Research Report
KTC-06-36/SPR291-04-1F

KENTUCKY TRANSPORTATION CENTER

COATINGS, SEALANTS AND FILLERS TO ADDRESS BRIDGE CONCRETE DETERIORATION AND AESTHETICS-PHASE 1

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Research Report
KTC06-36/SPR 291-04-1F

Coatings, Sealants and Fillers to Address Bridge Concrete Deterioration and Aesthetics-Phase 1

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16. Abstract
This study addresses experimental evaluation and testing of concrete coatings for maintenance purposes on structural (steel reinforced) concrete. The test methods employed are intended to identify coatings and sealers for eventual incorporation into a qualified products list for structural concrete coatings. Some of the methods/procedures used in this study will be used in the future to evaluate additional coatings and sealers

Developmental work focused on identifying relevant coatings systems and laboratory tests. The objectives of experimental project monitoring were to: 1) identify existing viable concrete coatings along with their properties/ characteristics/surface preparation requirements and determine effective acceptance/evaluation tests for those coatings; 2) provide a compendium of concrete coatings/properties/tests for consideration by KYTC; 3) evaluate laboratory tests of promising concrete coatings and develop new test procedures if existing ones prove unacceptable for KYTC purposes; 4) use those tests to evaluate KYTC-approved coatings; 5) conduct field tests of candidate coatings on existing structures; and 6) provide KYTC with a range of effective concrete bridge coatings and guidelines for selecting them to provide the best benefits to bridges.

This report provides a summary of the coatings systems tested and the overall results/findings of this research study.

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EXECUTIVE SUMMARY

The Kentucky Transportation Center (KTC) at the University of Kentucky is tasked with the research study "Coatings, Sealants and Fillers to Address Bridge Concrete Deterioration and Aesthetics-Phase 1" by the Kentucky Transportation Cabinet (KYTC) to conduct investigative work focusing on new concrete coating systems. The proposed materials can be used in new construction to provide enhanced concrete durability and aesthetics and also be incorporated as part of rehabilitation or repair projects. Some coatings identified under this study will provide enhanced durability and better properties (graffiti resistance and safety) than existing coatings.

Nearly all KYTC bridges have major components (decks, piers, abutments, barrier walls, beams) made from concrete. Many of those bridges have experienced some type of concrete deterioration (e.g., cracking, spalling, erosion, staining and corrosion of reinforcement). If left untreated, that deterioration can worsen and eventually require major concrete repairs. A variety of concrete coatings exist that offer the potential for enhanced concrete protection, improved aesthetics (including graffiti resistance) and, by using reflective materials, better safety compared to conventional concrete masonry coatings and stains currently employed by KYTC on bridge concrete. The latter products are not durable nor are they readily repairable. Such materials can be incorporated into PM (Preventive Maintenance) programs and applied by state forces or contractors or they can be used on new structures.

The main objective of this project was to develop KYTC standard specifications and a qualified products list of concrete coatings. This was achieved by running a set of laboratory tests and some preliminary field testing. To establish a preliminary evaluation of concrete coatings, the five laboratory test methods relevant to KYTC that were selected are 1) ASTM D 5894, 2) ASTM D4541, 3) AASHTO T260 & T259, 4) ASTM E96 and 5) ASTM D522. It was determined that ASTM D 4541, ASTM E96 and ASTM D522 test methods will establish a minimum failure criteria for further evaluation. The five laboratory tests shall identify candidate coatings systems that will be subsequently used in the KYTC experimental bridge maintenance painting projects. As part of the project, field testing of the concrete coatings was done on west bound barrier wall of a bridge crossing the KY River on the US 676/US 421 East-West Connector in Frankfort.

The analyzed data showed that the systems had different range of values and since this was the first time any major testing has been done on concrete coatings either in the KTC laboratory or by the manufacturer, there no comparable data values. The ASTM and AASHTO tests that were conducted on concrete coatings showed that a set of standard operating procedures can be adopted for future evaluation of concrete coatings at KYTC.

1. INTRODUCTION

Concrete coatings must have multiple capabilities of providing esthetics and protecting structural concrete from weathering. They are viable for use on all concrete elements including barrier walls, girders, abutments and wingwalls. Other state highway agencies have been routinely using or experimenting with some of these coatings (e.g. Ohio DOT and Pennsylvania DOT). Several of these coatings reduce the permeability of concrete (waterproofing) and limit the intrusion of harmful moisture and deicing salts. All of those coatings should provide enhanced aesthetics (compared to textured masonry coatings and stains) and better reparability. Beneficial coatings need to be identified and tested to determine their effectiveness in protecting concrete. Due to the wide latitude of properties of these different coatings, guidelines need to be developed for determining where they are best suited (new and maintenance concrete application).

1.1 BACKGROUND

In the past, Kentucky Transportation Cabinet (KYTC) officials involved in maintenance operations have had to address concrete deterioration and/or patch work of pier caps, barrier walls. There are about 6400 concrete bridges in the state of Kentucky and many bridges have some type(s) of concrete deterioration. Concrete on bridges is subject to environmental exposure and the application of deicing chemicals such as salt. The resulting service environment can lead to deterioration of the concrete (e.g. spalling) that may necessitate expensive repairs to replace or restore it.

The need exists to: 1) identify new concrete coatings being successfully used by other transportation entities, 2) investigate other new products that offer improved concrete protection, and 3) take necessary steps to promote the widespread use of those materials on KYTC bridges for both new construction and maintenance.

The Kentucky Transportation Cabinet approved Research Study KYSPR 05-291, entitled “Coatings, Sealants and Fillers to Address Bridge Concrete Deterioration and Aesthetics-Phase 1” in 2004. The objectives of this research study are listed below.

1. Identify existing viable concrete coatings and their properties/characteristics. Determine effective acceptance/evaluation tests for those coatings.
2. Provide a compendium of concrete coatings/properties/tests for consideration by KYTC.
3. Evaluate laboratory evaluations/tests of promising concrete coatings. Develop new test procedures if existing ones prove unacceptable for KYTC purposes. Use those tests to evaluate KYTC-approved coatings.
4. Conduct field tests of candidate coatings on existing structures.
5. Provide KYTC with a range of effective bridge coatings and guidelines for selecting them to provide the best benefits to bridges.

The study tasks are listed below.

<u>Task 1.</u> Conduct literature reviews of concrete coatings and surveys of transportation agencies to identify what types of coatings they are using and their service experiences with those. Review coatings manufacturers’ literature, AASHTO and ASTM standards and other sources to identify viable concrete coatings and test methods to determine their performance and suitability for

providing adequate service as concrete coatings. Conduct research on coatings that could be used to replace masonry coatings and stains currently employed by KYTC for new construction.

Task 2. Based upon the work performed in Task 1, prepare a compendium of concrete coatings, their properties and evaluation/acceptance test methods for consideration by the KYTC Study Advisory Committee. Meet with those officials and determine which coatings and tests will be employed throughout this study.

Task 3. Evaluate laboratory test procedures identified in Task 3 for concrete coatings selected by the KYTC Study Advisory Committee (including, hardness, chloride penetration and freeze-thaw testing). Use those test procedures to evaluate candidate concrete coatings materials.

Task 4. Conduct field trials of successful coatings identified in Task 4 on existing/new bridges. These can be done as test patches or full experimental bridge applications. Monitor all phases of the work and conduct follow-on evaluations.

Task 5. Prepare a final report. Provide KYTC with a range of effective concrete bridge coatings, sealants and fillers and other preservation treatments that can be used on new structures or incorporated into a PM program and guidelines for selecting them.

An additional task was to identify aesthetic and anti-graffiti coatings. However, that task was not addressed due to the significant effort directed toward identifying suitable qualification tests for concrete and the resulting amount of (and time required for) laboratory testing to evaluate candidate concrete coatings. The first final draft of this report was prepared in June 2006. The Study Advisory Committee requested that final publication be deferred until after October 2006 to allow KYTC Division of Materials personnel to conduct final evaluations of the coated concrete on the KY 676 bridge over the Kentucky River. That work was completed and the data provided to KTC researchers in late November. That data is included in this report.

2. EXPERIMENTAL COATINGS TESTING

2.1 COATINGS ACQUISITION AND TEST METHODS

A literature search was initiated to list all the concrete coatings available in the market and also those currently being used by other DOT's. In part, this was accomplished by an e-mail sent to Mr. Bob Kogler of the FHWA Turner-Fairbank Highway Research Center requesting him to post several questions on the SSPC DOT List Server that was accessed by coatings experts at most DOTs. Those questions were:

1) Identify organic concrete coatings (like new coatings or maintenance coatings or other specialty coatings for anti-graffiti or safety or elastomeric paints) other than stains and textured masonry coatings being used by highway agencies.
2) What are the specific uses for concrete coatings: like aesthetics, protection, safety, etc.?
3) Would like to have specifications written by highway agencies for concrete coatings.
4) Would like to know about any test methods and surface preparation techniques for concrete coatings systems.
5) Would like to know if there are any qualified product lists, how long the coatings systems have been in use and their service performance from highway agencies.

The summary of the responses to those questions from various DOT experts is provided below.

California DOT (Caltrans) and Indiana DOT (INDOT) have used polyurea based systems. Caltrans had concerns about UV stability in their systems. Their biggest area of concern has been repairing the existing concrete prior to coating. One example is the amount of bug holes and cracks that need filling and priming. INDOT has doubts about polyurea performance in "friction number" and skid resistance in the long run (which applies to driving and walking surfaces). The New Hampshire DOT currently lists one spray applied barrier membrane for waterproofing bridge decks (not a focus of this study). Acrylic concrete coatings have also been used for protection and aesthetics by the Michigan DOT. Their main issues of concern were the use of appropriate curing compounds, proper surface preparation, applications in cold weather, and scheduling problems with their 30-day curing requirement for new concrete prior to coating. The Ohio DOT has about 12 to 15 years of experience coating structures with a epoxy – urethane coatings system. They currently have application and mixing problems with the coatings and are meeting with the industry to address those issues. Ohio DOT started painting concrete in the early 80's with epoxy based systems and some of the problems they encountered over the years related to coating systems that wouldn't breathe (transmit water vapor) and ultraviolet light exposure stability problems . Those problems caused the epoxy coatings systems to eventually fail. Ohio DOT also uses sealers to fill cracks on new bridge decks and to do maintenance repairs on bridge decks. Several DOTs commented on the use of spray-on deck membranes, which were not a focus of this study

As the literature search progressed, it became evident that there were a wide variety of concrete coatings targeting specific concerns. There were anti-graffiti coatings, elastomeric coatings, and coatings intended for use on new concrete. Study Advisory Committee (SAC) members made the decision to investigate and focus on maintenance concrete coatings based on the KYTC's current requirements noting that some of those could also be used on new concrete. As a result, a letter requesting for product data sheets (PDS), material safety data sheets (MSDS), relevant service histories, and beneficial properties was sent to 18 concrete coatings manufacturers in September 2004. Six coating manufacturers responded by October, 2004. The manufacturers were subsequently asked to choose coatings that provided concrete protection and submit them for further evaluation. A listing those coatings, recommended surface preparation techniques and tests performed by the manufacturer is provided in Table 1.

KTC researchers obtained standards (ASTM and AASHTO) for concrete coatings. The following is a list of all the standards that KTC has reviewed pertaining to the concrete coatings industry:

1) ASTM D4587-01: *Standard Practice for Fluorescent UV-Condensation Exposures of Paint and Related Coatings.*
2) ASTM G155-04: *Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials.*
3) ASTM C793-04: *Standard Test Method for Effects of Accelerated Weathering on Elastomeric Joint Sealants,*
4) ASTM D3359-02: *Standard Test Methods for Measuring Adhesion by Tape Test,*
5) ASTM D412-98a (2002) e1: *Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension,*

6) ASTM D522-93a (2001): *Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings,*
7) ASTM D2243-95(2003): *Standard Test Method for Freeze-Thaw Resistance of Water-Borne Coatings,*
8) ASTM D3273-00: *Standard Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an Environmental Chamber,*
9) ASTM C672/C672M-03: *Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals,*
10) ASTM D3363-00: *Standard Test Method for Film Hardness by Pencil Test,*
11) ASTM D3274-95(2002): *Standard Test Method for Evaluating Degree of Surface Disfigurement of Paint Films by Microbial (Fungal or Algal) Growth or Soil and Dirt Accumulation*,
12) ASTM D4585-99: *Standard Practice for Testing Water Resistance of Coatings Using Controlled Condensation,*
13) ASTM B117-03: *Standard Practice for Operating Salt Spray (Fog) Apparatus,*
14) ASTM C67-03a: *Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile,*
15) ASTM C642-97: *Standard Test Method for Density, Absorption, and Voids in Hardened Concrete,*
16) ASTM D1653-03: *Standard Test Methods for Water Vapor Transmission of Organic Coating Films*,
17) ASTM D2370-98(2002): *Standard Test Method for Tensile Properties of Organic Coatings*,
18) ASTM D2794-93(2004): *Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact),*
19) ASTM D751-00: *Standard Test Methods for Coated Fabrics,*
20) ASTM E96-00e1: *Standard Test Methods for Water Vapor Transmission of Materials*,
21) ASTM G154-00ae1: *Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials,*
22) ASTM C672/C672M-03: *Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals*,
23) ASTM 5894–96: *Standard Practice for Cyclic Salt Fog/UV Exposure of Painted Meta,.*
24) AASHTO T259-02: *Resistance of Concrete to Chloride Ion Penetration*, and
25) AASHTO T260-97: *Sampling and Testing for Chloride Ion in Concrete and Concrete Raw Materials*.

To establish a preliminary evaluation of concrete coatings, the five test methods most relevant to KYTC purposes were selected by SAC members. They are 1) ASTM D 5894, 2) ASTM D4541, 3) AASHTO T260 & T259, 4) ASTM E96 and 5) ASTM D522. It was determined that ASTM D 4541, ASTM E96 and ASTM D522 test methods would establish a minimum failure criteria for further evaluation.

2.2 LABORATORY PERFORMANCE TESTING

The six coatings manufacturers supplied a total of nine coatings systems for the tests. Four of the coatings systems were one-coat systems. One manufacturer provided four coatings systems. One of the systems, submitted by resin manufacturer was an in-house experimental system that was not available commercially.

As stipulated by the Study Advisory Committee (SAC), the KYTC Division of Materials personnel sampled the coatings submitted and performed chemical analysis of them to assure that they conformed to manufacturer specifications.

2.2.1 AASHTO T260 & T 259 Tests

The resistance of concrete to chloride ion penetration test is an important criterion for coatings selection. The coating systems that protect concrete elements such as barrier walls, girders and pier caps must show good resistance to chloride ion penetration. This test was conducted by casting 12 in. x 12 in. x 6in. concrete blocks containing 10 in. x 10 in. x 1in. indentations on the top surface to permit the application of saline solutions for ponding tests. The blocks were made from mix design for KYTC type AA concrete[1]. The cast blocks were then cured for 24 hours prior to form removal. They were subsequently cured for 14 days immersed in lime water. After curing they were placed in a drying room at 73.4 ± 3^{o}F and humidity of 50 ± 4% and aged for 28 days. The dry concrete blocks were then swept blast in the ponding indentions using a coal-slag abrasive to provide a surface profile and painted with the coatings systems per the manufacturers' product data sheets. The coatings were cured for 30 days at ambient (room) temperature and humidity.

The coated indentations in the blocks were then subjected to continuous ponding with a 3 % sodium chloride solution to a depth of approximately 13mm (0.5in.) for 90 days. Plexiglas plates were placed over the ponded solutions to retard evaporation of solution and the solution was added as necessary to maintain that depth. After 90 days the blocks were drained of the solution and at three different locations, the coatings were removed using hand tools. Two samples were extracted from each location at depths of 0.5" and 1.0" using a 1-3/4" drill bit. The samples were labeled and taken to KYTC Division of Materials for chloride analysis and test results are provided in Table 2. Figures 1-8 show the various stages of this significant coatings performance test.

2.2.2 ASTM 5894 Tests

The capacities of the KTC laboratory test equipment limited the number of coatings tested (i.e. 9 systems) and also the number of panels of each coating type (5 panels each). The coatings from the manufacturers were applied in the KTC spray booth. Environmental conditions were measured prior to coatings application to ensure conformity with manufacturer requirements. The material used as a substitute for concrete for the test panels was *Durock*® cement board. The boards to be painted were swept blast with a coal-slag abrasive just above the reinforced web to give a profile to the surfaces being coated. All coatings were applied by spraying as recommended by the product data sheets. During painting, frequent measurements were taken using wet film thickness gauges to ensure that the dry-film coating thicknesses would be within manufacturer requirements. To achieve high confidence in the test results, each experimental coating system was spray applied to eight test panels. The best 5 panels of each coatings system were selected for testing.

The painted panels were cured for 28 days at room temperature and humidity prior to the onset of laboratory testing. Prior to testing, the coupons were photographed. Measurements were taken of the initial color using a *Color-Guide* $45^0/0^0$ meter in conformance with ASTM E308-01. The ASTM 5894 laboratory performance testing incorporated accelerated weathering (cyclic UV/humidity-QUV), and corrosion (cyclic condensation/evaporation-Prohesion).

The QUV light condensation chamber was used for the accelerated weathering test. Normal tap water was used in this test. A test cycle consisted of a four-hour UV exposure cycle with UVA-340 lamps set at normal irradiance at 60^o C alternated with a four-hour condensation cycle at 50^o C (Figure 3). The light intensity was adjusted using a factory calibrated spectrometer designed for use with the QUVs.

Prohesion tests were performed in a cyclic corrosion test chamber. The test employed an electrolyte solution of deionized water, 0.05% sodium chloride, and 0.035% ammonium sulfate (Figure 4). The Prohesion cycle consisted of a one-hour fog application (condensation) of the electrolyte followed by a one-hour dry off period (evaporation). Prohesion tests were performed at room temperature (approximately 20^o C). The Prohesion evaporation cycle was monitored periodically and tests were performed to ensure that the proper amount of salt-fog solution was being generated during the condensation cycle. Temperature gages were placed in the Prohesion chamber to ascertain that the condensation/evaporation temperatures were within specified limits.

The tests were conducted in the previously described sequence. Boards were exposed for one-week periods (168 hours) and then shifted to the following test chamber for the next test. The tests were stopped at 6-week intervals (1,008 hours) to examine the panels and take necessary measurements and photographs (Figure 6 & 7). The measurements consisted of color readings (ASTM E308-01). The tests were run for five 6-week intervals (5,040 hours). Table 3 provides the resulting color readings data.

KYTC reviewed the test data and identified the coatings systems that performed satisfactorily. Figures 9-12 show this test in progress.

2.2.3 ASTM D4541 Tests

This test was performed using a portable pneumatic adhesion test device, the *Patti®* tester to evaluate the pull-off strength of the coating system. For this test, KYTC Division of Material personnel cast AA concrete into cylinders 4 in. dia. x 8 in. high. The cylinders were cured for about 7 days. After curing, they were saw cut into halves vertically to provide flat surfaces for testing. The cylinder halves were then provided to KTC researchers for testing.

The cut faces were sweep-blasted using a coal-slag abrasive to obtain a roughened profile. Then, the faces of three cylinder-halves were spray painted with each coatings system. The coated cylinder-halves were subsequently cured for 30 days. Thereafter, one cylinder-half for each coatings system was subjected to adhesion testing (3 tests per cylinder-half) and averages taken of the pull-off readings. The test entailed bonding ½-in. dia. dollies to the coating surface and extracting the coatings from the concrete substrate under tension. The *Patti®* tester employs a dial gage that provides tension readings in psi. For each coatings system, two cylinder-halves were subjected to 5,000 hours of a continuous modified salt spray (fog) test (per ASTM G85). After this test was completed, the cylinder-halves were subject to three pull-off adhesion tests and the readings were averaged for both cylinders. The results of those tests are provided in Table 4. Figures 13-15 show the adhesion test in progress.

2.2.4 ASTM E96 Tests

The water vapor transmission test determines the passage of water vapor through the coating. This is significant as the concrete coatings must be able to breath (i.e. transmit water vapor) due to freezing and thawing of the concrete during the winter. A strip of a coatings system was applied on slick release papers using a film casting knife (adjustable micrometer film applicator). Five different release papers were tested/ employed to allow the applied coatings to cure as sheets/films of coatings/coating systems approximating their thicknesses when applied to concrete. After curing for one week at 23 ± 2^{o}C and 50 ± 5% relative humidity (RH) in an environmental test chamber, the coating systems were removed as solid films from the release papers and dried for an additional week. The films were cut into a three-inch diameter circles to fit inside perm dishes. Three dishes were prepared for each coating system by filling them with water and sealing them with films. Each dish was weighed daily at the same time and returned to the test chamber to be maintained at 23 ± 0.6^{o}C and 50 ± 2% relative humidity. Due to the limitations on the test chamber at KTC, KYTC officials allowed the relative humidity to be maintained at 50 ± 5%. The chamber was monitored for temperature and RH using a calibrated measuring device. The water vapor transmission rates for the coating systems were computed following the ASTM E 96 and are provided in the Table 5.

2.3 FIELD APPLICATION AND TESTING OF CONCRETE COATINGS

Field application tests were conducted to gain experience in applying the test coatings to concrete and to subsequently assess their field performance. A site on the westbound bridge barrier wall of KY 676 over the KY River in Frankfort was selected for the field tests. The bridge was over 20 years old with an existing masonry coating or stain that was barely visible with some honeycombing/cracks in the barrier concrete. KTC researchers and SAC members visited the site in early September 2005 and marked barrier wall panels with letter designations indicating the coating system to be applied and the concrete surface preparation methods. All of the experimental coatings were applied on the barrier walls using two surface preparation methods. Each coatings system was applied to two barrier wall panels; one abrasive blasted and the other pressure washed to determine the effect of substrate preparation on coating durability. The barrier wall panels are each approximately 23 ft long, 3ft high on the interior side facing traffic with a horizontal cap 1 ft wide. The interior face and cap were painted yielding an surface test area of approximately 184 ft^2 per panel.

KYTC personnel from Division of Materials took samples from the concrete substrate for preliminary chloride data prior to the surface preparation work. They drilled 6 holes to a maximum of 1 in. in depth at ½-in. increments. The dust generated from each ½-in. increment was collected and analyzed for chloride content. Three of the holes were drilled into the lower shoulder of barrier wall and the remaining three drilled into the vertical portion of the wall approximately 6 in. below the cap. KYTC personnel used a pachometer prior to drilling to avoid the reinforcing steel. Each drilled hole was patched with quick-curing concrete filler. Another set of samples were taken one year after the application of the paint systems to compare the chloride ion concentration data.

Shortly thereafter, KTC researchers prepared nine of the barrier wall panels by pressure washing and another nine by sweep blasting using a coal-slag abrasive. The abrasive blasting work was performed by KYTC District 5 maintenance personnel. Surface voids (i.e. “bug holes or honeycombing or cracks”) on all the panels were filled with *Tamms Speedcrete Redline* except for two panels that were filled with a special patching compound supplied by the coatings manufacturer. Due to the limited amount of areas on the wall requiring patching, *Speedcrete* was applied to a one foot section from top to bottom of the barrier wall on each abrasive blasted panel. The placement of the *Speedcrete* was to be consistent for tracking and evaluation purposes of each blasted panel. This was done to study the impact of patching materials (fillers) on the coating systems.

KYTC District 5 maintenance personnel supplied an air compressor used for the coatings application. The coating systems were applied using airless spray equipment to the top and face of the parapet for the remainder of the week as per the manufacturers’ product data sheets and material safety data sheets. A roller was used to apply a one-foot width of the barrier wall cap. Figures 16 thru 24 show the field application of coating systems. Table 3 provides color readings of the coatings systems (topcoats) applied in field.

3. SUMMARY OF TEST RESULTS

3.1 LABORATORY RESULTS

The AASHTO T 259 & T 260 (chloride penetration) test data shown in Table 2 indicated that coatings systems A, C, E, G and H had chloride ion concentrations that are below that of the concrete panels with no protection. The test results indicate that these coating systems inhibited chloride penetration. This would make them good candidates for protecting structural concrete from deicing salt damage.

The color reading data as shown in Table 3 from ASTM 5894 (accelerated weathering) testing gave an indication of how the coating systems performed in retaining their color when exposed to field environments. Concrete panels had to be alternated with steel panels in the lab tests, and as a result rust stains were observed on the concrete coating systems panels. None of the paint systems failed as a result of this testing. There was no disbonding and/or discoloration except for the aforementioned rust staining.

The ASTM D4541 (adhesion) test data shown in Table 4 were all above 500 psi. Typically, for structural coatings, adhesion values greater than 50 psi are considered acceptable. The test data indicate that adhesion is not a problem with all the coatings systems tested.

The ASTM E96 (water vapor transmission rate) tests indicate that all the coatings have some degree of vapor transmission which is desirable as it helps concrete to breathe. As minimum water vapor transmission rates have not been determined, the acceptability of the coatings in this regard will need to be assessed by field test results.

3.2 FIELD RESULTS

Coating systems applied in the field showed no disbonding and/or discoloration except for one system that had dust accumulated on its surface. In July 2006 when the coating systems were inspected, they were performing satisfactorily with paint adhering to on the top and sides of the barrier wall (horizontal and vertical surfaces). Besides indicating that all the coatings systems were functional in the short term, this indicated that both pressure washing and abrasive blasting were suitable for surface preparation. At the bottom of the barrier wall there was some damage as some pieces of paint on all coatings systems had come loose due to rock hits. If this proves problematic in the future, more abrasion resistant coatings may need to be employed for use on barrier walls.

The base line chloride content data obtained from the barrier walls in September 2005 (Table 2) when no paint systems had been applied indicated higher concentrations of chloride ion when compared with concrete blocks poured in lab and this was primarily due to salting during winters. Compared to this baseline data, the chloride data taken in November 2006 showed negligible increase if any, of chloride concentrations indicating either that coating systems were performing well or that a longer monitoring period was needed to detect any significant increases in chloride penetration into the barrier wall concrete.

4. CONCLUSIONS AND RECOMMENDATIONS

The KYTC/KTC coatings performance and acceptance testing provided a mechanism for assuring new coatings used on KYTC maintenance painting projects performed successfully. The data generated from the evaluation of the coatings systems at KTC has no comparative data sets from the manufacturers as the testing methods are evolving for concrete coatings along with surface preparation techniques. This presented a unique method of comparing coating systems with each other and for establishing new acceptance criteria which was done by KYTC Division of Materials personnel. Based on the data provided by KTC, KYTC personnel have established a Qualified Products List (QPL) for concrete coatings.

The following recommendations are provided:

1. The test results of ASTM 5894 may have been influenced by Durock® cement board substrate. For future weathering testing it is recommended that cement panels be tried instead. Comparative testing should be conducted between the two substrate materials to establish if there is any effect on coatings system performance. If a difference is observed the concrete should be substituted for the Durock®.
2. In the near future, the coatings manufacturers’ representatives should be asked to review the results of the field tests and suggest any possible improvements..

3. Research should be performed on surface preparation techniques for applying concrete coatings. The work conducted under this study did not firmly establish optimum surface preparation methods (i.e. patching holidays, filling cracks and overall surface preparation by either abrasive blasting or pressure washing).
4. Desirable vapor transmission rates must be established in the future based on long term monitoring of field tests.
5. Other coatings (e.g. anti-graffiti and reflective) offer additional benefits for KYTC. These need to be investigated under a follow-on (Phase II) study.

5. REFERENCES

1. *Kentucky Transportation Cabinet / Department of Highways Standard Specifications For Road and Bridge Construction.* Section 601.03.03.

6. TABLES

Table 1. Concrete Coatings Surface Preparation and Manufacturer Tests						
Paint Supplier	**Surface Preparation Required**			**Tests Performed by Manufacturer**		
	Primer	**Intermediate**	**Top**	**Primer**	**Intermediate**	**Top**
Tnemec - A	Clean and dry, remove loose concrete, not recommended for previously painting surfaces	Remove all loose paint, use 151 tape over cracks, and clean and dry	Clean and dry, 14 day cure, bare concrete may be dampened to slow curing	Adhesion, Freeze-Thaw, Impact Resistance	N/A	Adhesion, Freeze-Thaw, Fungal Resistance, Humidity, Moisture Vapor Transmission, QUV Exposure, Salt Spray, Tensile Strength & Elongation, Wind Driven Rain
PPG – B	Clean and dry, add primer where needed		Clean and dry, remove and kill all mildew (PPG Mildew Check) if surface is chalky apply prime coat of Perma-Crete Exterior Masonry Surface Sealer	N/A		N/A
Sherwin-Williams – C	Clean, dry, and sound condition		Clean, dry, and sound condition	N/A		Abrasion Resistance, Adhesion, Corrosion Weathering, Direct impact Resistance, Dry Heat Resistance, Flexibility, Humidity Resistance, Pencil Hardness, Salt Fog Resistance
Sherwin-Williams – D	Clean, dry, and sound condition		Clean, dry, and sound condition			Impact Resistance, Water Vapor Permeability, Water Vapor Transmission, Carbon Arc Testing, Salt Spray, Resistance to Wind Driven Rain, Freese/Thaw Resistance, Adhesion, Taber Abrasion, Flexibility, 1/8 inch mandrel, Water/Alkali Resistance, and Fungus Growth
Sherwin-Williams – E	Cured, clean, dry, and sound		Cured, clean, dry, and sound	Accelerated Weathering, Salt Spray Resistance,		Accelerated Weathering, Salt Spray Resistance, Water Vapor Transmission, Wind Driven Rain, Freeze-Thaw Test, Fungus Growth

				Water Vapor Transmission , Wind Driven Rain, Freeze-Thaw Test, Fungus Growth Resistance, and Applicable Standards		Resistance, and Applicable Standards
Sherwin-Williams – F	Clean, dry, and sound condition		Clean, dry, and sound condition			Accelerated Weathering, Salt Spray Resistance, Water Vapor Transmission, Wind Driven Rain, Freeze-Thaw Test, Fungus Growth Résistance
Porter – G	28 day cure, clean and dry, moisture contend below 12%		28 day cure, clean and dry, moisture contend below 12%	N/A		N/A
EPC – H	Clean of all loose paint and dirt		Dry and free of contamination	N/A		N/A
Rohm & Haas – I	N/A			N/A		

Table 2. Average Chloride Ion Concentration in PPM					
Coating System	Laboratory Samples		Field Samples		
	Depth of 13 mm	Depth of 25 mm	Concrete Barrier Wall Section and Sampling Depth	Chloride Ion Concentration	
				Sept. 2005	Nov. 2006
X – Without Coating	27.0	3.4	AW top 0.5”	7.5	
XX – No coating and/or solution	2.7	2.7	AW top 1.0"	5.5	
A	10.7	3.1	AW bottom 0.5"	7.8	8.2
B	34.7	4.7	AW bottom 1.0"	7.5	7.5
C	2.6	1.9	AA bottom 0.5”		6.7
D	24.6	2.0	AA bottom 1.0”		10.8
E	3.9	1.6	CW bottom 0.5”		7.7
F	22.3	3.2	CA bottom 0.5”		7.8
G	17.5	3.3	CW bottom 1.0”		9.8
H	7.9	2.0	CA bottom 1.0”		4.9
I	25.0	2.9	DW top 8’6” off Section	5.2	
			DW top 1.0"	6.7	
			DW bottom 0.5"	5.3	
			DW bottom 1.0"	4.2	
			HW Top 0.5" 13” off Beginning Section	5.2	
			HW Top 1.0"	4.3	
			HW bottom 0.5"	3.2	
			HW bottom 1.0"	7.4	

Table 3. Average ΔE Color Values After Every 1000 Hours of Testing for a Total of 5000 Hours															
Coating System	Laboratory Testing					Field Testing									
						Water Wash					Abrasive Blast				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
A	5.42	8.56	9.68	9.84	11.86	4.15	3.17	3.17	3.98	1.79	5.52	4.88	3.56	2.24	2.15
B	7.82	13.18	16.16	18.87	18.28	6.29	5.18	3.03	3.02	1.79	5.92	5.03	2.24	2.47	2.62
C	0.87	1.84	2.58	2.59	2.38	4.22	3.43	2.85	2.29	3.36	2.02	2.01	3.65	2.28	1.35
D	0.82	3.83	4.5	4.76	4.04	6.94	5.99	5.35	4.55	4.97	3.22	2.65	3.4	3.7	3.63
E	1.77	2.51	2.97	2.85	2.91	10.47	9.6	6.5	8.88	8.53	5.75	5.04	3.59	2.98	3.33
F	0.91	2.3	3.01	1.84	2.09	6.64	5.37	4.3	4.02	2.65	6.3	4.92	3.24	3.7	2.24
G	0.78	1.00	1.44	1.91	2.56	12.63	12.12	7.71	3.89	4.34	6.57	5.8	2.78	3.12	0.86
H	3.55	5.73	5.69	6.27	5.8	5.8	5.6	4.09	5.6	6.85	5.92	5.15	5.15	6.33	6.38
I	4.64	8.57	10.18	10.97	11.13	9.07	7.75	3.74	4.62	5.61	6.08	5.27	3.09	2.78	4.64

Table 4. Average Adhesion Test Results Prior to and After Salt Fog Testing		
Coating System	**Average Prior to Testing (psi)**	**Average After 5000 Hrs Testing (psi)**
A	1134.33	907.9
B	624.33	706.9
C	1209	891.8
D	522.33	528.7
E	808.03	676.1
F	637.93	565.8
G	583.53	764.1
H	416.85	N/A
I	556.3	N/A

Table 5. Average Water Vapor Transmission Rates for the Concrete Coatings	
Coating System	**Average Rates in gm per m^2 per 24 h**
A	70.05
B	105.03
C	16.04
D	247.48
F	541.15
G	218.22
H	110.29

7. FIGURES

Figure 1.KYTC Division of Materials Personnel conducting Slump Test on the concrete mix at KTC

Figure 2.Finished Concrete Blocks using AA highway concrete mix

Figure 3.Concrete Blocks cured in lime water for 14 days in environmental chamber

Figure 4.Concrete Blocks dried in environmental chamber for 28 days

Figure 5.Coatings applied to Concrete Blocks using a brush

Figure 6.Ponding test with Salt Solution poured on the coated concrete blocks

Figure 7.Sample collection for Chloride ion testing on concrete blocks

Figure 8.Applying a coating system on test panels using gravity feed spray gun

Figure 9.Spraying concrete cylinder blocks for adhesion tests

Figure 10.Test panels undergoing accelerated weathering testing in a QUV chamber

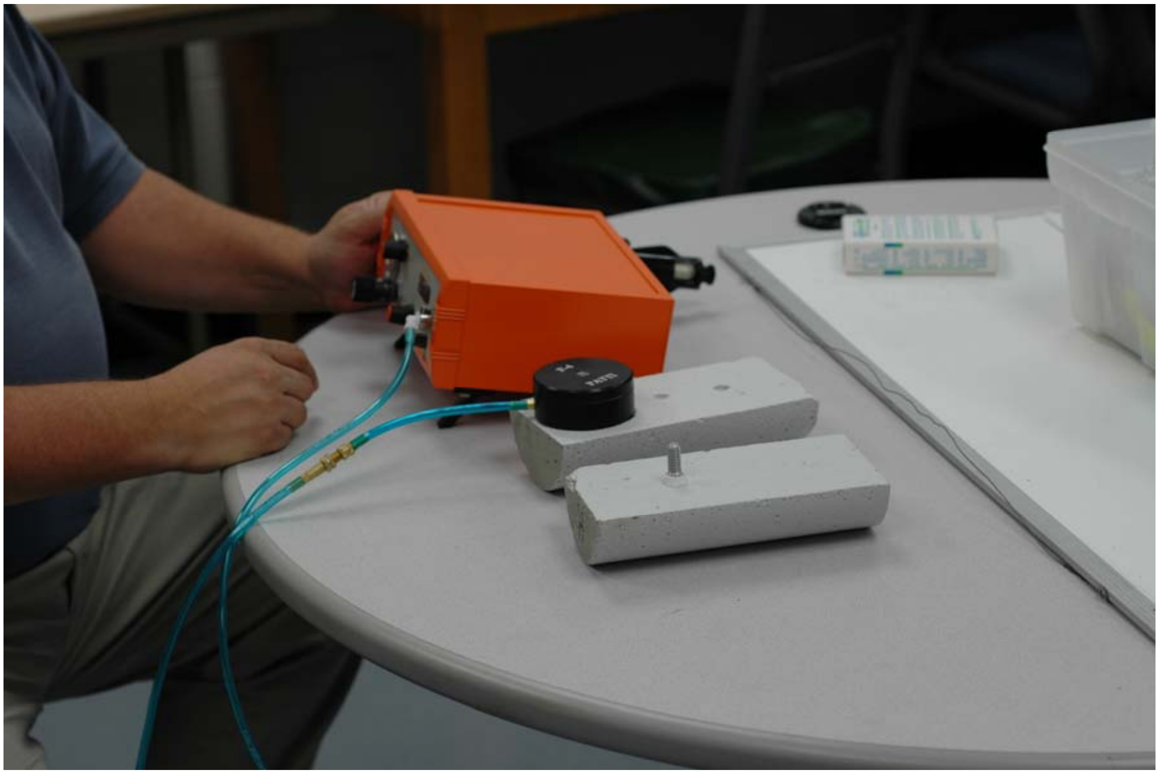

Figure 11.Adhesion test in progress on cylinder blocks using a Patti Adhesion Tester

Figure 12.Averaged adhesion test results for a cylinder block

Figure 13.Barrier wall panel on US 676 connector over KY river in Frankfort, KY prior to surface preparation and coating

Figure 14.Drilling barrier wall for taking concrete samples for baseline chloride data

Figure 15.Patching the drilled holes with Tamms Speedcrete Redline

Figure 16.Pressure washing the barrier wall with a 15^0 fan tip at around 2500 psi

Figure 17.Sweep blasting with black beauty

Figure 18.Rolling 12" patch of coating system on the back of barrier wall

Figure 19.Airless spraying of concrete coatings on the barrier wall

Figure 20.Finished spraying of a concrete coating on the barrier wall

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