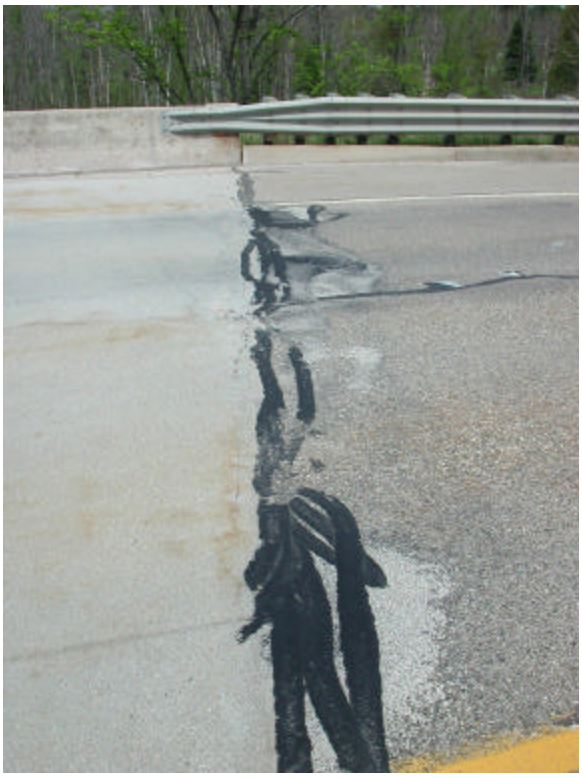

Figure 12. B01-16093 - South End.

B10-09035

The B10-09035 Bridge is located on I-75 northbound over the Saganing River 3.5 miles northwest of Pinconning in Bay County. The damage found was on the south side of the bridge at the expansion joint which looked like it was caused by a plow blade. Some delamination was evident around this area the cause of which is not evident. See Figure 13.

B03-09035

The B03-09035 Bridge is located on I-75 southbound over the Pinconning River 4.0 miles southwest of Pinconning in Bay County. The only damage found was on the north side of the bridge at the expansion joint which looked like it was caused by a plow blade.

B09-09035

The B09-09035 Bridge is located on I-75 northbound over the Pinconning River River 4.0 miles southwest of Pinconning in Bay County. The only damage found was on the south side of the bridge at the expansion joint which looked like it was caused by a plow blade.

Figure 13. B10-09035 - South End.

B02-76024

The B02-76024 Bridge is located on I-69 over the South Branch of the Looking Glass River 1.5 miles east of the Clinton County Line in Shiawassee County. This deck a was in very good shape.

B01-76024

The B01-76024 Bridge is located on I-69 over the South Branch of the Looking Glass River 1.5 miles east of the Clinton County Line in Shiawassee County. The only damage found was on the entrance end of the bridge at the expansion joint which looked like it was caused by a plow blade. This bridge is in excellent shape.

S15-19042

The S15-19042 Bridge is located on I-69 over Peacock Rd 0.5 miles west of the Shiawassee County line in Clinton County. This bridge looked very good with no damage found. The material used on this bridge was chipped flint.

S14-19042

The S14-19042 Bridge is located on I-69 over Peacock Rd Rd 0.5 miles west of the Shiawassee County line in Clinton County. This bridge looked very good with no damage found. The material used on this bridge was chipped flint.

S13-I19043

The S13-I19043 Bridge is located on I-69 over the I-96 Connector, eastbound turning roadway 6.0 miles northwest of Lansing in Clinton County. The only damage found on this bridge was some small cracks at the corners of a skewed joint.

S14-I19043

The S14-I19043 Bridge is located on I-69 (southbound) over Grand River Avenue (I-69 BL) 5.0 miles northwest of Lansing in Clinton County. No damage was found on this bridge.

S15-I19043

The S15-I19043 Bridge is located on I-69 (northbound) over Grand River Avenue (I-69 BL) 5.0 miles northwest of Lansing in Clinton County. No damage was found on this bridge.

S15-23063

The S15-23063 Bridge is located on I-69 (southbound) over I-96 2.0 miles south of I-496 in Eaton County. This is a slower speed on-ramp area. One area looks like it may have been patched. Some small delamination was noted. This is shown in Figure 14.

Figure 14. S15-23063 Delamination.

S14-23063

The S14-23063 Bridge is located on I69 (northbound) over I-96 2.0 miles south of I-496 in Eaton County. Delamination damage was found to occur mostly in the right lane and over about 5% of the area. Figure 15 shows some of these areas. Damage at the expansion joints from plowing was also found.

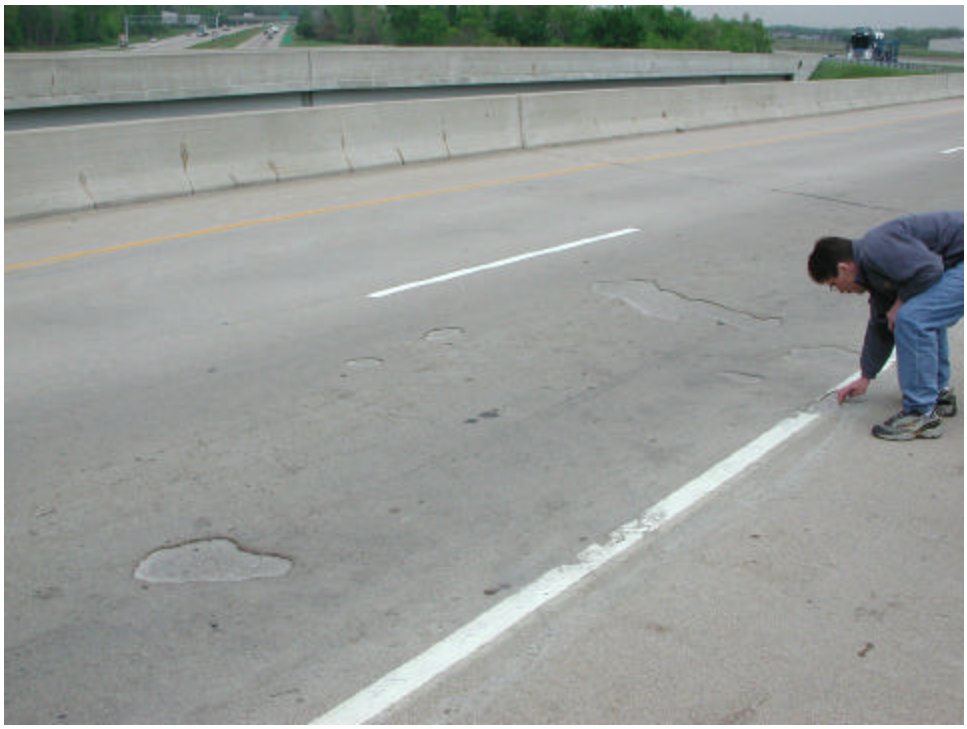

Figure 15. S14-23063 - Delaminated Areas.

R02-23063

The R02-23063 Bridge was located on I-69 (southbound) at the GTW Railroad and the Billwood Highway 4.0 miles northeast of Potterville in Eaton County. Generally this bridge looked good, however, a couple of small transverse cracks existed. Some delamination also was found near the shoulder (possible not enough liquid in the mixture) and a sample was taken.

R01-23063

The R01-23063 Bridge is located on I-69 (northbound) at the GTW Railroad and the Billwood Highway 4.0 miles northeast of Potterville in Eaton County. It was in good condition with no visible cracking. There were a couple of areas on the shoulder that looked like they had been patched and the patches were delaminating.

S11-23063

The S11-23063 Bridge is located on I-69 (southbound) at Nixon Road 2.0 miles northeast of Potterville in Eaton County. Generally, in good shape. Some damage to the north expansion joint from plowing. Also noted that you can see the tining patterns from the existing deck through the coating. Could be an indication that the coating was very liquid and quite thin when it was poured.

S10-23063

The S10-23063 Bridge is located on I-69 (northbound) at Windsor Highway and Nixon Road 2.0 miles northeast of Potterville in Eaton County. Generally, in good shape. Some damage to the south expansion joint from plowing.

S17-23063

The S17-23063 Bridge is located on I-69 (southbound) over M-100 at the south limits of Potterville in Eaton County. Some transverse cracking was seen and a couple small areas of delamination where found.

S10-67016

The S10-67016 Bridge is located on US-131 over US-10 1.5 miles northwest of Reed City in Osceola County. This bridge was in very good shape and no damage was found. Some pits in the coating were found. These pits did not go through the coating to the concrete.

B01-67016

The B01-67016 Bridge is located on US-131 northbound crossing over Johnson Creek near the 153 mile marker 1.5 miles northwest of Reed City in Osceola County. The bridge was in good shape except for a few pits in the coating and some damage near the expansion joints from plowing.

B02-67016

The B02-67016 Bridge is located on US-131 southbound crossing over Johnson Creek near the 153 mile marker 1.5 miles northwest of Reed City in Osceola County. The only damage on this surface was near the expansion joints from plowing.

B01-51021

The B01-51021 Bridge is located on M-55 over the Manistee River 0.1 miles east of US-31 in Manistee County. This coating exhibited the greatest amount of wear seen on any bridge to date. The coating was worn down to the pavement in the tire travel ruts. See Figure 16. Most of the tining grooves on the pavement were visible over the entire deck indicating that the coating was thin when applied.

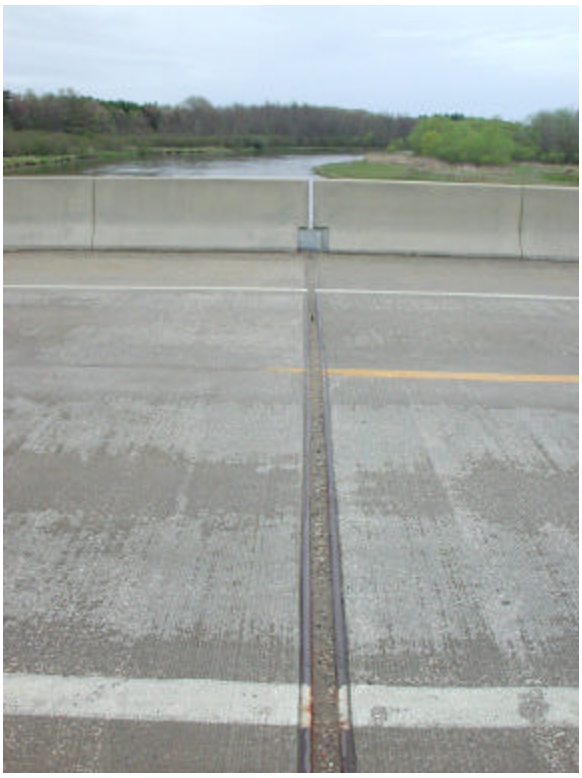

Figure 16. B01-51021 - Worn Lane Section.

B03-51021

The B03-51021 Bridge is located on M-55 across the Pine River 4.2 miles west of the Wexford County line in Manistee County. This bridge had damage near the expansion joints along with some delamination. Some of the delaminations look as though they were caused by snowplow blades. Some pitting in the coating was also noticed.

B02-57022

The B02-57022 Bridge is located on M-55 over the Muskegon River 1.8 miles west of the Roscommon County line in Missaukee County. This bridge had damage at the expansion joints and some pitting but generally was in good shape.

S04-16092

The S04-16092 Bridge is located on US-31 over I-75, south of Mackinaw City in Cheboygan County. The only damage found on this bridge was a scrape that looked like it was from a grader or plow blade. A JB 007 pull test was performed on this bridge deck surface.

B02-49023

The B02-49023 Bridge is located on US-2 over the Brevort River 6.9 miles southeast of Brevort in Mackinac County. This bridge was not fully coated but did have many cracks in the pavement

patched or covered with an epoxy resin. No aggregate was mixed into or applied on top of the epoxy.

R01-52041

The R01-52041 Bridge is located on US-41 over the LS&I Railroad at the west limits of Ishpeming in Marquette County. Some damage was found. Most was seen near the expansion joints. However, some cracks did exist, and delamination near a hot-poured asphalt joint seal was also found. See Figure 17.

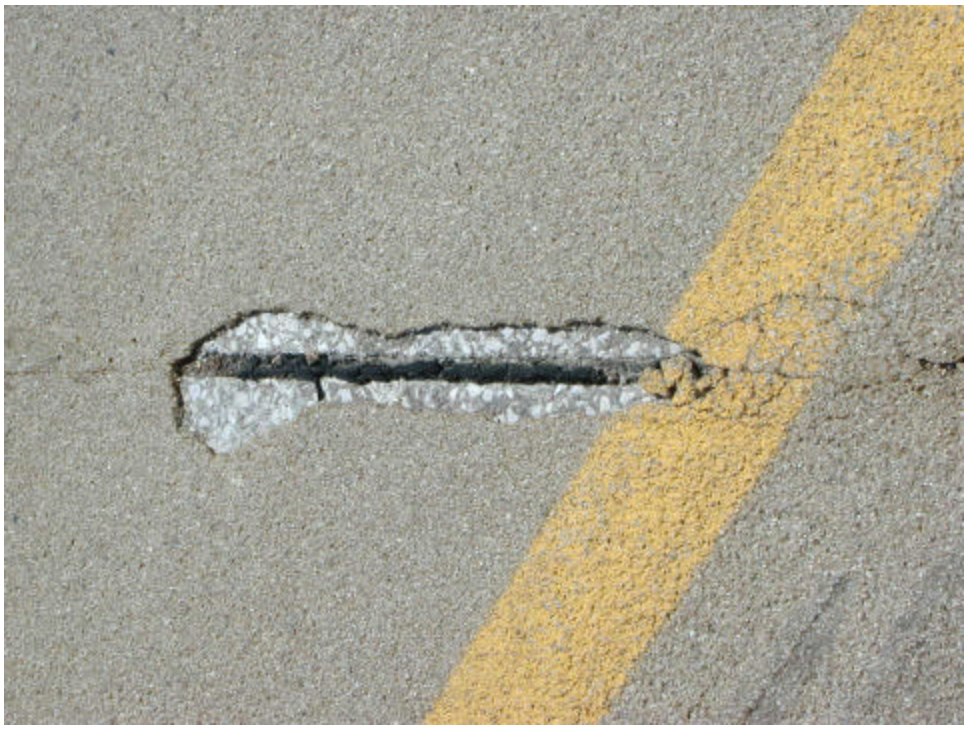

Figure 17. R01-52041 Damage.

JB-007 Tests

A limited number of bond strength tests were performed on overlays during the scope of this study. These tests were performed to determine if weak bonds could be documented with this device as well as determining how a "good" bond can be represented. Prior to these tests, it was already known by the author that it is difficult to measure the bond of a well placed overlay. This observation was reinforced during these tests. KRC engineers have performed in excess of 100 of these tests in the field. In general, a well placed overlay will not fail at the interface between the concrete and the overlay. Failures almost always occur between the measurement disc and the epoxy used to glue it to the surface or interior to the concrete itself. Failures normally occur somewhere in the neighborhood of 10 kN (2248 lb) force using the 5 cm (2 in) diameter disc. The 5 cm disc was used for all of the testing in this report, therefore all of the

results given will be related to this diameter and converted to stress. 10 kN of force using this disc is 5093 kPa (739 psi).

Tests were performed on the B01-66022 Bridge showed the bridge has one good lane and one very poor coated lane. On the well bonded side, 2 tests were performed. Both of these failed at the disc interface and the stresses were 4584 kPa (665 psi) and 5093 kPa (739 psi). On the poorly bonded side, three tests were performed with the failure at the bond interface. The failure stresses on these 3 were 1655 kPa (240 psi), 1146 kPa (166 psi), and 764 kPa (111 psi). Tests were also performed on the G. Mennen Williams Freeway over I-75 Bridge. Two measurements were made on this well bonded overlay and the results were 3565 kPa (517 psi) and 6112 kPa (887 psi) with both failures at the disc interface.

Using this information along with past experience at KRC, it is easy to conclude that analysis of overlays can be conducted with the JB-007 tester as long as it is noted that it will not measure the bond of a well placed overlay. These overlays have an interfacial bond that is stronger than the tensile strength of the concrete and / or the disc interface glue strength. Readings of approximately 2546 kPa (370 psi) or less show a poor bond and will delaminate at the original deck surface. This method should only be used to determine overlay bond quality and not in a quantitative sense. Overall, it is easier to see weak areas on decks after a failure starts to occur than to find weak areas on a seemingly stable coating.

Economic Evaluation

Part of the scope of this study is to analyze the benefits as compared to cost of overlay systems. Prior to the start of this effort, it was thought that this could be accomplished at this time. As it turns out, this information will be difficult to get a handle on without several more years of observation. Since the materials and methods have essentially been perfected only within the last 5 years or so, the durability of the coatings can only be estimated.

Some general observations can be made, however. In terms of new bridges, for instance, it is probable that an epoxy coating would eliminate chloride intrusion into the pavement. At present, 2 layer epoxy overlays cost between $3 and $4 per square foot. If, with close monitoring and repair of any cracks or delaminations, the coating would last 15 years at which time a third layer was applied possibly allowing the deck to be sealed for another 10 to 15 years, a substantial savings in both cost and safety would be realized. For all practical purposes, cracking, chunking, and steel corrosion should be almost eliminated on the new deck.

For older decks, it is much more difficult to do this analysis. If corrosion has started on reinforcing steel and surface spalling is initiated, it is difficult to determine if an epoxy coating would stop this deterioration. It is probable, however, that it would at least slow down considerably. In any event, the coating would be beneficial to eliminating further freeze thaw if the coating remains integral with the pavement surface. Further investigation of new bridges that are coated as well as older bridges will be necessary to determine how well the coatings perform as sealers. There is present interest at the State and Federal level to look further at chloride intrusion.

Conclusions

This study covered a large range of efforts pertaining to the use of sealers on bridge decks. One of the most important observations of all of the studies performed during this scope, is that research in this area over the past 15 or more years has progressed the development of these systems to a point where they are highly durable and will last long periods of time. All of the pertinent reports and papers uncovered in this investigation depict the progression of the materials and methods. It was difficult to obtain information at the state level, but enough was obtained to get an idea of the state-of-practice, at least for most of Michigan.

The materials used, both binders and aggregates, have been fine tuned to match specific sets of problems. Over the years, the binders have evolved to address specific bonding requirements to pavement surfaces. The materials that are being used today exhibit a bond strength that is generally higher than the tensile strength of the concrete deck. The elastic properties of the binders have also been fined tuned to allow for major expansion and contraction without failure at the bond interface. Aggregates that exhibit high wear, resistance to polishing, and frost susceptibility in combination with high friction characteristics have been identified through testing as well as field trials.

Methods to apply the overlays have also been significantly fine tuned by trial and error. Several failures have been observed and reported by others over the years that were a result of poor deck surface preparation prior to coating applications. The major failures examined during this project also appear to be caused by some from of poor surface preparation. This could be wetness or foreign material that was not properly cleaned off prior to application. The elimination of this failure mode is dependant upon thorough cleaning of the pavement surface by sand or shot blasting, elimination of any prior surface coatings, and making sure that the surface is dry, all seem to aid in developing a good bond.

Double coats have become the norm in most instances. This appears to assure a good seal and good surface structure. Figure 16 on page 28 is a good example of how a coating that is too thin can wear out. Durable aggregates such as flint and quartz will prolong the surface life considerably.

The cost of a full 2 coat overlay on a bridge deck can be crudely estimated as \$1.25 / ft^2 for shotblasting, some amount for traffic control, \$1.25 / ft^2 for epoxy, a small cost for aggregate, and a cost for labor. Methods of application are being fined tuned to make the job quick and easy, but at present a good estimate of time is about 1000 ft^2 per day.

Overall, these systems are quite useful for increased friction as well as prolonging the life of a pavement by sealing out unwanted moisture and chlorides. Service life will need to be monitored over the next few years since new materials addressing the needs of proper bridge overlaying have only been on the decks for 5 or so years. Looking at some of the most recent projects and the limited wear on those, it is not hard to envision a 15 year or longer service life.

Further investigation of the "anti-icing" characteristics of overlays is underway. The authors are currently working with a group of other scientists at MTU on the startup of a study of intrusion

of chlorides into concrete surfaces. Also, notable from the field surveys, further investigation of the nosing areas on decks should be made. This includes the nosings themselves, as well as methods to guard against chipping by plows at the intersection between coated and non-coated pavement.

Appendix A

Special Provision
For
Thin Epoxy Polymer Bridge Deck Overlay

MICHIGAN
DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION
FOR
THIN EPOXY POLYMER BRIDGE DECK OVERLAY

a. Description. This work shall consist of providing all labor, materials, and equipment for cleaning/preparing entire deck surface and applying a two coat epoxy overlay.

b. Materials. The epoxy system used to overlay the structure shall be a two component, high solids system. Containers shall be marked clearly **"Part A"** or **"Part B"**. The epoxies that are approved by MDOT for thin overlays, are as follows:

Tamms	Flexolith 216	Tamms Industries, Inc.(Steve Allegrina) 1705 East Lake Drive Novi, MI 48377 (248) 960-7424
Unitex	Propoxy Type III DOT	Unitex, Inc. (Jerry Byrne) 3101 Gardner Kansas City, MO 64120 (816) 231-7700
Poly-Carb	Flexogrid Mark - 163	Poly-Carb, Inc. (Bruce Roeder) 33095 Brainbridge Road Cleveland, OH 44139 (440) 248-1223
E-Bond	526-Lo-Mod	Jeene Technology (Stan Bosscher) 1900 Chicago Dr., S.W. Grand Rapids, MI 49509 (616) 245-2300

The aggregate shall be angular, having less than 0.2% moisture and free of dirt, clay, asphalt, and other foreign or organic materials. The aggregate shall have a minimum Mohs' hardness of 7. Unless otherwise approved, the aggregate shall be chosen from the following list:

Vendor	Product Gradation	Type
Best Sand Chris Calhoun P.O. Box 87 Chardon, OH 44024 (800) 237-4986 Fax: (216) 285-4109	#612	Quartz
Unimin Corp. Ken Booz P.O. Box 254 Mauricetown, NJ 08329 (800) 257-7034 Fax: (856)327-4107	EP-5 Modified	Quartz
Manufacturers Minerals Co. Jim Adderson 1215 Monster Road Renton, Washington 98055 (425) 228-2120 Fax: (425) 228-2199	BT - 6x10	River Rock
Humble Sand and Gravel, Inc. Mary 800 S. College Road, P.O. Box 217 Picher, Oklahoma 74360 (918) 673-1737 Fax: (918) 673-1749	Size: #7	Chipped Flint

c. Equipment. For the epoxy overlay, the distribution system or distributor shall accurately blend the epoxy resin and hardening agent, and shall uniformly and accurately apply the epoxy materials at the specified rate to the bridge deck in such a manner as to cover 100% of the work area including one inch of the vertical face of curb/barrier. The fine aggregate spreader shall be propelled in such a manner as to uniformly and accurately apply dry aggregate to cover 100% of the epoxy material. The vacuum truck shall be self-propelled.

For hand applications, equipment shall consist of calibrated containers, a paddle type mixer, notched squeegees, and stiff bristle brooms which are suitable for mixing and applying the epoxy and aggregate.

d. Construction.

Surface Preparation. Before placement of the overlay, the Contractor shall clean the entire deck surface by shotblasting to remove asphaltic material, oils dirt, rubber curing compounds, paint carbonation, laitance, weak surface mortar and other potentially detrimental materials, which may interfere with the bonding or curing of the overlay. Acceptable cleaning is usually achieved by significantly changing the color of the concrete and mortar and beginning to expose course aggregate particles. Mortar which is sound, and soundly bonded to the course aggregate, must have open pores due to cleaning to be considered adequate for bond. Traffic

paint lines shall be removed and replaced at the completion of the overlay. A vacuum cleaner or oil-free moisture-free air blast shall be used to remove all dust and other loose material. Brooms shall not be used.

The epoxy overlay shall not be placed on concrete deck patches less than 28 days of age. Patching and cleaning operations shall be inspected and approved prior to placing the overlay. Any contamination of the deck, or to intermediate courses, after initial cleaning, shall be removed. Both courses shall be applied within 24 hours following the final cleaning and prior to opening area to traffic. There shall be no visible moisture present on the surface of the concrete at the time of application of the epoxy overlay. A transparent polyethylene sheet (4 mil) shall be taped to the deck in accordance with ASTM D4263. All edges will be sealed with tape that will stick to the concrete substrate. The plastic sheet will be left in place for a minimum of 2 hours to detect the presence of moisture in the deck concrete. Alternate methods to detect moisture must be approved by the Engineer. There shall be no moisture visible on the polyethylene sheet. Compressed air may be used to dry the deck surface providing it is moisture and oil free.

During preparation of the surface, the expansion joints, and any other areas not to be overlayed, shall be protected from damage at all times. The protection shall be removed once the epoxy and aggregate has been applied and prior to initial set. Removing the protection shall be done soon enough to in no way harm the adjacent overlay. Protection shall be applied again prior to the second coat and removed again prior to initial set as to not damage adjacent surfaces. The protection shall meet the approval of the Engineer.

Application. Handling and mixing of the epoxy resin and hardening agent shall be performed in a safe manner to achieve the desired results in accordance with the manufacturer's recommendations for a two coat system or as directed by the Engineer. Epoxy overlay materials shall not be placed when surface or ambient temperature is less than 50° F. Epoxy overlay materials also shall not be placed if weather or surface conditions are such that the material cannot be properly handled, placed, and cured within the manufacturer's requirements and specified requirements of traffic control.

The epoxy overlay shall be applied in 2 separate courses in accordance with the manufacturer's recommendation for a two coat system with the following rate of application. First course shall be no less than 40 ft^2/gal. The second course shall be no less than 20 ft^2/gal.

Application of aggregate to both the first, and second courses, shall be of sufficient quantity so the entire surface is covered in excess. No bleed through, or wet spots shall be visible in the overlay.

After the epoxy mixture has been prepared for the overlay, it shall be immediately and uniformly applied to the surface of the bridge deck with a notched squeegee. Epoxy shall not be applied if the ambient air temperature is to fall below 50° F within 8 hours after application. The dry aggregate shall be applied in such a manner as to cover the epoxy mixture completely within 5 minutes, any foot traffic on the epoxy shall be minimized and only done with steel spiked shoes. Spikes shall be similar to steel spikes on golf shoes or as approved by the Engineer. First course applications, which do not receive enough sand shall be removed and replaced. A second course insufficiently sanded may be left in place, but will require additional

applications before opening to traffic. Each course of epoxy overlay shall be cured until vacuuming or brooming can be performed without tearing or damaging the surface. Traffic or equipment shall not be permitted on the overlay surface during the curing period. After the first course curing period, all loose aggregate shall be removed by vacuuming or brooming and the next overlay course applied to completion. The minimum curing periods shall be according to the manufacturer's recommendation or as follows or as directed by the Engineer.

Anticipated Cure Time (Hours)

Average Temp. of Deck, Epoxy and Aggregate Components, °F.							
Temp Range	60 -	60-65	65-70	70-75	75-80	80-85	85+
1st Course		4	3	2.5	2	1.5	1
2nd Course	***	6.5	5	4	3	3	3

***Second course shall be cured for minimum of 8 hours if the air temperature drops below 60 °F during the curing period, or per manufacturer's recommendation.

The Contractor shall plan and prosecute the work to provide the minimum curing periods as specified herein, or other longer minimum curing periods as recommended by the manufacturer prior to opening to public or construction traffic, unless otherwise permitted. First course applications shall not be opened to traffic. Any contamination of the first course, prior to application of the second course, detrimental to adhesion of the second course shall be removed from the first course at Contractor's expense.

In the event the Contractor's operation damages or mars the epoxy overlay, the Contractor shall remove the damaged areas and replace the various courses in accordance with this special provision at no additional cost to the Department.

For each batch provided, the Contractor shall provide the Engineer with all records including, but not limited to, the following:

1. batch numbers and sizes
2. location of batches as placed on deck, referenced by stations
3. batch time
4. temperature of air, deck surface, epoxy components, including aggregates
5. loose aggregate removal time
6. time open to traffic

e. Measurement and Payment. The complete work as measured for **Epoxy Overlay** will be paid for at the contract unit price for the following contract item (pay item):

Contract Item (Pay Item) **Pay Unit**

Epoxy Overlay Square Yard

Payment for **Epoxy Overlay** includes all material, labor, and equipment required to cleaning, preparing and applying a two coat overlay system including miscellaneous clean-up.