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Thin Film Concrete Coatings

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We provide services to the transportation community through research, technology transfer, and education. We create and participate in partnerships to promote safe and effective transportation systems.

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Research Report
KTC-16-03/SPR12-433-1F

Thin Film Concrete Coatings

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In cooperation with
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16. Abstract
KTC researchers obtained eight types of concrete coatings to assess their performance and resistance to chloride penetration. Researchers evaluated eight of the systems in the field and seven in the laboratory. In the field, coatings were applied to a bridge pier that had suffered degradation and chloride contamination. This site will undergo long-term monitoring in order to thoroughly evaluate the coating systems. Adhesion of all products in both field and laboratory application was sufficient to provide a durable coating, and ranged from approximately 500 psi to 1,600 psi. Researchers also tested color and gloss changes, which are early indicators of coating degradation, Although performance varied, one system (System 8) was by far the least effective. Three two-coat systems performed significantly better than the other five at retarding chloride transmission. Those coating systems use epoxy primers with polyurethane top coats.

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III. EXECUTIVE SUMMARY

Seven concrete coatings were evaluated in both field and laboratory applications for coating adhesion, resistance to chloride penetration, color retention, and gloss retention. Adhesion of all products in both field and laboratory applications was sufficient to provide a durable coating, ranging from approximately 500 psi to 1,600 psi. Color and gloss changes, which are early indicators of coating degradation, varied. However, System 8 exhibited much more pronounced changes than other systems. KTC researchers followed up initial findings by monitoring resistance to chloride penetration in the field and laboratory. Field data collected after the passage of one snow and ice season were insufficient to make decisive conclusions about coatings' performance. Laboratory testing and salt ponding tests indicated that Systems 1, 2, and 6 performed significantly better than others in their resistance to chloride penetration.

The adhesion of coatings to the substrate and their ability to resist chloride penetration are the two characteristics most important for concrete coating performance. Systems 1, 2 and 6, which are two coat systems with an epoxy primer and a urethane top coat, perform better in these characteristics than other systems tested. None of the other coating systems are epoxy–urethane systems.

1. INTRODUCTION

1.1 BACKGROUND

The use of steel-reinforced concrete for bridge construction has increased since the 1970s. One reason for this is that bridge owners are concerned about the maintenance burden due to the corrosion of structural steel. While reinforced concrete may reduce maintenance requirements over the short-term, recent studies have indicated that corrosion of the reinforcing steel in concrete has become a growing problem.

A study (1) conducted by the Kentucky Transportation Center (KTC) in 2011 determined that the chloride content of bridge abutments and pier caps has increased dramatically over the past 15 years. An undocumented in-house assessment of central Kentucky bridges in 2002 found that chloride contents of bridge decks at the upper mat level were less than 0.01% chloride by weight of concrete and therefore not a problem. KTC's 2011 study included an assessment of bridge decks and substructure elements. That study revealed that chloride contamination at the upper mat level in some bridge decks had increased to 0.20%–0.30%. Additionally, samples taken from pier caps and abutment seats indicated even higher levels of chloride contamination in the 0.30% to 0.40% range. The increase in chloride contamination has likely been caused by the increased use of deicing chemicals (1), particularly the use of pretreatment with liquid calcium chloride. That substructure elements have higher chloride contents than decks is likely caused by the use of a different concrete mix in those elements; the time-of-wetness is also much longer for those elements.

The action levels for chloride contamination of concrete that result in steel corrosion are:

- 0.03 percent chloride to weight of concrete = initiation of corrosion
- 0.08 percent chloride to weight of concrete = accelerated corrosion
- 0.18 percent chloride to weight of concrete = major section loss of steel (2)

1.2 WORK PLAN

The Kentucky Transportation Cabinet (KYTC) awarded KTC's Bridge Preservation section a research study with the following objectives:

a. Identify existing viable concrete coatings and their properties/characteristics. Determine effective acceptance/evaluation tests for those coatings.

b. Provide a compendium of concrete coatings/properties/tests for consideration by KYTC. The properties can include chloride ingress, durability, and aesthetic coating treatments.

c. Evaluate laboratory assessments/tests of promising concrete coatings. Develop new test procedures if existing ones prove unacceptable for KYTC purposes. Conduct field tests of candidate coatings on existing structures.

d. Provide KYTC with a range of effective concrete bridge coatings and guidelines to inform their selection and to provide the best benefits to bridges.

2. WORK ADDRESSING STUDY TASKS

This study included laboratory and field components. The research team began by soliciting manufacturers for commercially available protective concrete coatings. KTC researchers contacted all major coatings suppliers and asked for their recommendations and to supply small quantities of concrete coatings. These coatings were applied at the field site and on concrete specimens for laboratory evaluation. A total of eight coatings were submitted by various manufacturers.

All products were applied on concrete columns of a KYTC bridge. Seven of the products were applied on cast concrete specimens for laboratory evaluation. One system was not evaluated in the laboratory because the manufacturer specified a 24-hour cure of the primer before applying the top coat. The 24-hour requirement was unknown until after field application had begun. Six of the systems were thin-film coatings, while the other two might be classified as concrete sealers.

KTC's researchers sought to identify which coatings needed to have minimal total system application time requirements, because the products would likely be applied by KYTC crews with time constraints. While there was no *user friendliness* criteria, rollers were used to apply coating in the field and laboratory, with minimal effort needed to eliminate pinholes in the coating. This is significant because concrete coatings are prone to developing pinholes upon application, especially coatings with poor flow characteristics. This application quality could be viewed as *user friendliness*.

3. FIELD APPLICATION OF COATINGS

In the spring of 2013, KTC personnel applied eight coatings to several columns of Pier 3 of the I75/I64 bridge over US 68 in Lexington, Kentucky. Table 1 describes the products and conditions at time of application. Seven of the coatings were two-coat systems. The two-coat systems were a combination of urethane, epoxy, acrylic, silane, siloxane, silicon, and methyl methacrylate chemistries. The remaining system was single coat system base on a castor oil/gypsum mix (Table 2).

This site was chosen because it contained a leaking expansion joint that had allowed water and deicing chemicals to spill onto the pier. The leakage had been ongoing for years by the time KTC applied the coatings, and the leak continued after the field work was completed. This resulted in chloride contamination and spalling of the concrete columns and pier cap (Figure 1). Researchers applied the coatings on the three columns at locations that were not severely spalled. Before the coatings were applied, the concrete surfaces were pressure washed at 4,500 to 5,000 psi with a 0^o oscillating tip from a distance of approximately one foot. The tip was oriented approximately perpendicular to the surface (Figure 2).

The washed concrete surfaces dried for a minimum of 24 hours prior to coating application. Air temperature ranged from 65^o to 75^o F, while relative humidity ranged from 45 to 68% during application of all coatings (see Table 1). The locations of the field coatings are shown in Figure 3.

All coatings, with the exception of System 5, were applied by roller. A brush was used to fill spalls or large bugholes, larger than one inch in diameter (Figure 4). Minimal effort was made to repair pinholes that developed with the roller application. That effort was limited to an additional pass with the roller. Based on this field work, it is likely that most coatings applied to concrete will develop many pinholes (Figure 5) unless special care is taken in an effort to eliminate them. Researchers believed that the pinholed coatings were indicative of what would likely occur in project application. The supplier of System 5 requested that KTC apply it with a spray gun. The system was supplied with a portable spray gun for that purpose — a Graco *Proshot HD®* (Figure 6).

The concrete substrate was sampled for chloride content, and the field applied coatings were monitored for adhesion. This evaluated the coatings' ability to retard chloride transmission. Five months after application, KTC researchers obtained powder samples taken from concrete columns under each of the coatings and analyzed their chloride content. These samples established the baseline chloride content prior to the subsequent snow and ice season. Samples were obtained by first drilling three holes 1/16" deep and cleaning the equipment and drilled cavity with dry air. The powder sample was obtained from a depth of 1/16" to 1/2." Concrete was removed to a depth of 1 ½." After further cleaning, another sample was obtained from a depth of 1 ½" to 2.0". KTC collected the baseline samples on September 27, 2013. Follow-up samples were acquired on June 17, 2014. Table 3 summarizes the chloride content data. After one snow and ice season, there was not a significant increase in chloride content under any coating.

Adhesive strength of the coatings were evaluated six months after their application. A Defelsko PosiTest AT-A instrument was used with 20 mm dollies. Coating adhesive strengths ranged from 478 psi to 1635 psi. Breaks of the epoxy primer systems (1, 2, and 6) were cohesive failures within the concrete, while the other systems broke in cohesive failure of the coating or adhesive failure of the coating to the concrete. These data are summarized in Table 4.

4. LABORATORY TESTING

Laboratory testing consisted of applying coatings to concrete specimens (panels and blocks) and evaluating coatings using various performance criteria. Concrete blocks were cast for performing AASHTO T259-02 (2006), Resistance of Concrete to Chloride Ion Penetration and T260-97 (2009), Sampling and Testing for Chloride Ion in Concrete and Concrete Raw Material. Blocks, 12" x 12" x 6", were cast using the standard KYTC AA concrete mix. After the concrete had cured for 28 days, the blocks' ponding surfaces were blast cleaned to an ICRI CSP3 condition. The coatings were then applied to the ponding surfaces by roller and left to cure 10 days prior to ponding (as per AASHTO T259). Figure 7 illusrates a typical coated concrete block with pinholes.

All coatings were applied by roller. It was difficult to achieve consistent film build with System 8, and it did not fill bug holes. System 4 was applied in the field but was not evaluated in the laboratory. The manufacturer insisted that the primer cure for 24 hours before applying the top coat. Researchers decided this requirement would make KYTC's use of the system unlikely, especially if applied by field crews working under typical time constraints. All other systems could be applied in one day under normal painting conditions. Table 5 summarizes data for coating application on ponding blocks.

One block was not coated prior to salt ponding. It served as a control to establish a baseline for unprotected concrete. After ponding, three locations of each block were sampled by drilling the concrete, collecting the dust, and combining them into one sample. Samples were collected at ¼" to ¾" (reported as ½") and ¾" to 1 1/4" (reported as 1") depths (Figure 8). The concrete samples were analyzed for chloride content; test results were corrected for chlorides in the concrete mix. As Figure 9 shows, Systems 1, 2, and 6 were more effective than the others at reducing chloride penetration.

Panels (6" x 12" x ¾") were cast and cured according to ASTM D1734-93, Standard Practice for Making Cementitious Panels for Testing Coatings. The mix design calls for a 0.43 water-to-cement ratio but that mix proved difficult to mold in thin panels. It was modified to a 0.53 ratio. After an 18-day cure, the panels were prepared by abrasive blasting to an ICRI CSP3 condition, the edges were smoothed with a finishing stone, and coatings were applied by roller. Panel coatings cured for 20 days before initial adhesion testing. Panels were coated on their front and back to enable adhesion testing on the back, with color and gloss monitoring on the front (Figure 10). Data for coating application on panels is shown in Table 6.

Coating adhesion was measured according to ASTM D4541-02, Standard Test Method for Pull-off Strength of Coating Using Portable Adhesion Testers. Adhesion was measured after a 20-day cure prior to weathering exposure and at 1,000-hour intervals of exposure, up to 3,000 hours (Figure 11). Weathering exposure proceeded according to ASTM D4587-11, Standard Practice for Fluorescent UV-Condensation Exposures of Paint and Related Coatings. Initial adhesion testing used 50 mm dollies. The adhesive strength of the coating was greater than the capacity of the test equipment; therefore, 20 mm dollies were used for all. Coating adhesion tended to increase with weathering exposure, which indicates additional coating curing. All weathered coatings adhesion tests, with the exception of System 8, resulted in cohesive failure of the concrete substrate. Coating adhesion test results are shown in Table 7.

Color and gloss retention are important characteristics to monitor to gauge coating performance (3). Changes in these characteristics indicate degradation of the coating at a basic level, even though protection of the substrate may still be available. For color monitoring, KTC uses a Color-Guide $45^{o}/0^{o}$ meter which measures L*a*b* (three dimensional) color values and calculates a Delta-E, or change in color. One Delta-E is the least color change discernable to the human eye.

Gloss is measured by shining a known amount of light on a surface and quantifying the reflectance. Down-glossing occurs in all weathered coatings and is indicative of micro-fracturing or other degradation. KTC uses a Novo-Gloss $60^{o}/20^{o}$ meter and records the 60^{o} measurement.

The measurement scale, Gloss Units (GU), of a glossmeter is a scaling based on a highly polished reference black glass standard, which has a defined refractive index having a specular reflectance of 100GU at the specified angle. This standard is used to establish an upper point calibration of 100, with the lower end point established at 0 on a perfectly matte surface.

Color and gloss baseline values were established before the coatings were weathered. Those characteristics were evaluated at 1,000-hour intervals thereafter. Seven of the systems had good color stability, with Delta-E less than 4. System 8 had a color change of nearly 20 Delta-E. Three of the systems had gloss changes of less than 5 GU but System 8 down glossed 45 units. Color and gloss data are presented in Figures 12 and 13.

5. SUMMARY

Seven concrete coatings were applied and tested in both field and laboratory applications. One product applied in the field was excluded from laboratory evaluation because of extended application time requirements. Coatings were applied with a roller in both the laboratory and the field, and minimal effort was made to eliminate pinholes in the coating. KTC replicated the application method KYTC crews are likely use in the field.

Field coatings were evaluated for adhesion and the resistance to chloride penetration. Laboratory coatings were applied on concrete specimens and evaluated for resistance to chloride, adhesion, color retention, and gloss retention of weathered coatings. Adhesion of all products in both field and laboratory application was sufficient to provide a durable coating, and ranged from approximately 500 psi to 1,600 psi. Color and gloss changes, which are early indicators of coating degradation, varied. Based on these measures, System 8 was by far the worst performer. Resistance to chloride penetration was monitored in the field and laboratory. Field samples were assessed after one snow and ice season. As such, this is not a good indicator of performance. Laboratory salt ponding tests indicated that Systems 1, 2, and 6 have significantly better resistance to chloride penetration than other coatings.

The adhesion of coatings to the substrate and their ability to resist chloride penetration are the two characteristics most important for concrete coating performance. Systems 1, 2 and 6 perform better in these areas than the other systems tested. Each of these are two-coat systems with an epoxy primer and a urethane top coat.

6. REFERENCES

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7. TABLES

System	Manufacturer	Coating	Coating Location	Ambient Condition				WFT (mils)
				Date/Time	Temp (°F)	R/H (%)	Dew Point (°F)	
3	PPG	Perma-Crete 4-809	Pier 3, Column 1, East Face	5/2/13 10:30 AM	65.3	60.6	50.9	4-5
	PPG	Matte-Flex Elastomeric 4-310		5/2/13 2:45 PM	73.1	48.1	49.0	14-16
1	Sherwin Williams	Macropoxy 646	Pier 3, Column 2, South Face	5/2/13 9:15 AM	65.0	64.0	47.0	12
		Acrolon 218		None	None	None	None	None
2	PPG	Amerloc 2	Pier 3, Column 1, South Face	5/2/13 10:00 AM	67.6	57.8	55.0	9-10
	Devoe Coatings	Devflex HP		5/3/13 8:50 AM	63.7	68.1	53.0	6-7
7	Carboline	Sanitile 120	Pier 3, Column 5, East Face (top)	5/2/13 2:00 PM	72.5	51.0	54.0	5-6
		Carbocyrlic		5/3/13 10:00 AM	66.7	62.7	53.3	9-10
6	Carboline	Carboguard 890	Pier 3, Column 5, East Face (bottom)	5/2/13 2:20 PM	72.5	51.3	54.0	8
		Carbothane 133HB		5/3/13 11:00 AM	68.0	62.1	53.9	7-9
5	Sherwin Williams	CONSLR Low VOC B97 WW12	Pier 3, Column 2, West Face	5/2/13 3:50 PM	74.5	45.6	57.0	None
8	Castagra	Castor oil/Gypsum	Pier 3, Column 1, North Face	5/3/13	71.0	58.8	58.0	18-22
4	Klaas Coatings	Si-Prime (Penetrating Sealer)	Pier 3, Column 5, South Face	5/2/13 11:15 AM	None	None	None	None
		Si-Rex 3		5/3/13 9:20 AM	64.3	68.1	53.5	4-6
				5/16/13 9:30 AM	73.8	56.7	57.4	4-6

Table 1. Field Coating Application Data

System	Product Name	Description
1	Sherwin Williams Macropoxy 646	Two component, high solids, high build, polyamide epoxy, applied in one coat
	Sherwin Williams Acrolon 218 HS	Two component, polyester modified, aliphatic, acrylic polyurethane, applied in one coat
2	PPG Amerloc2	Two component, high solids epoxy, applied in one coat.
	Devoe Devflex 4216HP	Single component, water-born acrylic, applied in one coat.
3	PPG Perma-Crete 4-809	Single component, water-born acrylic sealer, applied in one coat.

	PPG Matte-Flex 4-310	Single component, elastomeric high build acrylic, applied in one coat.
4	Klaas Si-Prime	Single component, waterborne blend of silanes, siloxanes and acrylics, applied in one coat
	Klaas Si-Rex	Single component, waterborne, silicon resin coating, applied in two coats
5	Sherwin Williams Concrete Sealer 100	Methyl methacrylate-ethyl acrylate copolymer sealer, applied in two coats
6	Carboline Carboguard 890	Two component, cycloaliphatic amine epoxy mastic, applied in one coat.
	Carboline Carbothane 133HB	Two component, Aliphatic Acrylic-Polyester Polyurethane, applied in one coat.
7	Carboline Sanitile 120	Single component, Waterborne Acrylic, applied in one coat.
	Carboline Carbocrylic 3359 DTM	Single component, Modified acrylic terpolymer, applied in one coat.
8	Castagra EcoDur 201S	Two component castor oil/gypsum coating, applied in one coat.

Table 2. Products tested

(System) Depth	%CL 2013	%CL 2014
(1) 1/16"-1/2"	0.110	0.137
(1) 1-1/2" - 2"	0.080	0.089
(2) 1/16"-1/2"	0.062	0.013
(2) 1-1/2" - 2"	0.026	0.004
(3) 1/16"-1/2"	0.026	0.026
(3) 1-1/2" - 2"	0.004	0.003
(5) 1/16"-1/2"	0.010	0.015
(5) 1-1/2" - 2"	0.007	0.010
(6) 1/16"-1/2"	0.013	0.009
(6) 1-1/2" - 2"	0.006	0.018
(7) 1/16"-1/2"	0.010	No Access
(7) 1-1/2" - 2"	0.008	No Access
(8) 1/16"-1/2"	0.038	0.046
(8) 1-1/2" - 2"	0.004	0.016

Table 3. Chloride content of concrete substrates five months after field application

System Number	Surface Prep	Field Test	
		Psi	Failure Type
1	Power wash	493	100% Cohesive Concrete
2	Power wash	1452	100% Cohesive Concrete

3	Power wash	549	100 Cohesive Coating
4	Power wash	679	100% Adhesive Concrete/Coating
5	Power wash	1128	90% Adhesive Concrete/Coating 10% Cohesive Concrete
6	Power wash	1635	100% Cohesive Concrete
7	Power wash	551	90% Adhesive Concrete/Coating 10% Cohesive Concrete
8	Power Tool	478	100% Cohesive Coating
8	Hand Tool	519	100% Cohesive Coating

Table 4. Coating adhesion six months after field applications

System	Manufacturer	Coating	Ambient Condition				WFT (mils)
			Date/Time	Temp (°F)	R/H (%)	Dew Point (°F)	
2	PPG	Amerloc 2	5/28/13 11:00 AM	75.9	60.3	61.2	7-8
	Devoe Coatings	Devflex HP	5/29/13 3:50 PM	78.9	59.3	63.8	6-8
3	PPG	Perma-Crete 4-809	5/28/13 3:30 PM	77.3	54.0	59.4	4-5
	PPG	Matte-Flex Elastomeric 4-310	5/29/13 2:30 PM	77.8	63.0	63.9	12-14
1	Sherwin Williams	Macropoxy 646	5/28/13 11:45 AM	77.3	57.4	60.9	9-10
		Acrolon 218 HS	5/29/13 3:15 PM	77.7	60.9	63.2	6-8
7	Carboline	Sanitile 120	5/28/13 3:00 PM	76.2	75.9	60.7	4-5
		Carbocyrlic	5/29/13 2:45 PM	78.2	60.3	63.2	9-10
6	Carboline	Carboguard 890	5/28/13 11:30 AM	76.2	59.4	61.0	7-8
		Carbothane 133HB	5/29/13 3:30 PM	79.1	59.1	63.1	6-7
5	Sherwin Williams	CONSLR Low VOC B97 WW12	5/28/13 3:50 PM	79.1	49.3	58.5	5-6
8	Castagra	Castor oil/Gypsum	5/28/13 4:15 PM	79.9	49.9	59.6	18-20

Table 5. Laboratory coating application for ponding blocks

System	Manufacturer	Coating	Ambient Condition				WFT (mils)
			Date/Time	Temp (°F)	R/H (%)	Dew Point (°F)	
2	PPG	Amerloc 2	5/14/13 3:00 PM	73.4	45.6	51.2	7-8
	Devoe Coatings	Devflex HP	5/15/13 10:30 AM	76.0	54.0	58.0	4-6
3	PPG	Perma-Crete 4-809	5/14/13 3:30 PM	74.1	48.8	53.7	5-7
	PPG	Matte-Flex Elastomeric 4-310	5/15/13 10:45 AM	76.0	53.7	58.3	14-15
1	Sherwin Williams	Macropoxy 646	5/14/13 2:00 PM	71.5	43.4	48.1	10-12
		Acrolon 218 HS	5/15/13 9:30 AM	75.4	55.6	58.3	7-9
7	Carboline	Sanitile 120	5/15/13 9:30 AM	73.7	58.5	57.8	5-6
		Carbocyrlic	5/15/13 1:30 PM	77.6	52.6	58.0	9-11
6	Carboline	Carboguard 890	5/14/13 5:00 PM	74.4	51.6	55.4	8-10
		Carbothane 133HB	5/15/13 11:30 AM	77.2	53.8	59.0	7-8
5	Sherwin Williams	CONSLR Low VOC B97 WW12	5/14/13 4:15 PM	74.6	48.6	54.0	3-5
8	Castagra	Castor oil/Gypsum	5/15/13 9:50 AM	74.9	56.3	58.4	18-24

Table 6. Laboratory coating application data for panels

Sys	Pre-Exposure		Post-Exposure (1000 hrs)		Post-Exposure (2000 hrs)		Post-Exposure (3000 hrs)	
	Psi	Failure Mode	Psi	Failure Mode	Psi	Failure Mode	Psi	Failure Mode
1	738	100% cohesive/concrete	798	100% cohesive/concrete	811	100% cohesive/concrete	1005	100% cohesive concrete
1	744	100% cohesive/concrete	665	100% adhesive coating/dolly	825	100% cohesive/concrete	975	100% cohesive concrete
2	1029	100% cohesive/concrete	915	100% cohesive/concrete	1120	100% cohesive/concrete	860	100% cohesive concrete
2	n/a	Equipment malfunction	597	100% cohesive/concrete	732	100% cohesive/concrete	782	100% cohesive concrete
3	300	95% adhesive glue/coating	601	100% cohesive/concrete	668	100% cohesive/concrete	576	90% cohesive concrete
3	288	90% adhesive glue/top coat 10% cohesive concrete (within bugholes)	640	100% cohesive/concrete	707	100% cohesive/concrete	636	85% cohesive concrete
5	798	80% adhesive concrete/coating 20% cohesive coating	697	100% cohesive/concrete	746	100% cohesive/concrete	810	100% cohesive concrete
5	915	70% adhesive concrete/coating 30% cohesive coating	1055	100% cohesive/concrete	624	100% cohesive/concrete	733	100% cohesive concrete
6	1032	100% adhesive/concrete/ primer	638	100% cohesive/concrete	779	100% cohesive/concrete	706	100% cohesive concrete
6	1150	100% adhesive/concrete/ primer	723	100% cohesive/concrete	858	100% cohesive/concrete	754	100% cohesive concrete
7	505	100% cohesive/concrete	625	100% cohesive/concrete	758	100% cohesive/concrete	767	100% cohesive concrete
7	445	100% cohesive/concrete	707	100% cohesive/concrete	816	100% cohesive/concrete	775	100% cohesive concrete
8	283	100% cohesive coating	255	100% adhesive - glue failure	230	100% adhesive glue/coating	619	60% cohesive coating, 40% cohesive concrete
8	253	100% cohesive coating	503	50% adhesive glue/coating, 50% cohesive coating	n/a	glue failure prior to pulling	558	90% cohesive coating

Table 7. Coating adhesion on laboratory weathered panels

8. FIGURES

Figure 1. Deteriorated concrete columns and pier cap under leaking joint.

Figure 2. Pressure washing concrete substrate prior to coating.

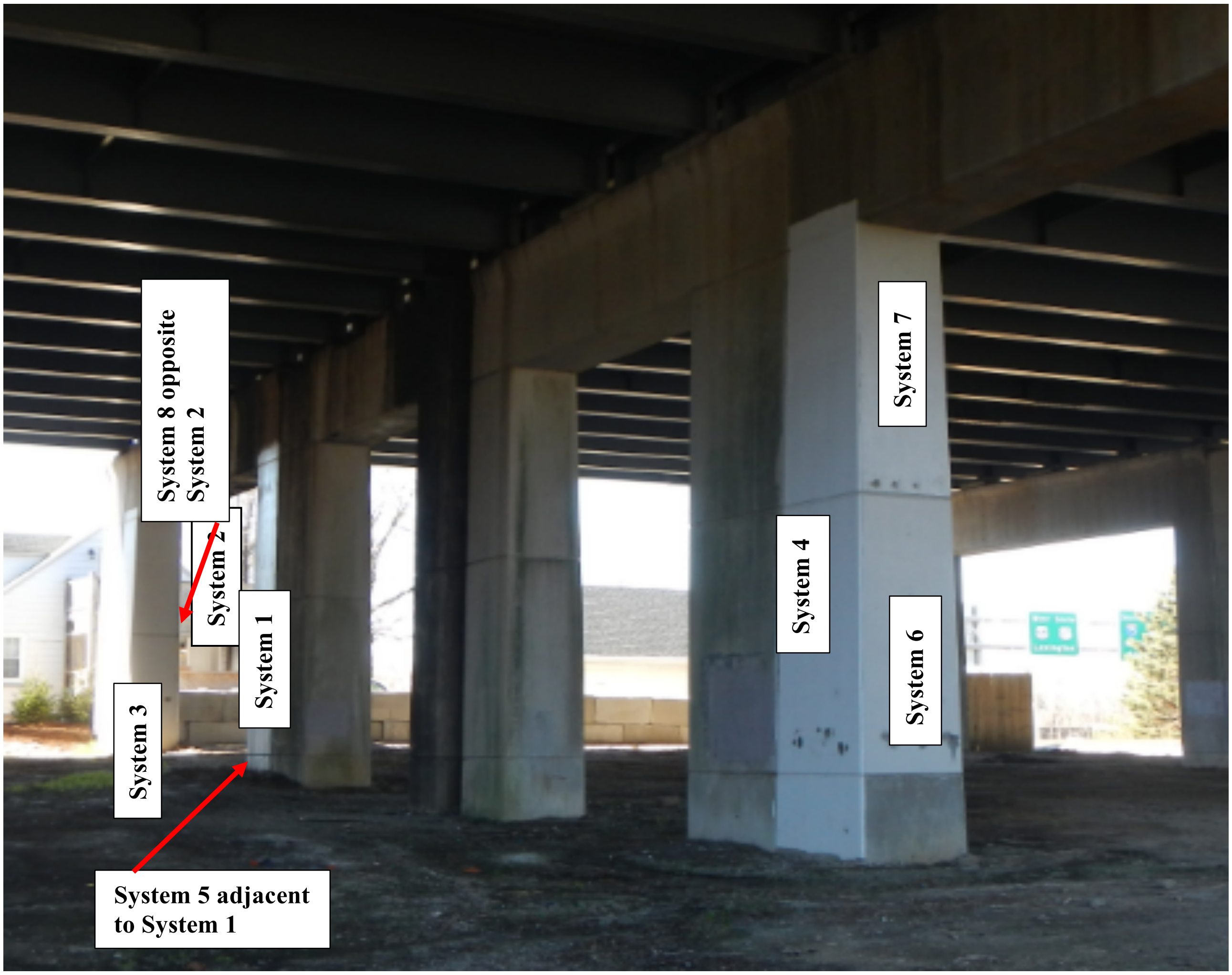

Figure 3. Location of coating systems on bridge columns


Figure 4. Applying coating to concrete on bridge column


Figure 5. Spalled areas coated but pinholes remain

Figure 6. Spray application with a Graco ProShot HD

Figure 7. Coated concrete block with pinholes

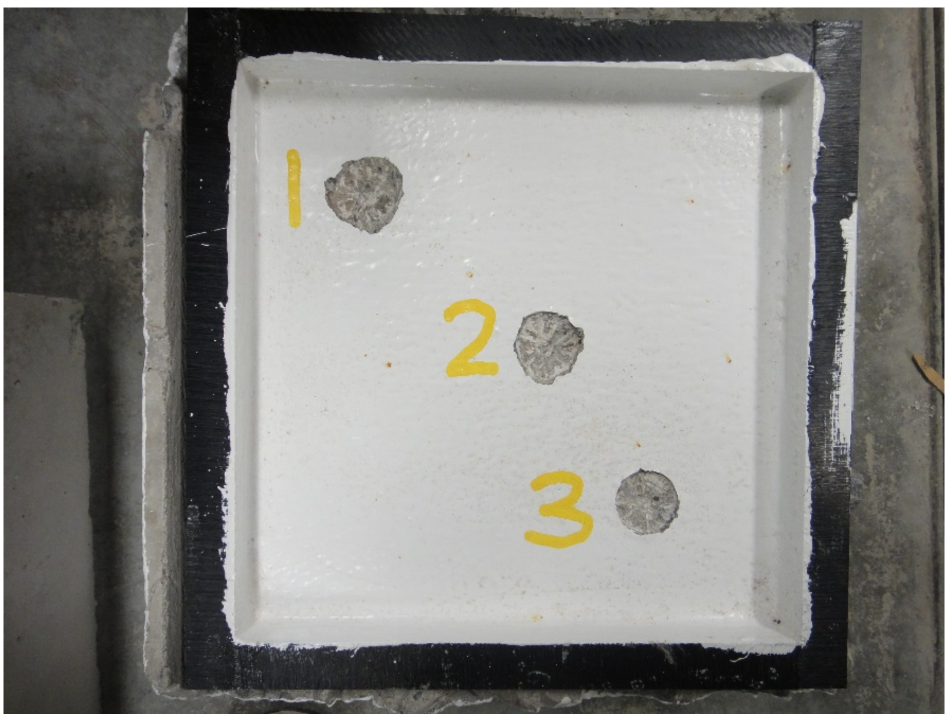

Figure 8. Salt ponding block after powder samples of concrete have been extracted after completion of the salt ponding test

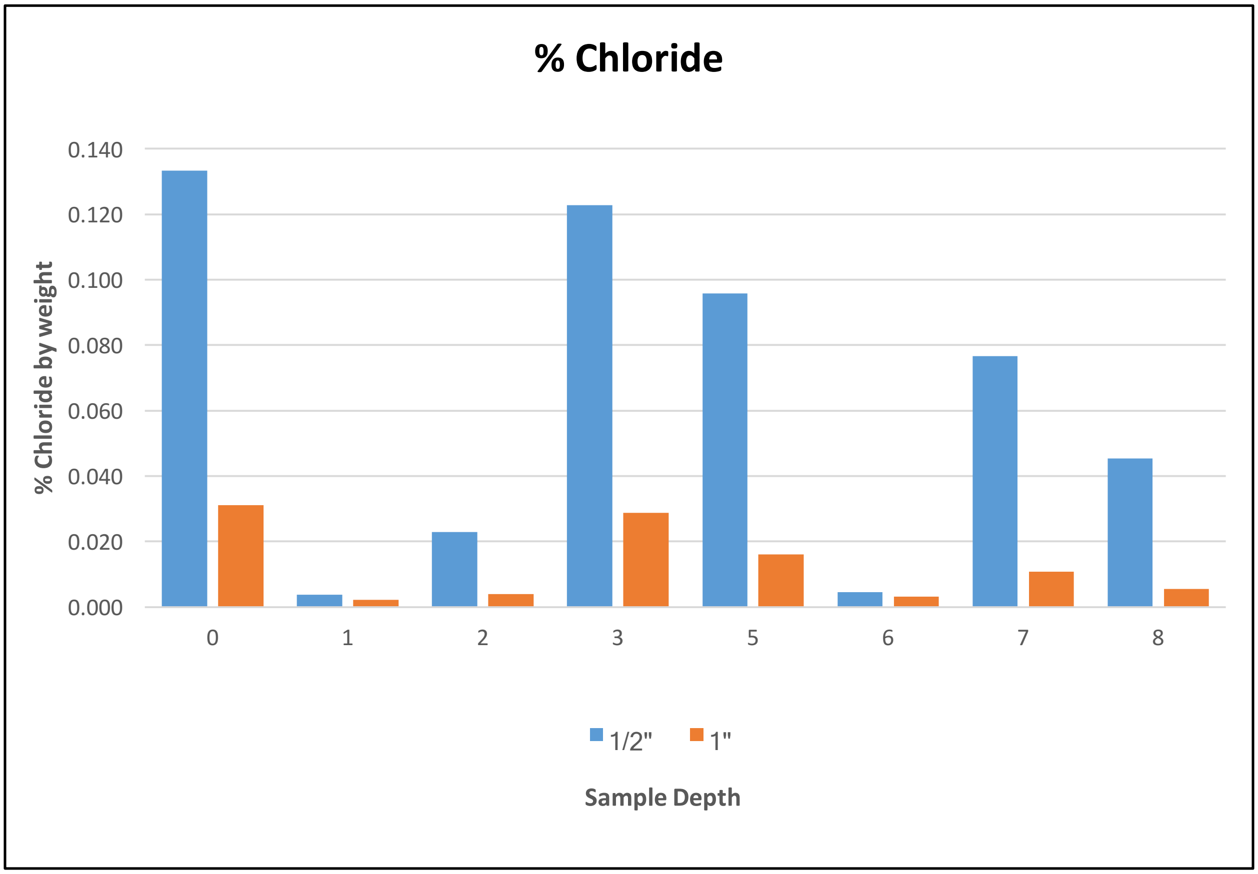

Figure 9. Chloride penetration of concrete after salt ponding

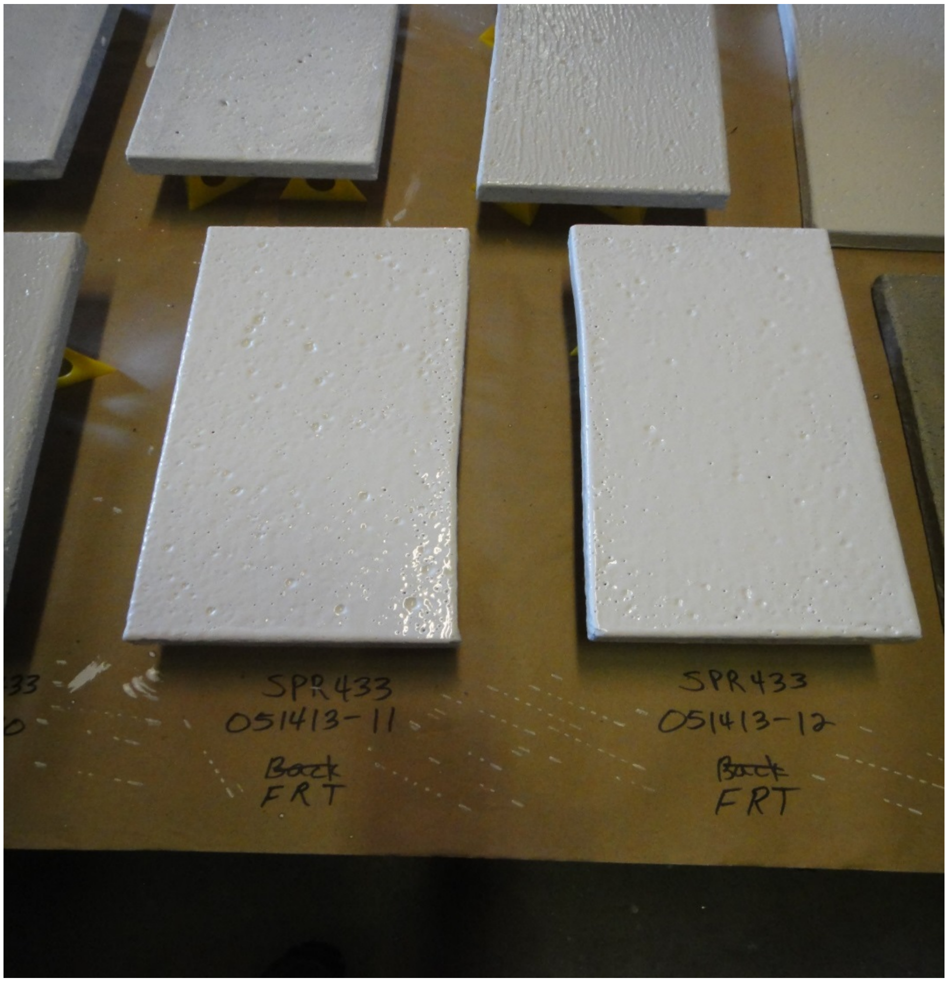

Figure 10. Concrete panels coated front and back

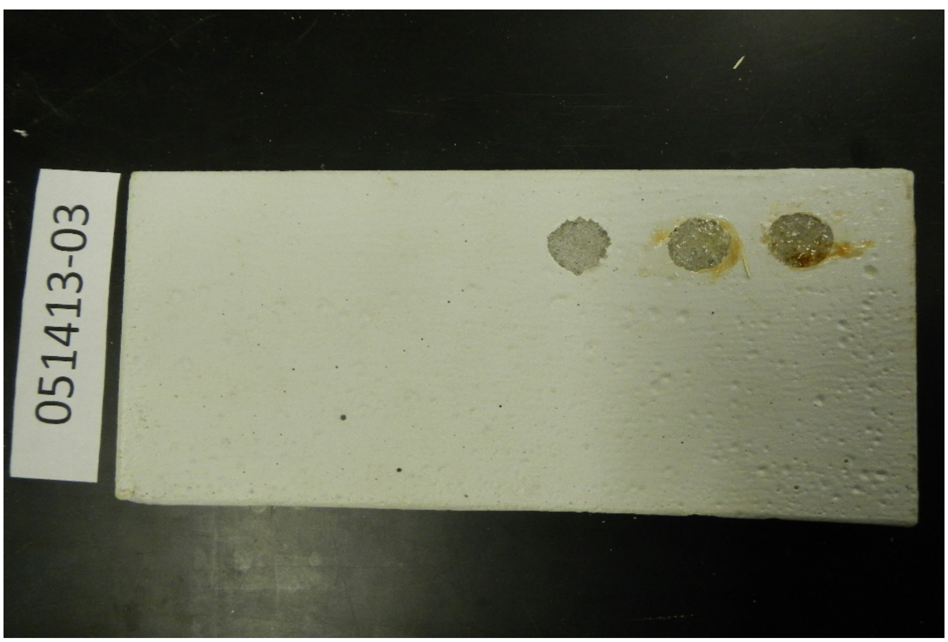

Figure 11. Direct adhesion testing at 1,000 hour intervals

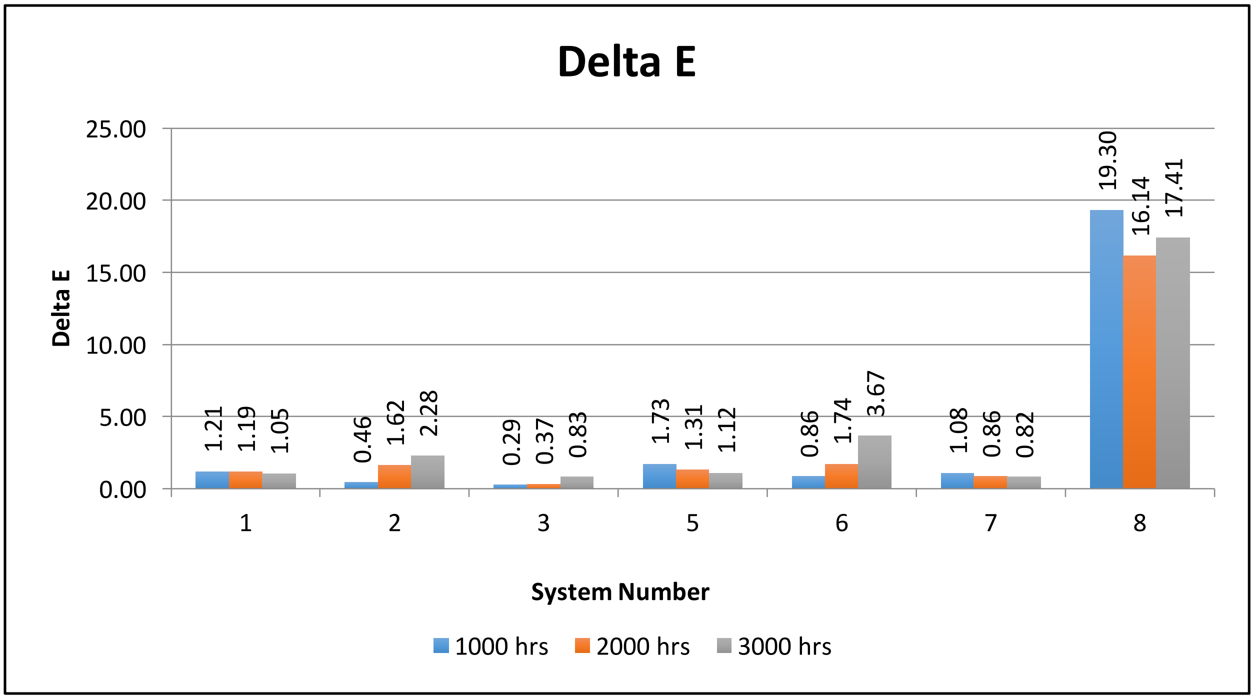

Figure 12. Color changes of laboratory weathered concrete coatings

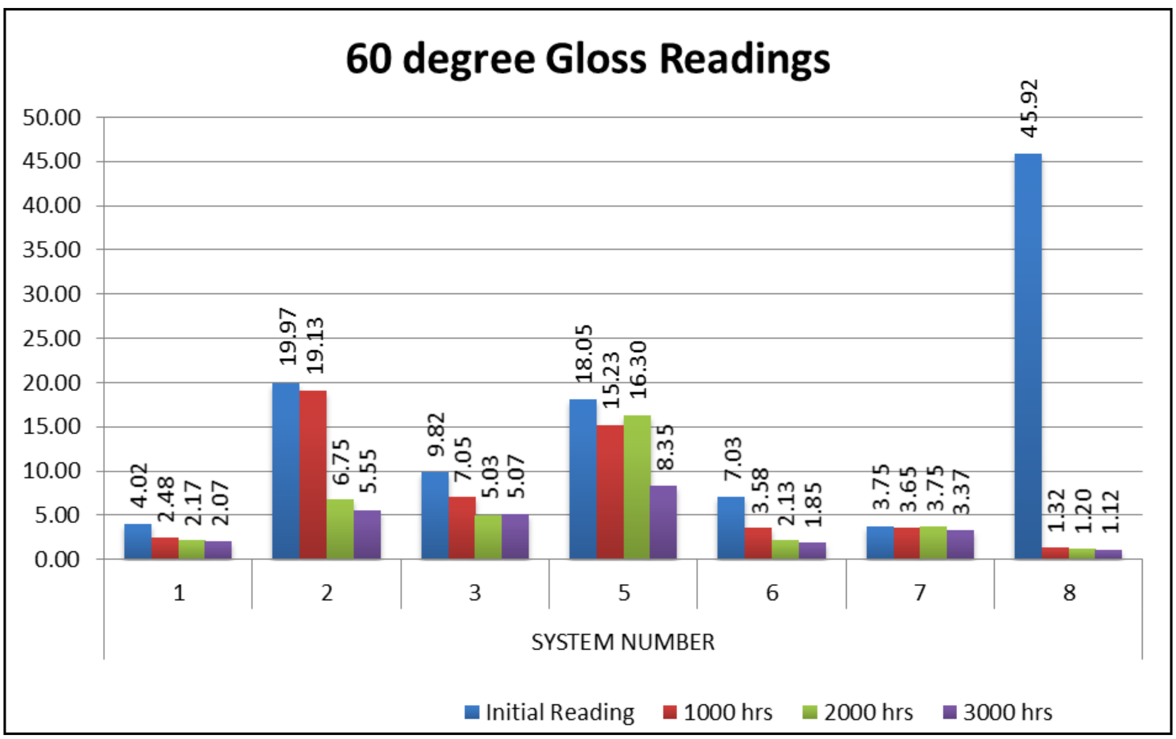

Figure 13. Down glossing of laboratory weathered coatings