March 2012

Progress Report Year 1
Field Performance of Sealers for Portland Cement Concrete Pavements (PCCP)

Nebraska Department of Roads

Research Project Title:

Progress Report Year 1
Field performance of Sealers for PCCP

Location: In-House Research

Starting Date: August 2010

Completion Date: December 2013

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Purpose of the In-House Research Project:

The Nebraska Department of Roads (NDOR) began to explore various sealer applications for pavements susceptible to Alkali Silica Reaction (ASR), this research was launched with the cooperation of the City of Lincoln to prevent deterioration to those pavements that have not mitigated ASR. NDOR occasionally uses concrete sealers on bridge deck applications; however, not for concrete pavements. Therefore, this investigation will analyze if concrete sealers may be used in the future as a preventative maintenance tool in order to delay deterioration in pavements that are susceptible to ASR. This is the first evaluation of concrete sealers for PCC pavements performed by NDOR Materials and Research. The most common concrete sealers are film formers, such as acrylics and thermoplastics; and penetrating sealers including silicones, siloxanes, silanes and silicates. All Types will be studied in this investigation.

Field Demonstration Experimental Layout:
This is the first of four years evaluating concrete sealers. For the purpose of this study, the effectiveness of each sealer will be evaluated based on the reduction of the penetration chloride ions from deicer chemicals into the concrete pavement. As part of this study, the field sample will be within the wheel path and non wheel path within each treated and untreated sections.
Each sample was collected in increments of one half inch from the joint and depth increments of 0 - ½", ½"-1" and 1"-1 ½" for analysis of chloride content in part per million (PPM) by AASTHO T 260 Test Method for Sampling and Testing Chloride Ion in Concrete. The products included in this evaluation are:

- Star Macro Deck, 100% acrylic polymer
- Aquapel Plus, 100% reactive, waterborne silane-siloxane with high solids
- Aquapel,100% reactive, waterborne silane-siloxane
- Hydrozo 40 , solvent-based material
- Enviroseal 40, water-based material
- Hydrozo 100, 100% active material
- Lithiseal ZLi 71, lithium application

Sealers were applied during August 2010. All sealers were applied by NDOR Materials & Research forces, with the exception of Lithiseal Zli 71, which was placed by its supplier. All sealers were applied by an industrial pump sprayer, as shown in figure1.

Figure1. Sealer Application by Industrial Sprayer

Lithiseal Zli 71- Lithium sealer was applied by the supplier after cleaning the pavement surface with hot water. The remaining of the sealers was applied after the pavement was washed with high pressure water and had four hours to dry. The sealers were applied at each of manufactures recommended rate.

The control sections and treated sections consisted of 16.5 feet long by 12 feet wide panels for an area of 6930 square feet as shown in Figure 2. The application started from the west and proceeded east. Figure 2 shows the layout of the field demonstration sealer test sections. Also, as part of the first year evaluation forensic examinations were conducted in-situ before the sealer application: density by ASTM C 642, permeability by ASTM C 1202 , Hardened Air void by ASTM C 457 and AASTHO T 260 for baseline of Chloride content.

Type of Sealer	Sampling and Testing for Each Field Test Sections Identification Panel Number
STAR MACRO DECK	35- Sealer 34- Sealer 33- Sealer 32-Sealer
UNTREATED	31- Untreated 30- Untreated
AQUAPEL PLUS	29- Sealer 28- Sealer 27-Sealer
UNTREATED	26- Untreated 25- Untreated
AQUAPEL	24- Sealer 23- Sealer 22-Sealer
UNTREATED	21- Untreated 20- Untreated
BASF- Hydrozo Silane 40 (Solvent Based Silane)	19- Sealer 18- Sealer 17-Sealer
UNTREATED	16- Untreated
BASF- Enviroseal 40 (Water based 40% Silane)	15 Untreated (but Treated in the Field) 14- Sealer 13- Sealer 12-Sealer
UNTREATED	11- Untreated 10- Untreated
BASF - Hydrozo 100 (100% Silane)	9- Sealer 8- Sealer 7-Sealer
UNTREATED	6- Untreated 5- Untreated
Lithiseal Zli 71	4- Sealer 3- Sealer
UNTREATED	2- Untreated 1- Untreated

Figure 2. Layout of Field Experimental Demonstration Sealer Test Section

First Year Evaluation:

The first year evaluation was performed by comparing the chloride content penetration or effectiveness of each individual sealer as given in Figures 3, 4 and 5. Samples were collected at depths increments of 0-½", ½"-1" and 1"-1 ½". Effectiveness of the sealers compared with the untreated sections were determined by the following formula:

$$\frac{(\text{Before Sealing (PPM)} - \text{After Sealing (PPM)})}{\text{Before Sealing (PPM)}} \times 100 = \text{Effectiveness } \%$$

The research will be based on the evaluation performance accordingly to its effectiveness for a three year evaluation period. The following data is for the first year only. Some sealers at depths of 0- ½" to ½' 1" and 1"-1 ½" seemed to allow greater chloride penetration. They are represented by a negative effectiveness as shown in Figure 4 and Figure 5.

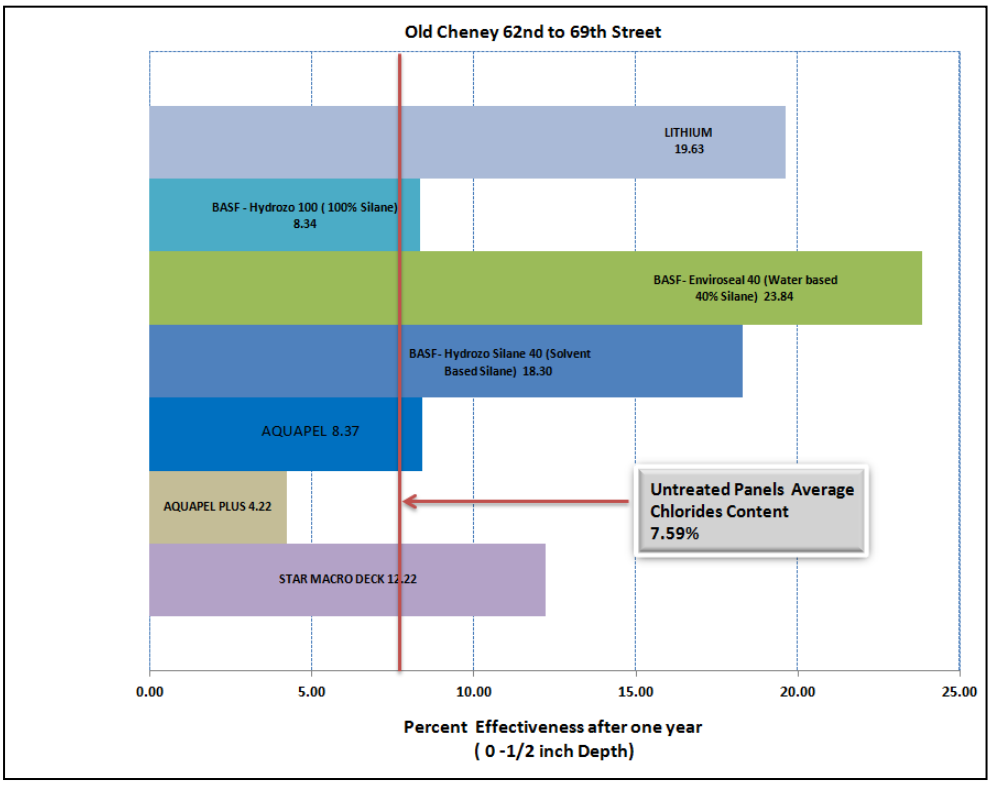

Figure 3.- Percent Effectiveness 0-½ inch depth

Figure 3 shows the degree of effectiveness all sealers showed with the exception of Aguapel.

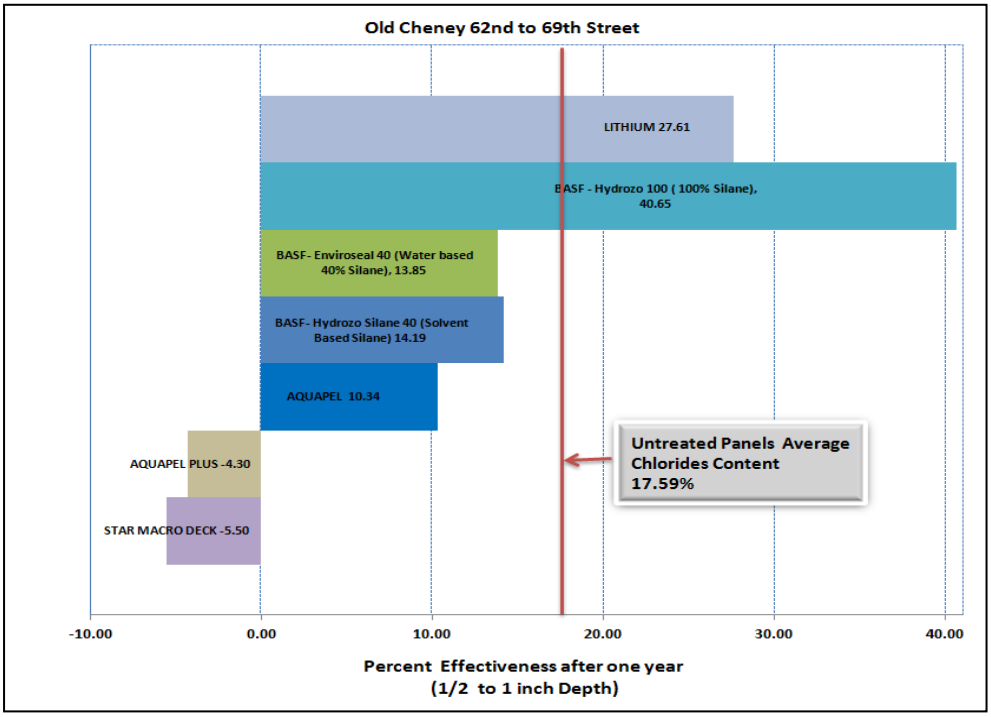

Figure 4.- Percent Effectiveness ½ to 1 inch depth

Figure 4 shows the percent effectiveness of the sealer against chloride content. The Hydrozo 100 Silane and Lithium rated top in effectiveness.

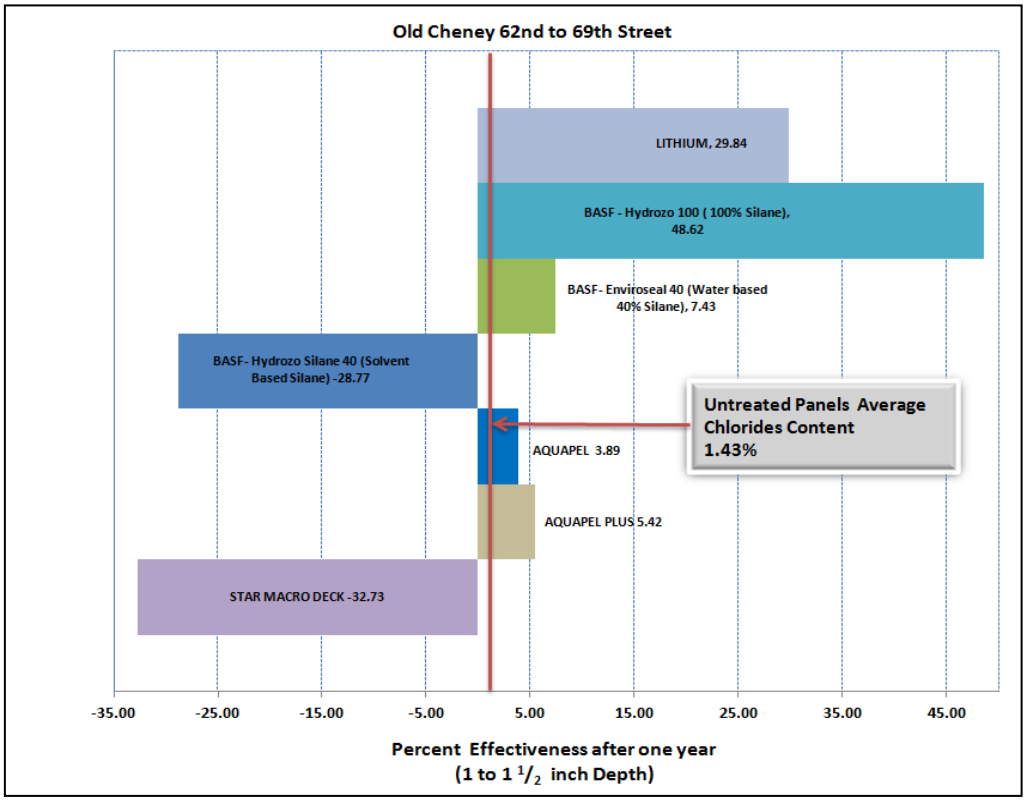

Figure 5.- Percent Effectiveness 1 to 1 1/2 1 inch depth

Figure 5 shows the effectiveness of the sealers compared the untreated control section; the sealers rated high on the effectiveness chloride content protection continue to be the Hydrozo 100 Silane and Lithium.

Year 1- Data Discussion:

The evaluation to date shows the results differ when comparing the effectiveness by depth increments. The Hydrozono Silane and Lithiseal sealers have performed adequately with no considerable variation regarding depth. These two sealers show increasing effectiveness with increased depth. In general, sealer effectiveness was greatest as shown in Figure 5; the Hydrozono 100 percent Silane exhibited slightly better effectiveness than Lithiseal sealer.

Since the penetration depth of both sealers, water and chlorides are affected by the substrate concrete quality; forensic examinations were performed on representative concrete samples from individual panels treated. The following table shows the results for the pavement before treatment (sealer application).

Table 5 – Forensic Evaluation Summary

Panel Number	Density lb/ft³	Hardened Air % *	Permeability (Coulomb Passed)	Uranium Acetate
3	147.08	Entrained: 4.92 Entrapped: 7.34 Total:12.26	Low	All cores showed reactivity as shown in Figure 6.
8	144.71			
13	142.84			
18	142.77			
23	144.40			
28	143.21			
33	145.33			

(*) total hardened air evaluated from one core sample

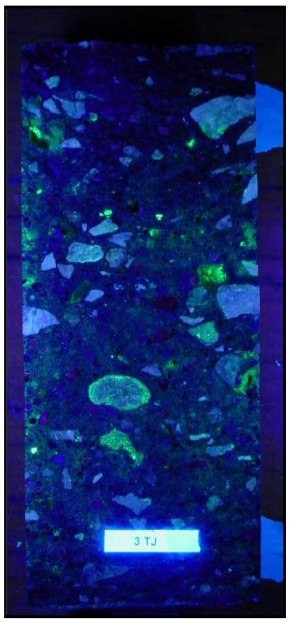

Figure 6. Identification of ASR by Uranium Acetate Test

The forensic evaluations indicate the concrete substrates are dense and overall in good condition. Therefore, it may be inferred that the concrete in the treated areas exhibited similar permeability characteristics of the untreated areas. The hardened entrapped air was high; however, the mix design used for the existing pavement project segment tended to entrap air due to a gap gradated mix design. Also, Alkali Silica Reaction was identified by C-315 for in-situ pavement.

Year 2- Activities:
Samples will be taken drilling 1 inch holes at depth increments of 0-½", ½"-1" and 1"-1 ½" (Figure 7) will continue to be collected from all fourteen test sections for the next three years and rated annually.

Figure 7. Drill and dust sample collector

The next activity will be the preliminary evaluation of the Rilem Tube Test Method, which is a method for measuring the water absorption of a concrete surface during a specified time period. The program testing will consist of taking field measurements of untreated and treated panels by the horizontal Rilem Tube (Figure 8). This test determines the degree of water absorption on the pavement surface for the untreated and treated panels. The visual bead test (Figure 9) will also be performed as an indicator of how well the pavement surface repels water. Food coloring will be used for the identification of the visual bead test. The research team understands these additional test will be for information purposes only and not a true it indicator of performance.

Figure 8. Rilem Horizontal Tube Test Method

Figure 9. Instrumentation for Bead Test

NOTE: Based on the first year test results, the research team will consider looking at the data trend to analyze data field collection. Therefore, the research team will be adding more samples at depth increments of 0- ½", ½"-1" and 1"-1 ½" in the middle of the pavement for all 14 test sections. This will evaluate the effectiveness of sealers away from the joint, since the joint allows moisture and chemicals to go through the pavement. All information will be reported at the end of the evaluation.

March 2013

Progress Report Year 2
Field Performance of Sealers for Portland Cement Concrete Pavements (PCCP)

Nebraska Department of Roads

Research Project Title:

Progress Report Year 2
Field performance of Sealers for PCCP

Location: In-House Research

Starting Date: August 2010

Completion Date: December 2014

Principle Investigators:

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Chemist II

PCC Laboratory:

Tim Krason
PCC Concrete Lab Manager

Field Demonstration Experimental Layout- Year 2 Activities:

- **Chloride Ion Testing:**

Each sample was collected in increments of one half inch from the joint and depth increments of 0 - ½", ½"-1" and 1"-1 ½" for analysis of chloride content in part per million (PPM) by AASTHO T 260 Test Method for Sampling and Testing Chloride Ion in Concrete Figure 1).

Figure 1. Drill and dust sample collector

The field samples were within the wheel path and non-wheel path within each treated and untreated sections. The products included in this evaluation are:

- Star Macro Deck, 100% acrylic polymer
- Aquapel Plus, 100% reactive, waterborne silane-siloxane with high solids
- Aquapel,100% reactive, waterborne silane-siloxane
- Hydrozo 40 , solvent-based material
- Enviroseal 40, water-based material
- Hydrozo 100, 100% active material
- Lithiseal ZLi 71, lithium application

Results to date: Based on the first year test results, the research team considered looking at the data trend to analyze data field collection. Therefore, the research team added more samples at depth increments of 0- ½", ½"-1" and 1"-1 ½" in the middle of the pavement for all 14 test sections. This will evaluate the effectiveness of sealers away from the joint, since the joint allows moisture and chemicals to go through the pavement. These additional testing is in progress and will be coming by July of 2013.

- **Rilem Tube Testing**:

The Rilem Tube Test Method is a method for measuring the water absorption of a concrete surface during a specified time period. The program testing consisted of taking field measurements of untreated and treated panels by the horizontal Rilem Tube (Figure 2). This test determines the degree of water absorption on the pavement surface for the untreated and treated panels. The visual bead test (Figure 3) was also being performed as an indicator of how well the pavement surface repels water. Food coloring will be used for the identification of the visual bead test. This test is an additional test that will be for information purposes only and not a true it indicator of the sealer performance. Forensic Cores were also taken for bead testing.

Figure 2. Rilem Horizontal Tube Test Method

Figure 3. Instrumentation for Bead Test

Results to date:

Figures 4-A and 4-B show the Rilem tube reading field measurements in the wheel path and center of panel. Also, are shown the results of the bead test performed on the pavement surface and the bead test of the core.

Figure 4A- Rilem Test Field Measurements Results and Bead Test (Pavement and Core) Testing

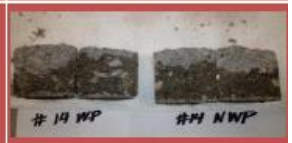
Panel Number	MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Wheel Path)		MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Center of Panel)		Bead Test (Pavement Surface)	Bead Test (Core)
2 Untreated	MINUTES	Reading (ml)	MINUTES	Reading (ml)		
	5	0.1	5	0		
	10	0.1	10	0		
	15	0.2	15	0		
	20	0.2	20	0.1		
	30	0.3	30	0.1		
	60	0.5	60	0.2		
Panel Number	MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Wheel Path)		MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Center of Panel)		Bead Test (Pavement Surface)	Bead Test (Core)
3 LITHIUM	MINUTES	Reading (ml)	MINUTES	Reading (ml)		
	5	0.1	5	0.1		
	10	0.2	10	0.2		
	15	0.25	15	0.25		
	20	0.3	20	0.3		
	30	0.5	30	0.4		
	60	0.75	60	0.6		
Panel Number	MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Wheel Path)		MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Center of Panel)		Bead Test (Pavement Surface)	Bead Test (Core)
9 Hydrozo 100 (100% Silane)	MINUTES	Reading (ml)	MINUTES	Reading (ml)		
	5	0	5	0		
	10	0	10	0		
	15	0	15	0		
	20	0	20	0		
	30	0	30	0		
	60	0	60	0		
Panel Number	MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Wheel Path)		MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Center of Panel)		Bead Test (Pavement Surface)	Bead Test (Core)
10 Untreated	MINUTES	Reading (ml)	MINUTES	Reading (ml)		NA
	5	0.5	5	0.5		
	10	1.5	10	1.5		
	15	2.5 leaked	15	1.5		
	20		20	1.5 leaked		
	30		30			
	60		60			
Panel Number	MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Wheel Path)		MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Center of Panel)		Bead Test (Pavement Surface)	Bead Test (Core)
14 BASF-Enviroseal 40 (Water Based 40% Silane)	MINUTES	Reading (ml)	MINUTES	Reading (ml)		
	5	0	5	0		
	10	0	10	0		
	15	0	15	0		
	20	0	20	0		
	30	0.125	30	0		
	60	0.25	60	0.125		
Panel Number	MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Wheel Path)		MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Center of Panel)		Bead Test (Pavement Surface)	Bead Test (Core)
16 Untreated	MINUTES	Reading (ml)	MINUTES	Reading (ml)		NA
	5	0	5	0		
	10	0	10	0		
	15	0	15	0		
	20	0	20	0		
	30	0	30	0		
	60	0	60	0		

Figure 4-A and 4-B shows the effectiveness of 100% Silane (Panel 9), 40% Water Based Silane (Panel 14) and 40% Solvent Based Silane (Panel 19) sealers are showing promise in penetrating the pavement surface. The penetration depth is shown clearly by the forensic cores through the bead test. The underline white layer (top of core) is showing that the sealer is repelling the water.

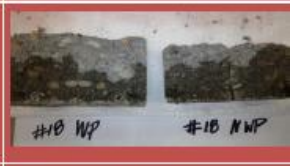
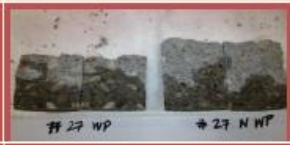
Panel Number	MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Wheel Path)		MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Center of Panel)		Bead Test (Pavement Surface)	Bead Test (Core)
19 BASF-Hydrozo Silane 40 (Solvent Based Silane)	MINUTES	Reading (ml)	MINUTES	Reading (ml)		
	5	0	5	0		
	10	0	10	0		
	15	0	15	0.25		
	20	0	20	0.25		
	30	0	30	0.25		
	60	0.25	60	0.5		
Panel Number	MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Wheel Path)		MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Center of Panel)		Bead Test (Pavement Surface)	Bead Test (Core)
22 AQUAPEL	MINUTES	Reading (ml)	MINUTES	Reading (ml)		
	5	0	5	0		
	10	0	10	0		
	15	0	15	0.25		
	20	0.25	20	0.25		
	30	0.25	30	0.25		
	60	0.5	60	0.25		
Panel Number	MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Wheel Path)		MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Center of Panel)		Bead Test (Pavement Surface)	Bead Test (Core)
29 Aquapel Plus	MINUTES	Reading (ml)	MINUTES	Reading (ml)		
	5	0	5	0		
	10	0	10	0		
	15	0.25	15	0		
	20	0.25	20	0		
	30	0.25	30	0		
Panel Number	MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Wheel Path)		MEASUREMENT RILEM HORIZONTAL TUBE FIELD READING (Center of Panel)		Bead Test (Pavement Surface)	Bead Test (Core)
32 Star Macro Deck	MINUTES	Reading (ml)	MINUTES	Reading (ml)		
	5	0	5	0		
	10	0.25	10	0		
	15	0.25	15	0		
	20	0.25	20	0		
	30	0.25	30	0		
	60	0.25	60	0		

Figure 4B- Rilem Test Field Measurements Results and Bead Test (Pavement and Core) Testing

Note: The research team will provide the Year 2 Activities report by late fall 2013. The report will summarize the Chlorides Ion Testing results from 0- ½", ½"-1" and 1"-1 ½" within the wheel path, non-wheel path and in the middle of the pavement for all 14 test sections.