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Sealants, Treatments and Deicing Salt Practices to Limit Bridge Deck Corrosion and Experimental Deck Sealants and Pier Cap Coating on Interstate 471

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KTC-14-4/FRT194, SPR388-12-1F

Sealants, Treatments and Deicing Salt Practices to Limit Bridge Deck Corrosion and Experimental Deck Sealants and Pier Cap Coating on Interstate 471

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16. Abstract
This project evaluated the ability of concrete sealants to impede the ingress of chloride ions into concrete bridge decks. Laboratory testing evaluated 24 concrete-penetrating sealants and four film-forming products. The products were selected based on survey results from adjacent state transportation agencies. KTC assisted the KYTC in developing Special Notes for applying four experimental sealants to two bridges (B00056L & B00056R) located on Interstate 471, over 6th Street in New Port, Kentucky. The sealants chosen for the field-testing were intended to reduce the ingress of chloride ions when deicing materials are applied to road surfaces. Pre- and post-application friction test data were collected – three of the four sealants increased friction resistance. The ongoing performance of sealants will be evaluated as part of a long-term monitoring plan.

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EXECUTIVE SUMMARY

The application of deicing salts to bridge decks significantly impairs their concrete/steel components. Monitoring performed on Kentucky Transportation Cabinet (KYTC) managed bridges has underscored that reinforced structural concrete bridge elements are becoming increasingly contaminated with chlorides at high concentrations. The deterioration of these bridge elements has accelerated over the past 12 years, and there is strong evidence pointing to the increased application of deicing chemicals as a primary driver of this degradation. Preserving existing KYTC bridges and newly constructed bridges requires protecting them against the intrusion of chloride into concrete.

This report discusses the numerous sealant products available on the markets to ward off chloride intrusion and their performance in laboratory testing. Kentucky Transportation Center (KTC) researchers examined 28 products to determine how successfully they attenuate chloride intrusion. Four of the products were film formers (ultra-thin overlays) and 24 were penetrating sealers. Testing indicated that nine of the penetrating sealers reduced chloride intrusion by at least 50 percent and an additional six sealers reduced chloride content by at least 25 percent. Each of these 15 better performing products are silane/siloxane-based materials.

KTC researchers administered a survey to other states to understand how they implement deck sealants. The survey results showed that the average cost of penetrating deck sealers applied by state transportation agencies ranges from \$0.30 to \$1.50 per ft^2. Based on this information, KTC developed Special Notes for an experimental field project to apply deck sealers. The cost for contractor-applied deck sealers for the KYTC experimental project was \$0.24 per ft^2. A field test of deck sealants, which sought to determine their ease of applications and effectiveness, indicated they could be applied without closing down lanes for extended periods. Field tests confirmed that deck sealants can maintain a surface's friction resistance – three out of four sealers evaluated increased the friction resistance. Fully evaluating the effectiveness of deck sealants at slowing chloride intrusion will entail performing extended monitoring of the bridge decks. Incorporating the test sites into a long-term monitoring plan will let researchers develop more robust conclusions about the effectiveness of deck sealants.

1. INTRODUCTION

The degradation of structural concrete, especially bridge decks, pier caps, and abutments, is a major problem for transportation infrastructure. A critical driver of this degradation is the application of deicing salts during winter months. The salts most commonly used by KYTC are sodium chloride (NaCl), which is referred to as rock salt or – in its liquid form – brine. Calcium chloride ($CaCl_2$) is also used in liquid form for ice and snow removal when temperatures are lower than 22^0 F. There are two mechanisms that catalyze degradation in concrete.

The first mechanism is the penetration of chloride ions into concrete. Once a critical concentration is reached at the concrete-steel interface (0.02-0.03 percent by weight of concrete) the corrosion of steel is set in motion. Commonly accepted guidelines specify the thresholds for different magnitudes of steel corrosion:

- 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 (1)

Two undesirable conditions emerge when reinforcing steel corrodes. First, the corrosion product expands and creates sufficient internal stresses to break the concrete. This results in cracking (Figure 1), delamination (Figure 2), and spalling (Figure 3). A second problem is that corrosion reduces the cross section of the reinforcing steel to the point – in some cases – where no steel and thus no reinforcement remain (Figure 4).

A second degradation mechanism is that the application of calcium chloride may produce a reaction that generates hydrated calcium oxychloride ($Ca(ClO)_2$). Calcium oxychloride is an expansive material that may break up the concrete, thus enabling higher quantities of contaminants (chlorides) access to the reinforcing steel (2, 3).

In, Kentucky, epoxy coatings are used on embedded reinforcing steel in structural concrete to ward off corrosion. However, the protection it offers is finite and field data have shown increasing chloride contamination of bridge decks when they are subjected to typical highway service environments (for bridge decks). In decks, concrete cracks and cold joints open up direct paths for chlorides to penetrate to the epoxy and attack the reinforcing steel through coating defects (e.g. pin-holes). Other reinforced concrete bridge elements, abutments and piers, employ more permeable concrete and, therefore are more susceptible to damage caused by the wholesale ingress of deicing chemicals. Many existing KYTC bridges contain bare (black steel) reinforcing bars whose protection against corrosion extends only as far as the permeability and depth of the concrete cover. KTC reviewed the use of deicing chemicals in Kentucky, conducted a survey of other agencies focused on the use of deck sealants, conducted a laboratory evaluation of commercially available sealants, and assisted KYTC officials in developing a field application test of promising sealants by producing Special Notes and a Project List of Approved Materials for inclusion in a KYTC rehabilitation project on Interstate 471.

1.1. PROBLEM STATEMENT

For new construction, common methods for chloride mitigation include the incorporation of impermeable concrete/asphalt, protective membranes and overlays, corrosion inhibitors, and corrosion resistant reinforcing steel (coated, clad, and stainless steel). In the past, KYTC adopted a "do nothing" approach to bridge deck deterioration, electing to repair damaged decks by applying thin rigid overlays – usually of latex concrete. While this approach was economically viable in the past, the growing number of aging bridges along with motorist demands for unhindered travel is placing new financial and operational constraints on KYTC's bridge maintenance efforts. It is imperative that KYTC develop effective measures to address the corrosion of bridge decks and other structural concrete. These measures should involve proactively limiting chloride intrusion while minimizing motorist inconvenience.

1.2. BACKGROUND AND SIGNIFICANCE OF WORK

The corrosion of reinforcing steel in concrete is a major problem for the transportation infrastructure, especially bridge decks. It is caused primarily by applications of deicing salts during winter months. Those chlorides penetrate concrete and eventually reach a critical concentration at which the onset of corrosion begins (0.02-0.03 percent by weight of concrete). In Kentucky, epoxy coated embedded reinforcing steel has been used to protect bridge decks against corrosion. However, the protection it provides only lasts 20-30 years when exposed to typical highway service environments. Many Kentucky bridge decks still contain black (uncoated) reinforcing steel, but these may also include overlays of latex or low-slump concrete.

Penetrating sealants include (but are not limited to) surface applications of vegetable oils, silanes (and siloxanes), polymers, and a variety densifiers or silica-gel formers. Typically, sealants are sprayed or manually spread onto concrete surfaces. In some cases, these applications have to be supplemented by follow-up applications of water to complete chemical reactions with the concrete. Typically, sealants permeate into concrete pores and subsequently provide barriers against entering moisture, water vapors, chlorides and other deleterious chemicals. This study addresses crack sealer/healers, but it will not include materials that also constitute riding surfaces such as spray applied membranes/wearing surfaces, polymer overlays, and rubberized asphalts. Treatments include: electro-chemical methods including galvanic protection, impressed-current cathodic protection, and impressed current chloride extraction to either stop corrosion in a high chloride environment or reduce chlorides in concrete to a non-damaging level. Additionally, chemical applications have been promoted that inhibit corrosion of reinforcing steel and extract chlorides. These materials and the claims associated with them are new and have been neither widely investigated nor verified.

Several deicing salts have been promoted as being able to decrease corrosion via chemical composition (no chlorides), corrosion inhibition, or dilution and chloride extenders (e.g. beet juice). In addition to those chemical effects, improved application procedures may prove advantageous for reducing chloride penetration into concrete (dry vs. liquid applications). Some state highway agencies may have chloride application/removal practices that limit long-term corrosive effects.

The mechanisms used to limit deck deterioration and maintenance costs include: 1) optimizing deicing salt applications, 2) using deicing salts that less aggressively promote corrosion, and 3) reducing salt penetration into the concrete. The Transportation Research Board has funded an in-depth guidance document that addresses some, but not all of these factors. KYTC will investigate the full range of options to identify/adopt actions and practices that will extend the service lives of bridge decks.

1.3. OBJECTIVES

2. Determine current KYTC practices for applying deicing salts to bridge decks, including monitoring deicing materials, methods of deicing application (i.e. wet/dry), application frequency and application rates statewide. Identify candidate bridges to monitor annual deicing salt application, chloride penetration into bridge decks, resultant deck deterioration (spalling and/or corrosion). Review KYTC bridge inventory to identify typical categories of bridge decks based upon route type (traffic), structure type, age, condition, materials and possibly general location (for anticipated chloride application quantities).
3. Identify sealants, densifiers and inhibitors used nationwide to protect reinforced concrete bridge decks against chloride-induced corrosion. Identify deicing salt substitutes, inhibitors and extenders used to limit deicing salt induced corrosion. Identify treatments/practices that minimize bridge deck exposure to deicing salts or to associated damage (e.g. spring washing).
4. Identify electrochemical treatments used to stop/reduce bridge corrosion and determine key operational factors for their deployment.
5. Evaluate various sealants, densifiers, and inhibitors along with salt substitutes, salt inhibitors and extenders to determine which ones are effective for addressing/limiting corrosion of bridge deck reinforcing steel. Evaluate treatments to limit deicing salt use in the experimental projects.
6. Assess application procedures for experimental bridge deck treatments (sealants, densifiers, and inhibitors) found to be effective in laboratory tests. Assess the use of effective salt substitutes, salt inhibitors or extenders on selected bridges. Assess other experimental deck treatments/practices that are effective in limiting long-term exposure/concrete penetration by deicing salts.
7. Provide KYTC with practical guidelines to implement methods that will preserve bridge decks, including the application of sealers, densifiers and/or inhibitors to bridge decks, including the use of electrochemical treatments. These guidelines will provide useful

information with respect to implementing those treatments on specific bridge types (determined in the study). Additional recommendations will be provided for the use of any effective salt substitutes, inhibitors, and extenders. Any related treatments/practices found to be effective will also be recommended.

1.4. WORK PLAN

Task 1. Survey KYTC Districts to determine current KYTC practices for applying deicing salts to bridge decks, including the types of deicing materials employed, methods of applying deicers (i.e. wet/dry), application frequency, and application rates. Review KYTC bridge inventory to identify typical categories of bridge decks based upon route type (traffic), structure type, age, condition, materials and possibly general location (for anticipated chloride application quantities). Identify candidate bridges to monitor annual deicing salt application, chloride penetration into bridge decks, and the resulting deck deterioration (spalling and/or corrosion).

Task 2. Conduct literature reviews and surveys of state highway agencies (SHAs) to identify sealants, densifiers, and inhibitors used nationwide to protect reinforced concrete bridge decks from chloride-induced corrosion. Determine application frequencies and costs. Contact transportation officials and vendors to identify deicing salt substitutes, inhibitors, and extenders used to limit deicing-salt-induced corrosion. Determine treatments/practices that minimize bridge deck exposure to deicing salts or to associated damage (e.g. spring washing).

Task 3. Contact SHAs to determine electrochemical treatments used to stop/reduce bridge corrosion and key operational factors for their deployment. Identify costs and performance of systems/treatments.

Task 4. Conduct laboratory salt-ponding tests of sealants, densifiers, and inhibitors along with salt substitutes, salt inhibitors, and extenders that do not have extensive histories of deployment by SHAs to assess their effectiveness in limiting chloride ingress in concrete/corrosion of bridge deck reinforcing steel. Conduct laboratory tests of treatments that limit deicing salt use in the experimental projects.

Task 5. Monitor experimental bridge deck treatments to evaluate application procedures for sealants, densifiers, and inhibitors found to be effective in laboratory tests. Apply effective salt substitutes, salt inhibitors, or extenders on selected bridges. Monitor other experimental deck treatments/practices determined to be effective in limiting long-term exposure/concrete penetration by deicing salts.

Task 6. Prepare guidelines to implement bridge deck preservation actions, including the application of sealers, densifiers, the use of electrochemical, and/or inhibitors to bridge deck treatments. Prepare recommendations on methods to assess whether bridge decks are candidates for sealers or treatments.

Task 7. Prepare a final report to document study conclusions and provide recommendations.

2. REVIEW OF PRACTICES AND PRODUCTS

The research team reviewed articles and publications focused on the use of alternative products for deicing. Several products have been adopted (e.g. cheese brine, beet juice, sugars, et al.) primarily as sodium chloride extenders. Typically, these materials are the by-products of local industry. Due to various issues such as traction reduction, availability, odor, and tackiness, none have been considered a widespread success. The most popular choices for chemical deicing remain sodium chloride and calcium chloride.

KYTC uses solid sodium chloride (rock salt), liquid sodium chloride (brine), and liquid calcium chloride as deicing products. Rock salt has been used for many years, but in recent years it has become more of a post-event (after a snowfall or icing) treatment. As Figure 5 indicates, the total amount of rock salt used continues to increase, albeit with annual fluctuations due to the number of snow and ice events. While rock salt can damage reinforced concrete (bridge decks), it has been used for decades with less apparent effect on bridge decks than has been observed recently. Some rock salt may be removed from roads and bridges by traffic action if placed on dry or frozen surfaces. Rock salt on bridge decks with considerable amounts of snow or ice will eventually dissolve, and most of it will run off as thawing occurs.

Researchers reviewed the use of deicing chemicals by KYTC Department of Highways districts and determined that certain districts tend to use more than others. The amount each district uses appears related to the amount of traffic and the number of high priority snow and ice routes. Two higher use Districts (5 and 7) and two lower use Districts (8 and 11) were selected for further investigation. Interviews were conducted with officials in these districts to determine what deicing practices are used – and the amounts applied – on bridges

KYTC uses a Field Operations Guide (FOG Manual) to manage field activities of the KYTC Division of Maintenance. All districts comply with the FOG Manual and guidance from the "Snow Fighters' Hand Book," which is published by the Salt Institute. Several methods are used to apply snow and ice treatments to KYTC-managed bridges. KYTC crews are responsible for deicing activities on many bridges around the state. However, some bridges are maintained by contractors, and in a few cases through reciprocal agreements with other agencies, i.e. local governments. Under these agreements bridges owned by one agency may receive winter maintenance from another. In many cases, an equipment operator may have the freedom to apply extra deicing chemicals at locations that are the most problematic during snow and ice events (e.g. curves and bridges). The research team concluded that the quantities of deicing chemicals applied to specific bridges are impossible to determine using currently available information.

KYTC sampled bridge deck concrete, at top reinforcement mat depth, on several bridges in central Kentucky in 2002. Reinforced structural concrete in KYTC bridges typically has a two-inch concrete cover atop the reinforcement. Therefore samples were collected from 1.5 to 2.0 inches deep. All tests indicated chloride contents in the 0.01 percent (by weight of concrete) range. Based on these results, KYTC concluded that chloride was not a problem for bridge decks.

By 2012 reinforced structural concrete in KYTC bridges showed visible signs of deterioration, with increasing deck and substructure damage. In 2011, KTC collected samples from 24 KYTC bridges in central Kentucky. Samples were taken from bridge deck wheel paths, deck gutters, abutments, and where accessible, pier caps. The concrete samples were taken at a depth of 1.5 to 2.0 inches. KTC collected samples from the deck gutter and wheel path and both ends of each bridge. Samples were also obtained from one abutment at each bridge and from one pier cap where accessible. These data are more fully discussed in Kentucky Transportation Center Report No: KTC-14-3/SPR406-10-1F. Testing revealed that chloride contamination had greatly increased from 2002 to 2011. As shown in Figure 6, many samples from bridge decks exceeded the 0.03 percent chloride level which initiates rebar corrosion.

As part of this project, the research team distributed a survey (see Appendix A for a complete version of it) to other Departments of Transportation (DOTs) asking them about the products and practices used to seal bridge decks. Surveys were dispatched to state DOTs in the same region as Kentucky. Nine DOTs responded, with seven reporting the use of some type of deck sealing activity; Appendix B contains a list of respondents and summarizes key findings. Six of the seven DOTs use a penetrating silane or siloxane sealer. The penetrating sealers' expected service life ranged from four to 10 years. One DOT relies on asphaltic membranes and resin/aggregate overlays for deck sealing.

Practices vary widely throughout the region. Most DOTs responding to the survey use a mix of state forces and contractors to apply sealants. According to this survey, costs of silane/siloxane deck sealers applied by state forces ranged from about \$0.30 ft^2 to \$1.50 ft^2. The same sealers applied by contract cost approximately \$4.00 ft^2.

Based on the results drawn from literature searches and surveys, the research team concluded that electrochemical treatments, deicing extenders, and inhibitors were not used with success by other agencies. Meetings with KYTC District personnel revealed that available records did not allow for the tracking of deicer usage on particular bridges. Based on these findings, KTC researchers decided to shift their focus to the evaluation of deck sealers designed to minimize chloride intrusion into concrete bridge decks.

3. LAB TESTING

KTC solicited penetrating deck sealers from a number of manufacturers identified through product searches and a survey of DOT agencies. The solicitation asked that any product submitted include a product data sheet and a record of all DOTs that include the product on its List of Approved Materials or Products (LAM or LAP). Twenty-eight submitted products (Table 1) appeared on DOT LAMs or LAPs.

To test sealants, 12 inch x 12 inch x 4.5 inch specimen blocks were cast and cured in accordance with AASHTO T-259, “Resistance of Concrete to Chloride Ion Penetration,” although with the following methodological adjustment. In an effort to duplicate concrete bridge decks, KYTC Class AA concrete provided by Irving Materials, Inc. was used instead of the required mix design in T-259. They were cast with a 0.75 inch lip around the edges of one surface to allow for ponding a salt solution. After casting, blocks were covered with plastic and let cure for 24 hours. The blocks were then submerged in water saturated with $Ca(OH)_2$ (Calcium Hydroxide) for 28 days, removed, and allowed to dry. After the blocks were dry, the test surface was prepared for sealant application using a needle gun in accordance with ICRI CSP3. Following the manufacturers’ recommended procedures, the blocks were coated with the sealants (Figure 7). After curing for the proper amount of time they were exposed to 90 days of “salt ponding” (AASHTO T-259 “Resistance of Concrete to Chloride Ion Penetration”) in a controlled environmental chamber using a three percent NaCl solution.

Two control blocks were left uncoated. Control Block 7 was tested in the as-cast condition for background chlorides in the concrete. Control Block 15 was not sealed before salt ponding in order to simulate the unhindered penetration of chloride into the concrete. During ponding, Plexiglas plates were placed over the blocks to minimize evaporation. The blocks were monitored during the 90-day period and the NaCl solution replenished as necessary (Figure 8). After the 90-day ponding test period, the blocks were allowed to dry and the test surface was cleaned by scraping, brushing, and wiping it to remove residual surface salt.

In accordance with AASHTO T-260, “Sampling and Testing for Chloride Ion in Concrete and Concrete Raw Materials”, a 1/2” rotary hammer drill was used to drill three holes approximately 1/16 inch to 1/8 inch deep in each block to evacuate chloride contamination from the surface. The surface and hole were cleaned using dry air and the depth gauge was reset to drill to a depth of 1/2 inch. Concrete dust obtained from the three holes was combined into one test sample. A second combined sample was collected using the same process at a depth from ½ inch to one inch. The concrete dust samples were preserved for testing (Figure 9).

The samples were then tested using the Germann Rapid Chloride Test (RCT) kit (see Table 2 and Figures 10 and 11). At the request of the Study Advisory Committee, KYTC’s Division of Materials performed comparison testing. Results from the RCT method were comparable to T-260 Procedure A (Table 3).

Of the 28 products submitted and tested, four products (Samples 21, 23, 26, and 27) are in fact “coatings” or “film formers” that are not suitable for application to driving surfaces. Film formers without a traction-inducing aggregate are not suited for application to driving surfaces. Those products, however, tend to perform better than penetrating sealers in “salt ponding” tests. The test results from AASHTO T-260, “Sampling and Testing for Chloride Ion In Concrete and Concrete Raw Materials,” at 1/2 inch and 1.0 inch depths are not directly comparable to those obtained during field testing. This is because the field samples were collected at concrete depths above the normal concrete cover, which sits atop the top mat reinforcing in bridges decks (nominally 2.0 inches). Further, salt ponding will not replicate the pumping effect of traffic in deck wheel paths. KTC salt ponding tests established a performance comparison between products by evaluating their ability to resist the ingress of chlorides into concrete. If the performance criteria were set at less than 0.03 percent chloride by weight of concrete at 1.0-inch depth, nine of the 24 sealers would provide acceptable performance

4. FIELD WORK

KYTC Contract 121002 for rehabilitation of a section of Interstate 471 in Newport was let to contract in February 2012. This project included overlaying several bridge decks on Interstate 471. Two other bridges in that contract (B00056L and B0056R – northbound and southbound bridges on Interstate 471 over 6th Street in Newport, KY) had decks in relatively good condition and were not slated for overlay. Both of those bridges have 28 spans with a total length of 2,165 feet. KYTC Division of Maintenance officials requested that KTC recommend concrete sealants and crack sealers to be applied experimentally to the deck surfaces as well as a suggesting a concrete coating that would be applied to one Ohio River pier cap. KTC personnel conducted a visual survey of the site and identified numerous transverse cracks at each negative moment area of the two bridges (Figure 12). Otherwise the decks were in relatively good condition. At the request of KYTC and as part of Federal Aid Research Task 194 (Experimental Deck Sealants and Pier Cap Coatings on Interstate 471), KTC drafted Special Notes for KYTC that were included in the contract (Appendix C). These notes contained the guidelines for applying sealants and specified how the bridge deck would be partitioned into specific test areas. Appendix D includes a suggested Approved List of Materials. The recommended deck sealer and crack sealer product lists with sample number as tested are available in Table 4. Due to uncertainty regarding the scope of work during project development, KYTC deleted the pier cap coating.

Two crack sealers that other DOTs had placed on their LAMs were included as project crack sealers. However, KTC had not evaluated them previously. These sealers were recommended for cracks equal to or greater than ¼ inch in width. Cracks identified for repair on bridges were up to ¼ inch wide in some locations, but most were narrower. KYTC ultimately omitted crack sealing from the project due to the small crack size.

Seven sealers from the KTC test program were placed on a project LAM for deck sealers. Because the laboratory testing had not been completed, performance data were not used to select sealers. Instead Product Data Sheets and application notes provided guidance. "Deck cleaning and sealing" was a "lump sum" line item bid. KYTC accepted a bid of $55,000.00 for that item, with an estimated 225,000 ft^2 of deck. The unit bid was thus $0.24 per ft^2.

Fieldwork began on May 26, 2012 on the northbound bridge. Concrete samples were collected to establish baseline chloride levels at Piers 1, 15, 17, and 27 (Figure 13 and Figure

14). All samples were collected in the wheel path 14 feet from the outside barrier wall. Chloride levels ranged from 0.062 percent to 0.133 percent and averaged 0.100 percent (Table 5).

Due to issues with traffic control, as well as problems with the contractor accessing other work areas, the test areas were modified as follows (see the accompanying diagram):

- Test Area 1 – I-471 northbound and south 2 from End Bent 1 to Pier 13. This test area was a control area and did not receive deck sealing.
- Test Area 2 – I-471 southbound from Pier 13 to Pier 20.
- Test Area 3 – I-471 northbound from Pier 13 to Pier 20.
- Test Area 4 – I-471 southbound from Pier 20 to Pier 26 (Pier 26 to End Bent 2 received no sealer).
- Test Area 5 – I-471 northbound from Pier 20 to End Bent 2.

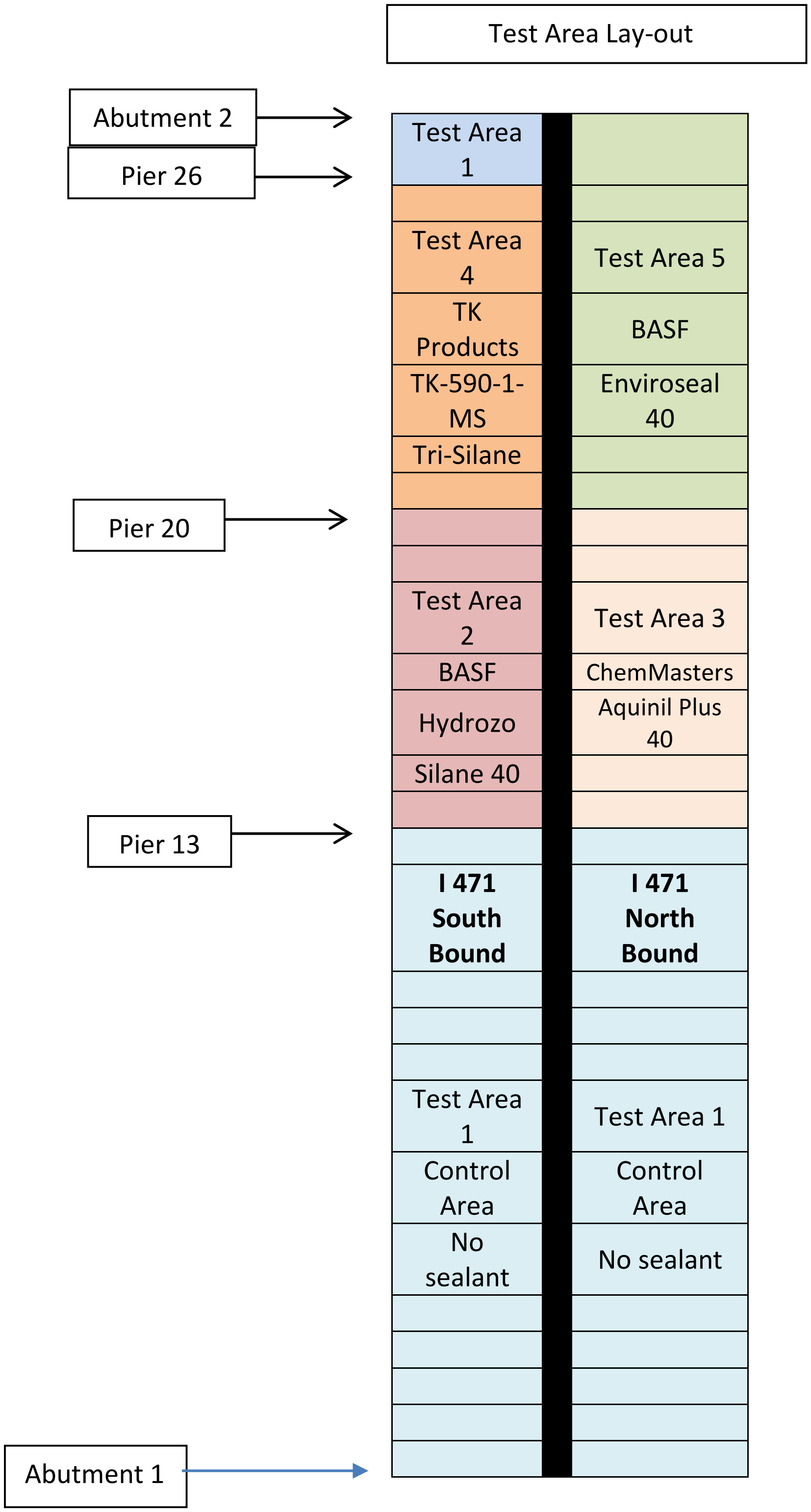


Diagram: Layout of I471 Deck Sealer Test Areas

The contractor began pressure washing the two right lanes of the northbound bridge (half of Test Areas 3 & 5) on June 12, 2012 **(**Figure 15**)**. The contractor used an NLB Corporation Series 125 pressure washer, operating two wands fitted with 0° spinner tips. The pressure washer generated approximately 7,000 psi (Figure 16) and water usage calculated to approximately 6 gallons per minute for each wand. Representatives from BASF and ChemMasters were on site to observe the surface preparation, and both approved of the surface preparation. After completing the pressure washing, the decks were allowed to dry overnight.

The Contractor selected the following products to seal the bridge decks:

Manufacturer	Product
BASF	Enviroseal 40
BASF	Hydrozo Silane 40
ChemMasters	Aquinil Plus 40
TK Products	TK-590-1-MS-Tri-Silane

Application of the sealants began at approximately 8:00 AM on June 13, 2012. The contractor's crew consisted of a foreman, two equipment operators, and three helpers. A leaf blower was used to clean any residual debris from the deck before sealants were applied. ChemMasters Aquinil Plus 40 was applied to the two right lanes and shoulder of Test Area 3 (Figure 17). Two power spray pumps were used – a BMS 75 and an Allen Engineering Razorback. There were no specifications available for either pump and pressure gauges were not used. However the output of both pumps appeared adequate. Both pumps were equipped with typical pressure-washer wands and 20° fan tips. The amount of sealant used was measured using two methods. A graduated "dip stick" was used to monitor the level of sealant in the 55-gallon drums that housed it. Workers also periodically stopped the application process to measure square footage treated and the amount of material used. The pumps drew material from a separate drum, enabling calculations for the total usage. The output of the BMS 75 exceeded the Razorback, but the contractor had two people working with brooms to spread the sealant and even out the application. The ChemMasters rep advised the contractor to apply one gallon per 100-200 ft^2, so the contractor used 150 ft^2/gallon as a target. The test area measured 17,190 ft^2 and the targeted usage was 115 gallons. One hundred twenty gallons were used, which amounts to 143 ft^2/gallon. Application was done in multiple passes until desired coverage was attained. Spray out was completed at 10:45 AM. After this the equipment was cleaned and prepared for application of the next product.

BASF Enviroseal 40 was applied to the two right lanes and shoulder of Test Area 5 beginning at 11:15 AM using the same procedure (Figure 18). The fan tips were changed in an effort to equalize output. The BMS75 used a 45° tip and the Razorback used a 65° tip. The BASF representative advised targeting 100 to 200 ft^2/gallon of sealant and recommended using the same target application rate as ChemMasters Aquinil Plus 40. The same method of application was used to achieve the desired application rate. After changing the tip size the output from the pumps appeared more evenly matched. As recommended by the manufacturer, the contractor used brooms to spread the material evenly over the decks. This sealant was applied to approximately 18,300 ft^2 and total usage was 160 gallons (114 ft^2/gallon). Spray out was completed at 12:30 PM.

Due to work taking place in other areas, traffic control was not moved to allow workers access to seal the left two lanes of Test Areas 3 and 5 until June 21, 2012. Work resumed on June 22, 2012. The deck was washed with the same equipment and at the same pressure as used previously. KTC identified two transverse cracks – one was located six feet north of Pier 14, the other six feet north of Pier 23 (measurements were in relation to the center barrier wall). The contractor pre-washed these two cracks (Figure 19) by positioning the wand perpendicularly and keeping the tip approximately six inches from the deck surface. The contractor also pre-flooded the cracks when applying sealant (Figure 20). One crack was treated with Aquinil Plus 40, while the other was treated with with Envirosil 40. As long-term monitoring proceeds, KTC Researchers plan to return to the flooded crack and core the deck to measure the depth of sealant penetration.

Application of ChemMasters Aquinil Plus 40 began at approximately 9:00 AM on June 23, 2012 using the same process as the prior applications. This area was 14,200 ft^2 and target usage was 95 gallons. The actual usage was 98 gallons, or 145 ft^2/gallon. This area was completed at 10:30 AM.

BASF Enviroseal 40 was then applied to the left two lanes of Test Area 5 beginning at 11:15 AM. The 15,250 ft^2 area had a target usage of 102 gallons. The application rate on the first 5,500 ft^2 was 76 ft^2/gallon. Although the same tip sizes were used as during the previous application, the output of the Razorback pump outstripped the BMS75 and could not be adjusted. The contractor used the BMS75 to complete the application, and usage for the remainder of the area was 155 ft^2/gallon. This work was completed at 2:45 PM.

The project shifted its focus to the southbound bridge beginning in 2013. Because of problems with traffic control, the test areas were modified. The adjusted Test Area 2 extended from Pier 13 to 33 feet north of Pier 20. The reworked Test Area 4 stretched from 33 feet north of Pier 20 to Pier 26. And the control area was tweaked to run from Pier 26 to the north abutment. KTC personnel were unavailable to monitor both the pressure washing and the first half of the sealant application. On July 9, 2013 sealant application was monitored on the two left lanes of the southbound bridge. KTC received no information on type of pump used, however, one typical garden hose and spray nozzle were utilized for the application (Figure 21). Usage was measured with the same methods employed at previous test sites (Figure 22). BASF Hydrozo Silane 40 was applied to Test Area 2. This area was 13184 ft^2 and usage was 100 gallons or 132 ft^2/gallon. TK Products TK-590-1-MS-Tri-Silane applied to Test Area 4 was also 13,184 ft^2 and usage was 90 gallons or 146 ft^2/gallon.

On August 8, 2013 six concrete dust samples were collected from each of the southbound test areas to establish baseline chloride levels. These samples were collected using a ½-inch hammer drill (Figure 23) from a depth of 1.5 to 2.0 inches. Three samples were collected at one-foot intervals 12 inches from the barrier wall. An additional three samples were collected at one-foot intervals 21 feet from the barrier wall over Pier 20 (Test Area 2). Data collection efforts were the same at Pier 21 – Test Area 4 (Table 6). The research team did not collect samples from the control area.

4.1. DECK SEALERS TESTED WITH DYNAMIC FRICTION TESTER

A Dynamic Friction Tester (DFT) loaned from the Federal Highway Administration (Figures 24 and 25) was used to test the four sealants for friction resistance. Testing followed the guidelines set out in ASTM E1911-09, "Standard Test Method for Measuring Paved Surface Frictional Properties Using the Dynamic Friction Tester". DFTs are portable instruments that are designed to measure pavement surface friction as a function of speed for various surfaces. The instrument consists of a measuring unit and a control unit. Either an XY-plotter or laptop can record data. The measuring unit contains a disc that rotates horizontally at a specified velocity; once the desired velocity is reached, the unit is lowered onto a wetted test surface to measure friction. The torque generated by the resistance between the test surface and the spring-loaded rubber sliders affixed to the underside of the rotating disc is continuously monitored. The unit converts collected data into a friction measurement. This test was performed at multiple locations and data were collected at three separate spots in each location. These spots were in the left wheel path (LWP), center wheel path (CWP), and right wheel path (RWP).

Initial data collection, which occurred before sealant application, took place on the northbound bridge on June 6, 2012. Post-application data were collected on June 14, 2012 after at least 24 hours had passed, which allowed the sealant to cure. Friction tests were performed in Test Areas 1 (control), 3, and 5 (Table 7 and Figure 26). In 2012, the friction values on the control area – none of which were sealed – dipped as low as 0.34, but averaged 0.47 across all readings. Repeat testing performed at the same location in 2013 were as low at 0.43 and averaged 0.53. The friction values obtained in 2012 for Test Area 3, before sealing, were as low as 0.37 and averaged 0.44. Friction data collected at the same location – after they were sealed with with ChemMasters Aquinil Plus 40 – yielded values as low as 0.39 while averaging 0.49. Friction values in Test Area 5 – where BASF Enviroseal 40 was applied – were as low as 0.39 and averaged 0.47 before sealant application. After sealing the area, friction values were as low as 0.33 and averaged 0.41. Friction values, averaged across all locations, exceeded the KYTC action level of 0.39 but the sealer used on Test Area 5 appeared to reduce traction.

Data for the southbound bridge were collected post-application on July 10, 2013. Pre-application data for the southbound bridge was not collected because the DFT was unavailable. The location of Control Area had been changed and extended from Abutment 1 to Pier 13 and from Pier 26 to Abutment 2. No sealant was applied in the Control Area. This area was tested at the same time as Test Areas 2 and 4 (see layout Diagram). In the Control Area, friction values were as low as 0.34 and averaged 0.45. Friction values in Test Area 2 – sealed using BASF Hydrozo Silane 40 – were as low as 0.38 and averaged 0.46. In Test Area 4 – sealed with TK - 590-1-MS Tri-silane – friction values were as low as 0.34 and averaged 0.43. Figure 27 summarizes the friction test results of the southbound bridge.

5. CONCLUSIONS

After investigating current KYTC anti-icing/deicing practices and alternative methods, the research team found no alternatives to sodium chloride or calcium chloride that could be used on a widespread basis on Kentucky's roads. While other products have been used as deicers or extenders of chloride salts, none have proven more effective for general use. The deteriorating condition of steel reinforced concrete bridge elements, however, demonstrates that reinforced concrete demands additional protection. A review of KYTC maintenance snow and ice practices indicated that the quantity of chemicals has been on a steady upward trajectory, albeit with some inter-annual variability. Problematically, current practices prevented the research team from estimating the quantities of deicing materials applied to specific locations (e.g. bridge or shaded area). In addition, along with the increased use of chloride salts, it has become more common to apply a liquid chemical pre-treatment at the prospect of treacherous winter conditions. Steel reinforced concrete bridge decks absorb a greater percentage of liquid chemicals than rock salt. The amount of chlorides at the top-reinforcing mat of bridge decks has increased significantly since 2002 (≈ 0.01 percent chloride to weight of concrete on a few bridges) to an extremely corrosive level (≈ 0.13 percent at various locations on many bridges) in 2011.

A survey of State DOTs revealed that most DOTs use deck sealants in place of, and sometime in conjunction with, overlays to improve deck protection. Silane and Siloxane are the most commonly used deck sealant materials. Based on the survey, these sealers typically cost \$0.30 to \$1.50 ft^2 when applied by state workers and up to \$4.00 ft^2 when the job is contracted out to an external firm. The typical service life of sealants is five to eight years.

KTC solicited deck sealers to evaluate their effectiveness in a controlled laboratory setting. Researchers assessed 28 products in the laboratory in accordance with AASHTO T-259 "Resistance of Concrete to Chloride Ion Penetration". Of these, 24 were penetrating deck sealers. Since 0.03 percent chloride by weight of concrete is generally accepted as initiating corrosion in reinforcing steel, that level of chloride was selected as a target performance criterion. Nine deck sealant products met this goal.

Bridge deck sealant products and crack sealers were experimentally applied and tested on a KYTC rehabilitation project on I-471 in Newport. The original test conditions were modified due to field conditions, traffic control issues, and construction scheduling changes. Ultimately, the experiment did not study crack sealing, however, four deck sealers were bound. After the deck sealants were applied, friction values of the sealed decks were obtained. The amount of friction data collected was limited in the southbound lanes, however, compared to an unsealed deck, three of the four sealants maintained or improved the friction values, while the fourth sealant returned lower values than the unsealed deck but still averaged 0.41.

6. RECOMMENDATIONS

Sealing concrete is the most effective method to protect structural concrete against chloride-induced corrosion. New concrete bridge decks should be sealed as soon as possible after curing to prevent the accumulation of chlorides in the concrete. Bridge decks should be resealed after three – five years of service. Bridges with high Average Daily Traffic (ADT), which typically receive the greatest number of deicing applications, should be resealed at more closely spaced intervals (three to four years), whereas bridges that carry few vehicles and are less exposed to deicing products should be resealed every four to five years. The products listed in Table 2 and Figure 11 that had the best performance will significantly hinder the intrusion of chlorides into concrete decks. Additionally, the research team suggests that bridge decks, splash zones, and leakage/drainage areas be washed each spring after the snow and ice season to flush remaining chlorides.

The bridges included in the experimental project (FRT 194) should be added to KTC's Long Term Monitoring Project to collect further performance data on the deck sealants applied. Further monitoring of chloride levels will provide valuable information to KYTC for future projects. KYTC would benefit from additional research related to crack repair and sealing compounds that inhibit the intrusion of chlorides.

7. REFERENCES

1. Morse, K.L, Effectiveness of Concrete Deck Sealers and Laminates for Chloride Protection of New and In Situ Reinforced Bridge Decks in Illinois, FHWA/IL/PRR-155, 2009.
2. S. Monosi, M. Collepardi, Research on 3CaO·CaCl2·15H2O identified in concretes damaged by CaCl2 attack, Il Cimento 87 (1990) 3–8.
3. M. Collepardi, L. Coppola, C. Pistolesi, Durability of concrete structures exposed to CaCl2 based deicing salts, in: V.M. Malhotra (Ed.), Durability of Concrete ACI SP-145, 3rd CANMET/ACI International Conference, Nice, France, 1994, pp. 107–115.
4. Krauss, P.D., Lawler, J.S. and Steiner, K.A., "Guidelines for Selection of Bridge Deck Overlay, Sealants and Treatments", Wiss, Janney, Elstner Associates, Northbrook, IL, Draft Document Prepared for the Transportation Research Board, May 29, 2009.

8. APPENDIX A - SURVEY ON USE OF BRIDGE DECK SEALANTS

Date_ ______________________ Agency___________________________

Responder________________________ Title________________________

Phone______________ e-mail_________________________________

1. Please provide a web address for your Approved Product List (APL) for bridge deck sealants?

____

2. If you do not have a APL, how do you specify bridge deck sealants.______________

____

____

____

3. Do you have a policy for selecting bridge decks to be sealed? Yes__ No__

4. Please complete the following table.

Product Name	Generic Type	Bid Cost (Applied)	Service Life Expected (yr)	

5. Approximately, how many bridge decks do you seal annually? __________________

6. What is your annual deck sealing budget? ___________________________________

7. Do you consider polymer overlays an alternate to deck sealing? Yes__ No__

8. Any comments concerning deck sealants, laminates, or overlays are welcome.____

____

9. APPENDIX B - SURVEY SUMMARY

Agency	Product Name	Generic Type	Applied Cost	Service Life
Arkansas	n/a	n/a	n/a	n/a
Texas	n/a	Silane	$2.86 sy	7 years
Texas	n/a	Linseed Oil	$0.98 sy	3 years
Minnesota	TK Tri-silane	Silane	$0.45 sf	5 years
Illinois	Tri-Siloxane TK-590	Siloxane	$0.40 sf	4 years
Illinois	Tri-Siloxane TK-590	Siloxane	$0.30 sf	4 years
Illinois	TK-290 BDS OTC		$0.44 sf	4 years
Tennessee		asphaltic sheet	$7-$8 sy	15 years
Tennessee		epoxy-aggregate	$75-$45 sy	20 years
Michigan	Euclid Flexolith 215/Dural 335	Overlay/healer Sealer	$34 sy - $16 sy	10 years
Michigan	Unitex Propoxy III/Bridge Seal	Overlay/healer Sealer	$34 sy - $16 sy	10 years
Michigan	Poly-Carb Flexogrid Mark 163/154/127	Overlay/healer Sealer	$34 sy - $16 sy	10 years
Michigan	E-Bond 526 Lo-Mod	Overlay	$34 sy	10 years
Michigan	Axson Akabond 811	Overlay	$34 sy	10 years
Michigan	Sika Sikadur 55 SLV	Healer Sealer	$16 sy	10 years
New York	Sil Act 100	Silane	$1.50	5 years
New York	Hydrozo BHN	Silane	$1.50	5 years
Iowa	n/a	n/a	n/a	n/a
Missouri	linseed oil	linseed oil	$0.06 sf in house	1 year
Missouri	Star MacroDeck	Latex	$0.11 sf in house	4 years
Missouri	Pavon InDeck	Petroleum	$0.14 sf in house	3-5 years
Missouri	Prorectosil BHN	Silane	$4.00 sf	8-10 year
Missouri	Prorectosil CIT	Silane	$4.10 sf	8-10 year

10. APPENDIX C - SPECIAL NOTE FOR EXPERIMENTAL BRIDGE DECK SEALANTS ON I-471 BRIDGE OVER 6TH STREET IN NEWPORT, KY.

For the purpose of this experimental crack and deck sealant project, the bridge will be divided into five Test Areas as described in the following;

Test Area 1 I-471 North bound from End Bent 1 to Pier 13. Include the off ramp (Ramp L) up to Pier 13.

Test Area 2 I-471 South bound from End Bent 1 to Pier 13.

Test Area 3 I-471 North bound from Pier 13 to Pier 26.

Test Area 4 I-471 South bound from Pier 13 to Pier 26. Include the Southbound on ramp (Ramp K) from Pier 24 into the south bound lanes.

Test Area 5 Both north bound and south bound I-471 from Pier 26 to End Bent 2. Test Area 5 is a control area and will not receive crack or deck sealing.

Cleaning Cracks Clean all visible cracks, extending across the width of the deck, to remove debris by pressure washing (2,000 to 3,000 psi rated capacity) with fan tips to remove all debris.

Crack Sealing The crack must be dry (no water is visible) when applying sealer. Seal all visible cracks with one product on the project List of Approved Materials-Crack Sealer. A manufacturers' representative must be present and approve surface preparation and application for a minimum of 10 percent the total crack length for the project.

Cleaning Deck Clean all visible hydrocarbons from the deck surface (Test Areas 1 through 4) with a detergent approved by the manufacturer of chosen deck sealer for each Test Area. Clean all deck surface to be sealed by pressure washing (2,000 to 3,000 psi rated capacity) with fan tips to remove all debris.

Sealing Deck The deck must be dry (no water is visible) when applying sealer. Apply a sealer from the project List of Approved Materials – Deck Sealer to Test Area 1. Apply a second sealer (different from the Test Area 1 sealer) to Test Area 2. Apply a third sealer (different from Test Areas 1 or 2) to Test Area 3. Apply a fourth sealer (different from Test Areas 1, 2, or 3) to Test Area 4. A manufacturers' representative for each product applied must be present and approve surface preparation and application for the project.

All crack sealing, cleaning, and deck sealing will be conducted in compliance with the traffic control requirements, including lane closure times, for this project.

The Contractor will submit a list of the products chosen for crack and deck sealing at the Pre-construction Conference.

All costs for work and materials for cleaning and sealing cracks are incidental to the lump sum bid for "cleaning and sealing cracks". The approximate total length of cracks is 17,000 ft. but the contractor is responsible for determining quantities for bidding. All costs for work and materials for cleaning and sealing decks are incidental to the lump sum bid for "cleaning and sealing deck". The approximate deck area to be cleaned and sealed is 225,000 ft^2 but the contractor is responsible for determining quantities for bidding.

11. APPENDIX D - Project List of Approved Materials

Project List of Approved Materials - Crack Sealer

Sikasil 728 Sl	SIKA Corp.
Sonalastic 150	BASF Construction Chemicals

Project List of Approved Materials - Deck Sealer

Product name	Supplier
Enviroseal 40	BASF
Hydrozo Silane 40	BASF
PowerSeal 40	Vexcon Chemicals Inc.
Pavix CCC100	Chem-Crete
BMS 5122 Clear Cladding	Belzona
Aquinil Plus 40	ChemMasters
TK-590-1-MS-Tri-Silane	TK Products

11. TABLES

Table 1. Deck Sealant Products Submitted and Application Notes

Sample Number	Supplier	Product	Coverage Rate 1st coat	2nd coat	Date of Application	Temp ^{0}F	Humidity %	Comments
1	IMCO Technologies	Aqua Concrete Primer 1111H	0.57 ounces	N/A	12/5/2011	65	69	Brushed single coat - too thick to spray with planned method
2	Chemical Products Industries, Inc.	SW-244-100 DOT	0.54 ounces	N/A	12/5/2011	65	69	Sprayed single coat with block in vertical position
3	Chemical Products Industries Inc.	Vapor Lock VL 0/0	0.34 ounces	0.34 ounces	12/5/2011	65	69	Sprayed two coats with block in vertical position. Second coat applied after first coat was visibly dry.
4	Vexcon	PowerSeal 80	0.51 ounces	N/A	12/5/2011	65	69	Applied mist coat approximately five minutes prior to spraying the remainder of the specified amount with block in vertical position.
5	Vexcon	CertiVex Penseal BTS	0.51 ounces	N/A	12/5/2011	65	69	Applied mist coat approximately five minutes prior to spraying the remainder of the specified amount with block in vertical position.
6	Chemical Product Industries, Inc.	CP-2000W	0.85 ounces	N/A	12/5/2011	65	69	Sprayed single coat with block in vertical position then worked in with brush to aid in penetration.
7	Control Sample	N/A	N/A	N/A	12/5/2011	65	69	No NaCl solution applied
8	ChemTec Int'l, Inc. EPC	ChemTec One	1.14 ounces	N/A	12/5/2011	65	69	Sprayed single coat with block in vertical position. Worked in with brush to aid in penetration. Per PDS a second coat should have been applied at the same coverage rate.
9	BASF	Hydrozo Clear 40 VOC	0.68 ounces	N/A	12/5/2011	65	69	Sprayed single coat with block in vertical position
10	Chem-Crete	Pavix CCC100	0.73 ounces	N/A	12/5/2011	65	69	Sprayed single coat with block in vertical position
11	ChemMasters	Aquinil Plus 40A	1.02 ounces	N/A	12/5/2011	65	69	Sprayed single coat with block in vertical position
12	Evonik Industries	Protectosil CIT	0.64 ounces	0.64 ounces	12/5/2011	65	69	Sprayed two coats with block in vertical position. Second coat was applied after approximately 15 minutes.
13	Vexcon	Certivex Penseal 244 O/W 80	0.51 ounces	N/A	12/5/2011	65	69	Applied mist coat prior to spraying the remainder of the specified amount with block in vertical position.
14	Vexcon	Certivex Penseal 244 80	0.51 ounces	N/A	12/5/2011	65	69	Applied mist coat prior to spraying the remainder of the specified amount with block in vertical position.
15	Control Sample	N/A	N/A	N/A	12/5/2011	65	69	Ponded with 3% NaCl solution

16	TK Products	TK-590-40 Tri-Silane 40%	0.85 ounces	N/A	12/5/2011	69	65	Applied mist coat prior to spraying the remainder of the specified amount with block in vertical position.
17	BASF	Hydrozo 100	0.39 ounces	N/A	12/5/2011	69	65	Applied mist coat prior to spraying the remainder of the specified amount with block in vertical position.
18	IMCO Technologie s, Inc.	D-Tech 470	0.68 ounces	N/A	12/5/2011	69	65	Applied mist coat prior to spraying the remainder of the specified amount with block in vertical position.
19	Evonik Industries	Protectosil 300	0.68 ounces	N/A	12/5/2011	69	65	No Product Data sheet available - Sprayed specified amount in one coat.
20	TK Products	TK-590-1 MS Tri-Silane	0.85 ounces	N/A	12/5/2011	69	65	Applied mist coat prior to spraying the remainder of the specified amount with block in vertical position.
21	Poly-Carb, Inc.	Mark-154	12.2 ounces	N/A	12/5/2011	69	65	No aggregate was used so the recommended two coat application was combined into one coat. Material was mixed and poured onto block then worked in with a brush.
22	Fox Industries	FX-821 MMA	1.37 ounces	N/A	12/5/2011	69	65	One coat applied with brush
23	Poly-Carb, Inc.	Mark-163	12.2 ounces	N/A	12/5/2011	69	65	No aggregate was used so the recommended two coat application was combined in one coat. Material was mixed, poured onto block and worked in with a brush.
24	Evonik Industries	Protectosil BHN	0.79 ounces	N/A	12/5/2011	69	65	Applied mist coat prior to spraying the remainder of the specified amount with block in vertical position.
25	Sherwin-Williams	Loxon A31T00840	0.85 ounces	N/A	12/5/2011	69	65	Applied mist coat prior to spraying the remainder of the specified amount with block in vertical position.
26	Sherwin-Williams	FasTop Urethane Coating 4090TC	0.78 ounces	N/A	12/5/2011	69	65	One coat applied with brush
27	Unitex	Pro-Poxy Type III DOT	4.27 ounces	N/A	12/5/2011	69	65	One coat applied with brush
28	ChemMaste rs	Aquinil Plus 40	1.02 ounces	N/A	12/5/2011	69	65	Applied mist coat prior to spraying the remainder of the specified amount with block in vertical position.
29	BASF	Enviroseal 40	0.85 ounces	N/A	12/5/2011	69	65	Applied mist coat prior to spraying the remainder of the specified amount with block in vertical position.
30	BMS, Inc.	Clear Cladding	0.63 ounces	N/A	12/5/2011	71	60	Applied mist coat prior to spraying the remainder of the specified amount with block in vertical position.

Table 2: Products Tested and Test Data from Germann RCT kit (chloride content by % weight of concrete).

		1/2 Inch Depth		**1 Inch Depth**	
Supplier	**Product**	**Block (avg)**	**%Cl**	**Block (avg)**	**%Cl**
IMCO Technologies	Aqua Concrete Primer 1111H	1	0.235	1	0.068
Chemical Products Industries, Inc.	SW-244-100 DOT	2	0.087	2	0.027
Chemical Products Industries, Inc.	Vapor Lock VL 0/0	3	0.225	3	0.043
Vexcon	PowerSeal 80	4	0.092	4	0.035
Vexcon	CertiVex Penseal BTS	5	0.129	5	0.045
Chemical Product Industries, Inc.	CP-2000W	6	0.194	6	0.040
Control Sample	N/A	7	0.023	7	0.017
ChemTec Int'l, Inc. EPC	ChemTec One	8	0.245	8	0.035
BASF	Hydrozo Clear 40 VOC	9	0.099	9	0.022
Chem-Crete	PaviX CCC100	10	0.457	10	0.090
ChemMasters	Aquanil Plus 40A	11	0.187	11	0.034
Evonik Industries	Protectosil CIT	12	0.202	12	0.059
Vexcon	Certivex Penseal 244 O/W 80	13	0.103	13	0.021
Vexcon	Certivex Penseal 244 80	14	0.093	14	0.040
Control Sample	N/A	15	0.207	15	0.042
TK Products	TK-590-40 Tri-Silane 40%	16	0.133	16	0.027
BASF	Hydrozo 100	17	0.104	17	0.050
IMCO Technologies, Inc.	D-Tech 470	18	0.142	18	0.040
Evonik Industries	Protectosil 300	19	0.088	19	0.013
TK Products	TK-590-1 MS Tri-Silane	20	0.152	20	0.016
Poly-Carb, Inc.*	Mark-154	21	0.033	21	0.016
Fox Industries	FX-821 MMA	22	0.155	22	0.041
Poly-Carb, Inc.*	Mark-163	23	0.025	23	0.018
Evonik Industries	Protectosil BHN	24	0.079	24	0.016
Sherwin-Williams	Loxon A31T00840	25	0.117	25	0.030
Sherwin-Williams*	FasTop Urethane Coating 4090TC	26	0.021	26	0.017
Unitex*	Pro-Poxy Type III DOT	27	0.017	27	0.016
ChemMasters	Aquanil Plus 40	28	0.182	28	0.034
BASF	Enviroseal 40	29	0.107	29	0.031
BMS, Inc.	Clear Cladding	30	0.133	30	0.026

*Products are film formers

Table 3: KTC/KYTC Comparison Testing

UK Probe		Mat'l Probe	
Cal. based	**on mV**	**Cal. based**	**on mV**
% Cl-	mV	% Cl-	mV
0.005	103.7	0.005	103.7
0.02	77.6	0.02	77.6
0.05	56.7	0.05	56.7
0.5	0.2	0.5	0.2

Code:	**Samples A from Sugar Creek Samples B from New Circle**				
Sample	Avg mV	% Cl- Graph	Sample	Avg mV	% Cl- Graph
A1	36	0.08	A1	29.17	0.08
A2	26.2	0.1	A2	18.8	0.1
A3	47.7	0.06	A3	42.2	0.06
B1	34.3	0.09	B1	27.9	0.09
B2	39.2	0.08	B2	33.3	0.08
B3	33.8	0.09	B3	27	0.09
Cal. Based	**on % soln**				
		Meter Read % Cl-			Meter Read % Cl-
A1		0.11	A1		0.11
A2		0.18	A2		0.18
A3		0.07	A3		0.08
B1		0.13	B1		0.11
B2		0.1	B2		0.1
B3		0.12	B3		0.12
Cal. Based	**on ppm**				
	Ppm	% Cl		ppm	Cl-
A1	20	0.07	A1	27	0.09
A2	42	0.15	A2	47	0.16
A3	19	0.07	A3	24	0.08
B1	23	0.08	B1	22	0.08
B2	28	0.09	B2	30	0.1
B3	23	0.08	B3	21	0.07

Average	UK Probe	Mat'l Probe		
A1	0.08	0.08		
	0.11	0.11		
	0.07	0.09		
Avg	**0.09**	**0.09**	Grav.	0.14
A2	0.1	0.1		
	0.18	0.18		
	0.15	0.16		
Avg	**0.14**	**0.15**		
A3	0.06	0.06		
	0.07	0.08		
	0.07	0.08		
Avg	**0.07**	**0.07**		
B1	0.09	0.09		
	0.13	0.11		
	0.08	0.08		
Avg	**0.11**	**0.10**		
B2	0.08	0.08		
	0.1	0.1		
	0.09	0.1		
Avg	**0.09**	**0.09**	Grav.	0.11
B3	0.09	0.09		
	0.12	0.12		
	0.08	0.1		
Avg	**0.10**	**0.10**		

Table 4: Recommended Material List and Corresponding Sample Numbers

Project List of Approved Materials – Crack Sealers		
Manufacturer	Product	
SIKA Corporation	Sikalastic 728 SI	
BASF construction Chemicals	Sonalastic 150	
Project List of Approved Materials – Deck Sealers		
Manufacturer	Product	Sample #
BASF	Enviroseal 40	29
BASF	Hydrozo Silane 40	9
Vexcon Chemicals Inc.	PowerSeal 40	4
Chem-Crete	Pavix CCC100	10
Belzona	*BMS 5122 Clear Cladding*	*30*
ChemMasters	Aquinil Plus 40	28
TK Products	TK-590-1-MS-Tri-Silane	20

Table 5: NB Base Line Chloride Ion Test Data

Chloride Ion Penetration Test

Bridge ID: B00056R	**Route: I 471 NB over 6th St. in Newport**	**Date: 6/19/12**		**Tester Name**
Sample #	**Sample Location/Depth**	**mV**	**% Cl**	
1	Pier 1 14' from curb / 1.5 - 2" deep	44.6	0.078	Danny Wells
2	1' south of pier 1 14' from curb / 1.5 - 2" deep	43.4	0.083	
3	2' south of pier 1 14' from curb / 1.5 - 2" deep	37.8	0.107	
4	Pier 17 14' from curb / 1.5 - 2" deep	34	0.129	
5	1'south of pier 17 14' from curb / 1.5 - 2" deep	35.7	0.119	
6	2' south of pier 17 14' from curb / 1.5 - 2" deep	45	0.077	
7	Pier 27 14' from curb / 1.5 - 2" deep	40.3	0.096	
8	1' south of pier 27 14' from curb / 1.5 - 2" deep	33.3	0.133	
9	2' south of pier 27 14' from curb / 1.5 - 2" deep	37.2	0.111	
10	20' south of pier 15 14' from curb / 1.5 - 2" deep	43.5	0.082	
11	21' south of pier 15 14' from curb / 1.5 - 2" deep	35.5	0.120	
12	22' south of pier 15 14' from curb / 1.5 - 2" deep	49.4	0.062	

Calibration Liquid	**Clear**	**Purple**	**Green**	**Pink**
% Cl	**0.005**	**0.02**	**0.05**	**0.5**
mV before	101.3	77.2	57.9	-0.2
mV after				

Date of Issue: April 4, 2012

Approved by:

Table 6: SB Base Line Chloride Ion Test Data

Chloride Ion Penetration Test

Bridge ID: 019B00056L	**Route: I-471 South Bound**	**Date: 9/25/13**		Tester Name
Sample #	**Sample Location/Depth**	**mV**	**% Cl**	D.Wells
1	Directly over Pier 21 - 12" from curb	91.80	0.010	
2	12" north of Pier 21 - 12" from curb	107.30	0.005	
3	24" north of Pier 21 - 12" from curb	83.90	0.014	
4	Directly over Pier 21 - 21' from curb	60.20	0.041	
5	12" north of Pier 21 - 21' from curb	53.00	0.056	
6	24" north of Pier 21 - 21' from curb	38.10	0.109	
7	Directly over Pier 20 - 12" from curb	45.80	0.077	
8	12" north of Pier 20 - 12" from curb	41.50	0.094	
9	24" north of Pier 20 - 12" from curb	71.70	0.025	
10	Directly over Pier 20 - 21' from curb	61.20	0.039	
11	12" north of Pier 20 - 21' from curb	58.20	0.045	
12	24" north of Pier 20 - 21' from curb	47.80	0.071	

Calibration Liquid	**Clear**	**Purple**	**Green**	**Pink**
% Cl	0.005	0.020	0.050	0.500
mV before	103.60	81.40	58.70	1.30
mV after				

Date of Issue: April 4, 2012

Approved by: [signature]

Table 7: North Bound Friction Test Data

North Bound Before Sealing											
Control 30’			Control 60’			Control 90’			Control 120’		
LWP	CWP	RWP	LWP	CWP	RWP	LWP	CWP	RWP	LWP	CWP	RWP
0.43	0.51	0.58	0.48	0.48	0.53	0.45	0.50	0.54	0.45	0.50	0.52
Pier 5			Pier 8			Pier 11			Pier 14		
LWP	CWP	RWP	LWP	CWP	RWP	LWP	CWP	RWP	LWP	CWP	RWP
0.38	0.39	0.50	0.36	0.45	0.53	0.34	0.50	0.41	0.41	0.61	0.50
Pier 17			Pier 20			Pier 22			Pier 25		
LWP	CWP	RWP	LWP	CWP	RWP	LWP	CWP	RWP	LWP	CWP	RWP
0.41	0.41	0.40	0.37	0.50	0.38	0.43	0.60	0.41	0.45	0.51	0.39

North Bound After Sealer											
Control 30’			Control 60’			Control 90’			Control 120’		
LWP	CWP	RWP	LWP	CWP	RWP	LWP	CWP	RWP	LWP	CWP	RWP
0.53	0.59	0.64	0.52	0.51	0.60	0.51	0.56	0.60	0.51	0.59	0.55
Pier 5			Pier 8			Pier 11			Pier 14		
LWP	CWP	RWP	LWP	CWP	RWP	LWP	CWP	RWP	LWP	CWP	RWP
0.43	0.47	0.61	0.44	0.57	0.43	0.43	0.59	0.47	0.43	0.64	0.54
Pier 17			Pier 20			Pier 22			Pier 25		
LWP	CWP	RWP	LWP	CWP	RWP	LWP	CWP	RWP	LWP	CWP	RWP
0.44	0.57	0.39	0.45	0.55	0.39	0.39	0.50	0.41	0.33	0.44	0.36

12. FIGURES

Figure 1 Crack in concrete deck.

Figure 2 Delamination in concrete deck.

Figure 3 Spalling in concrete bridge deck.

Figure 4 Corroded steel reinforcing in bridge deck.

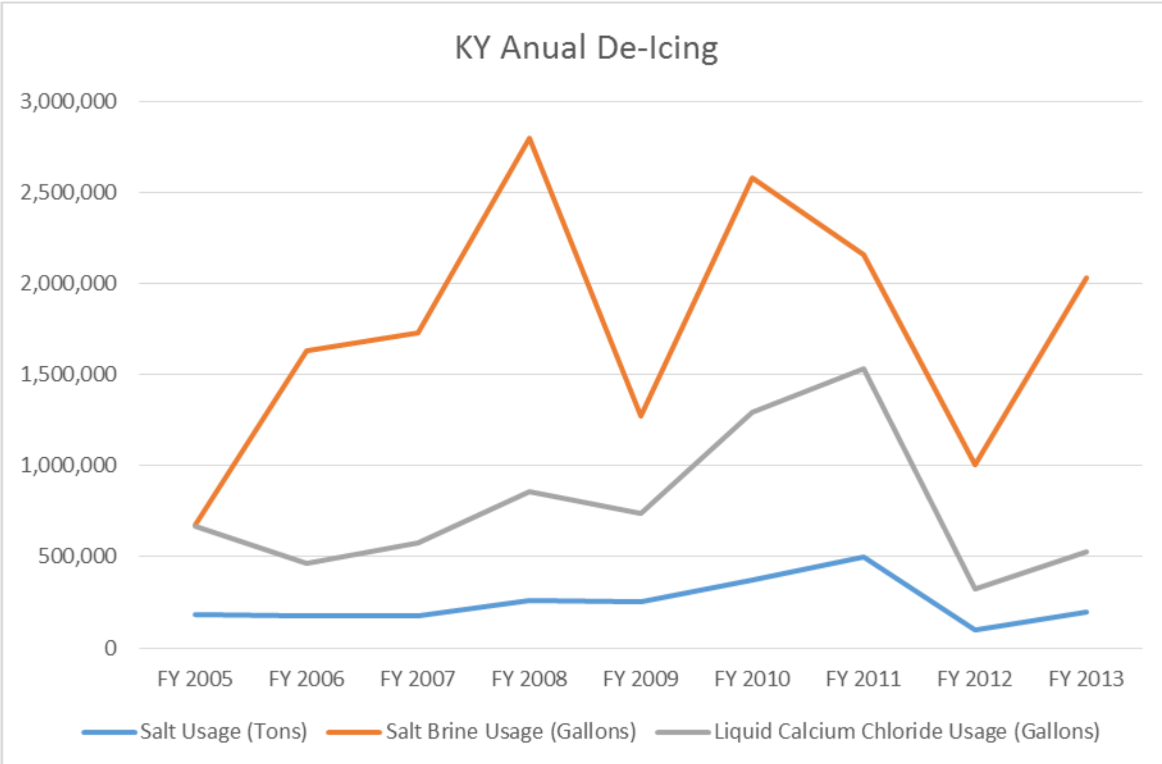


Figure 5 Deicing chemical usage by KYTC districts.

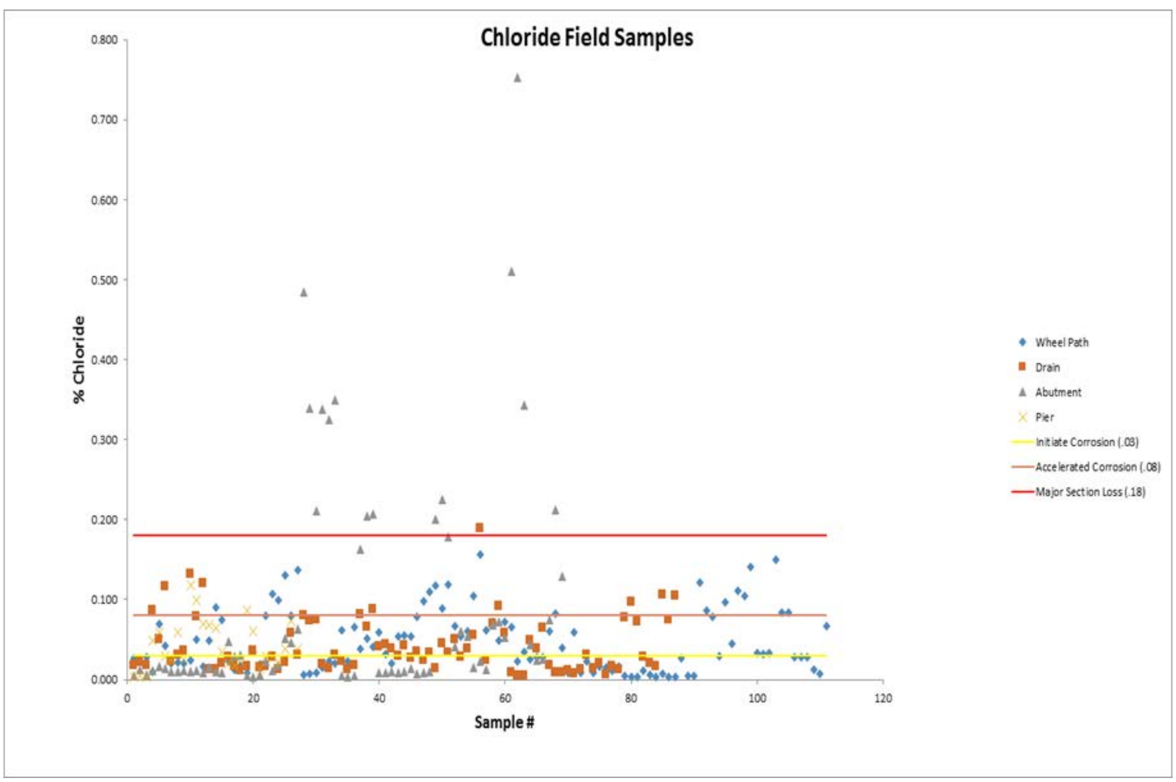


Figure 6 Chloride contamination in KYTC bridges.

Figure 7 Application of sealant to ponding block.

Figure 8 Refilling Sodium Chloride solution.

Figure 9 Collecting sample for test content.

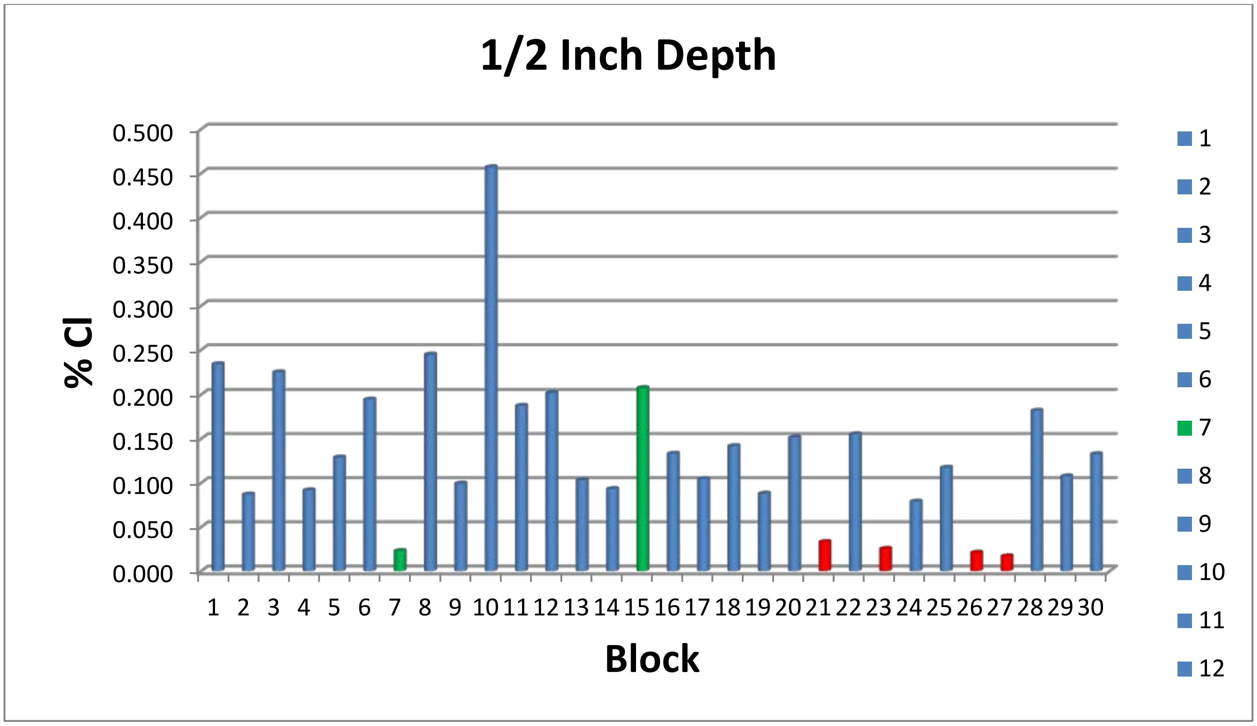


Figure 10. Chloride by percent weight of Concrete at ½ inch depth (Germann test results).

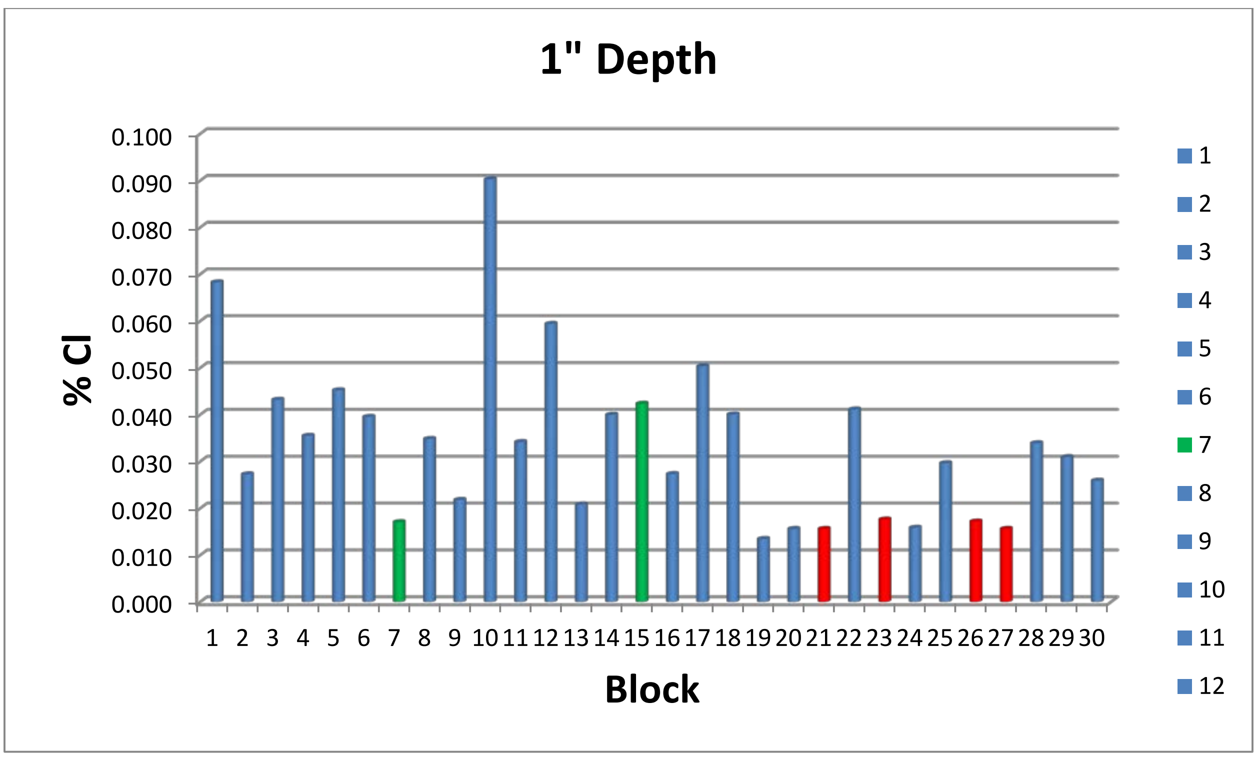


Figure 11. Chloride by percent weight of Concrete at 1 inch depth (Germann test results).

Figure 12. Transverse cracking in negative moment area.

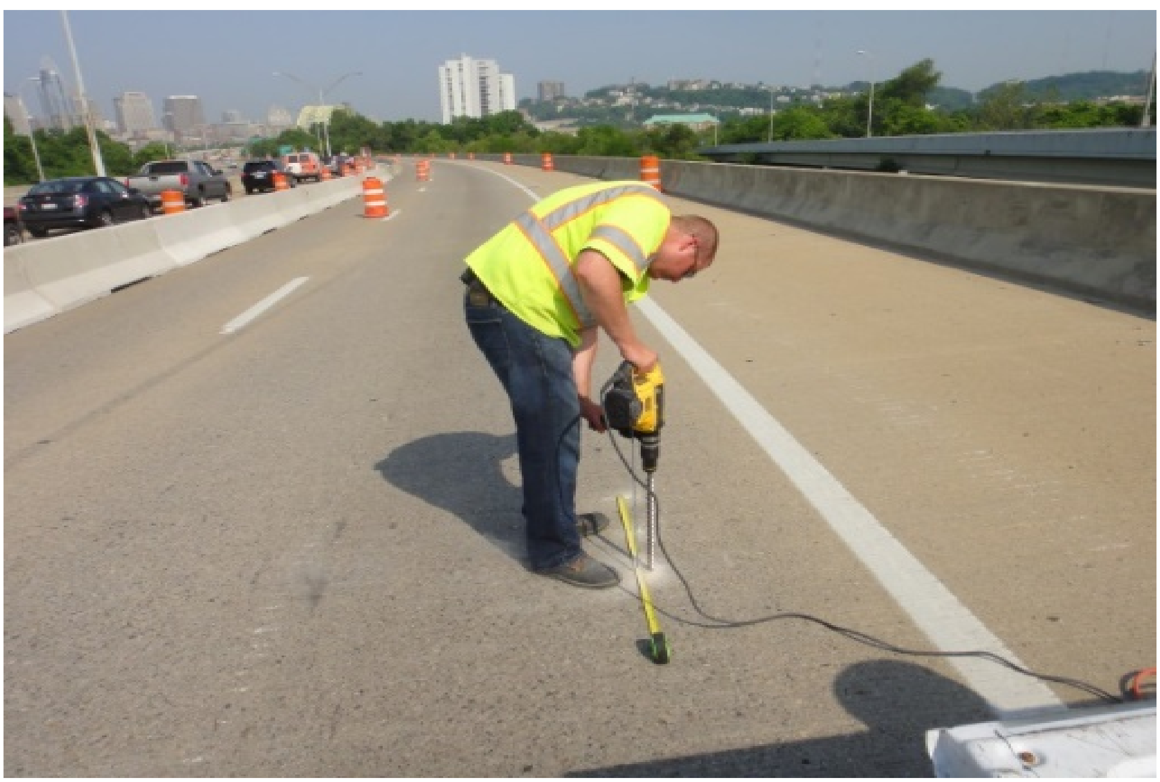


Figure 13. Collecting concrete samples from bridge decks.

Figure 14. Collecting concrete deck samples.

Figure 15. Cleaning bridge deck by pressure washing.

Figure 16. Cleaning water pressure gauge at the washer.

Figure 17. Aquinil Plus 40 sealant application.

Figure 18. BASF Enviroseal 40 sealant application.

Figure 19. “Pre-washed” crack on the deck.

Figure 20. Flooding “Pre-Washed” Crack with pre-sealer.

Figure 21. Application of sealant with garden hose.

Figure 22. Measurement of sealant applied on the deck.

Figure 23. Sample Collection after Deck Sealing.

Figure 24. Dynamic Friction Tester.

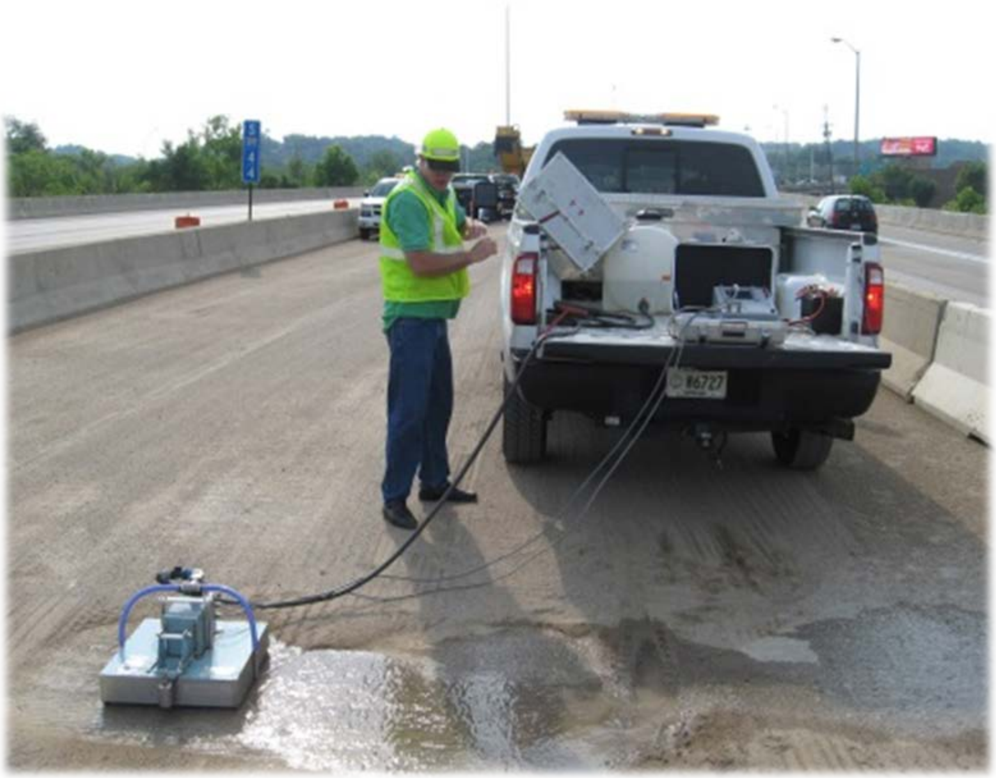
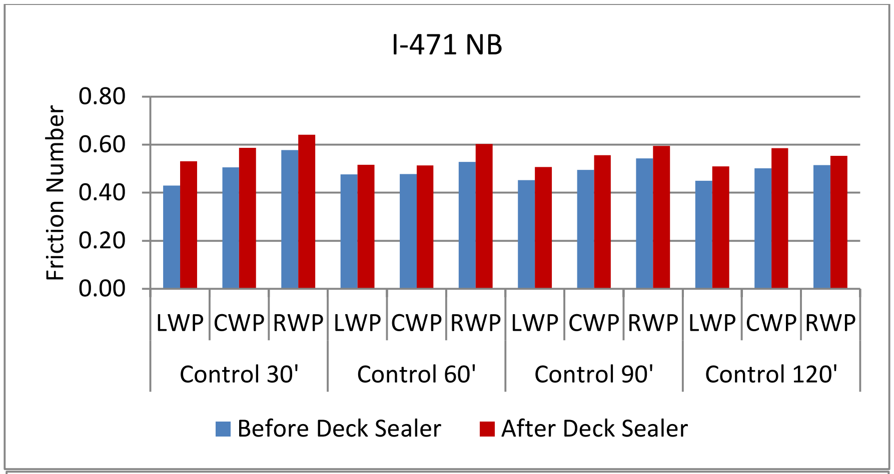
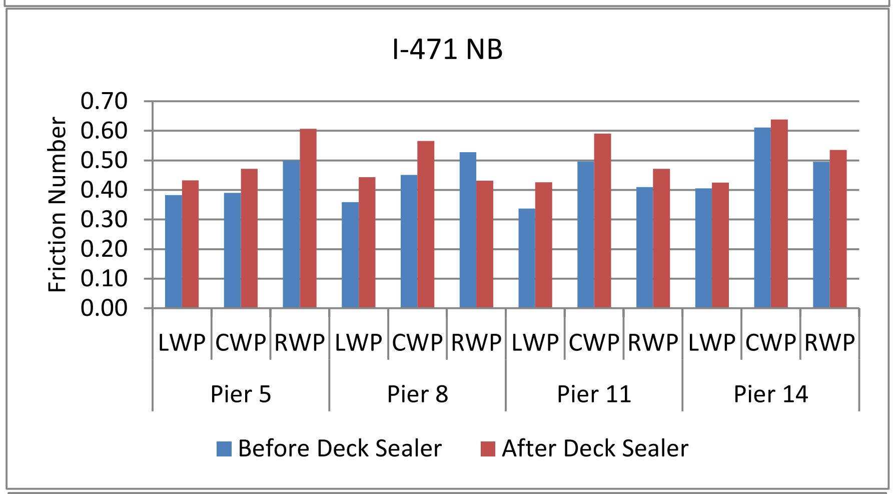


Figure 25. Dynamic Friction Tester in use.





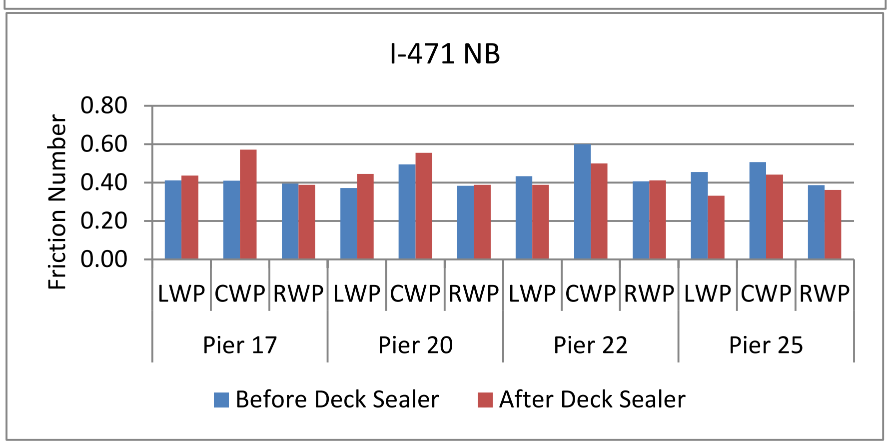
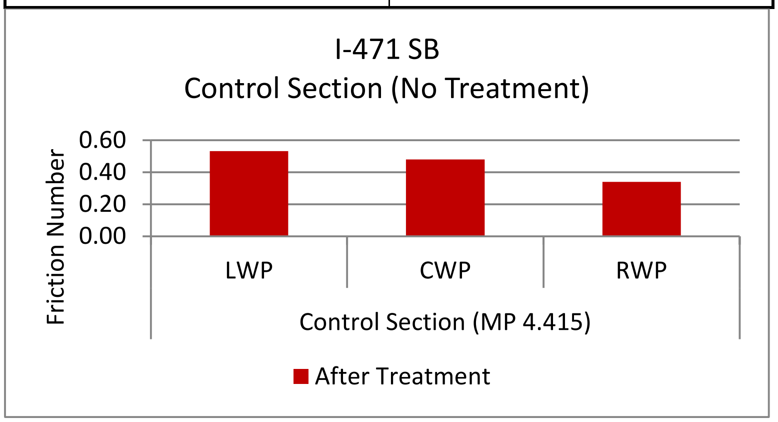


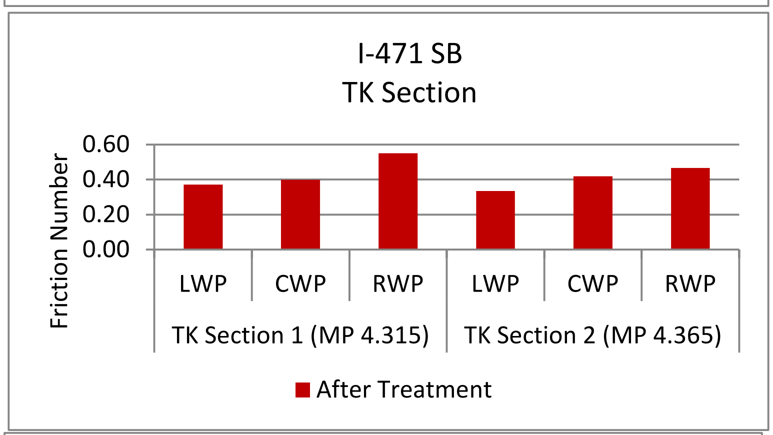
Figure 26. North Bound Friction Test Graph

Control Section (MP 4.415)		
LWP	CWP	RWP
0.53	0.48	0.34

TK Section 1 (MP 4.315)			TK Section 2 (MP 4.365)		
LWP	CWP	RWP	LWP	CWP	RWP
0.37	0.40	0.55	0.34	0.42	0.47

BASF Section 1 (MP 4.21)			BASF Section 2 (MP 4.26)		
LWP	CWP	RWP	LWP	CWP	RWP
0.47	0.38	0.54	0.38	0.54	0.43





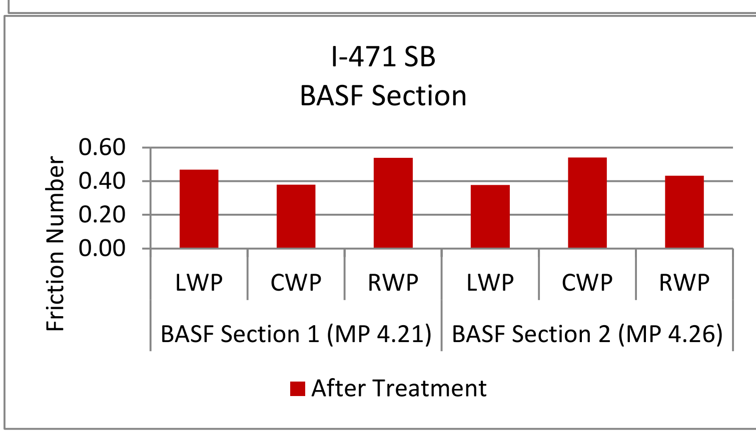


Figure 27: South Bound Friction Test Data