MITIGATION OF ALKALI-SILICA REACTION IN CONCRETE PAVEMENTS BY SILANE TREATMENT

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Abstract

Alkali-silica reaction (ASR) in concrete pavements is difficult to mitigate and causes maintenance issues, which often require overlays or replacement. The only effective method for mitigating ASR in pavements is by limiting moisture within the concrete, which reduces ASR related expansion. For pavements placed on well drained base layers it may be possible to mitigate ASR through surface treatment. Silane provides a breathable barrier on the surface of the concrete, which blocks water, while allowing water vapor to escape. The silane penetrates into the surface of the concrete and chemically bonds to it, providing a long term treatment. The ongoing research project at the University of Arkansas will assess the efficacy of silanes applied to concrete pavements. The mitigation efforts will be assessed through expansion and relative humidity monitoring, in addition to quantitative deterioration tests. Preliminary results show that silane can slow the progression of ASR in pavements.

KEYWORDS: Alkali-silica reaction (ASR), silane, concrete pavements, mitigation

1. INTRODUCTION

Alkali silica reaction is difficult to mitigate in concrete pavements, moisture enters the concrete from the subgrade and is impossible to control. Fortunately, modern pavements are constructed on an open graded base layer that allows adequate drainage and provides drying between rain events. Therefore, it is possible to mitigate ASR in concrete pavements by treating the surface of the pavement with a hydrophobic, breathable, penetrant, such as silane [1]. Silane penetrates into the surface and bonds with the concrete providing a layer that endures traffic wear for several years. The silane is hydrophobic, preventing water from entering the concrete. However, silane is also breathable meaning water vapor can pass through, which allows the concrete to dry over time, provided the air is at a lower humidity than the concrete. This process has been used successfully but others [1, 2, 3 4] to mitigate ASR in concrete structures such as median barriers and bridge elements. ASR is more difficult to mitigate in pavements because silane can only be applied to the exposed surface. Although silane will provide drying from the exposed surface, moisture can enter the concrete from the subgrade. In modern pavements the subgrade is openly graded and drains quickly, which allows drying between rain events. Therefore, it may be possible to mitigate ASR in concrete through surface treatment with Silane. Researchers have attempted to establish the efficacy of silane applied to concrete pavements in the past [5, 6] but these projects have not been carried out for a sufficient length of time. Published literature is lacking on the efficacy of silanes applied to pavements, likely because it takes several years to establish results.

Between 2008 and 2014, four pavements in Arkansas were diagnosed with ASR and related deterioration. Silane was first applied to a test section in Pine Bluff Arkansas under the FHWA *Alkali-Silica Reactivity (ASR) Development and Deployment Program*. However, this program has since ended and limited results are available [6]. In addition, the concrete pavement has deteriorated so rapidly that it has been scheduled for replacement before sufficient monitoring can occur. Therefore, and additional test section was established near Fayetteville, Arkansas. The research program established between the authors and the Arkansas State Highway and Transportation Department (AHTD) includes 3 years of monitoring to establish the efficacy of mitigating ASR in concrete pavements. The objectives of this research program is to determine the efficacy of silane in mitigating ASR within concrete pavements, to better understand the relationship between relative humidity and ASR in pavements, and to assess the deterioration of concrete pavements using quantitative methods. Extensive RH testing will be conducted to better understand how pavements dry and what effects the moisture gradient within the concrete introduces. The results of 18 months of monitoring in addition to quantitative damage tests are discussed herein, including preliminary conclusions. Another 18 months of monitoring, in addition to quantitative petrographic testing will be conducted to establish the efficacy of silane and changes in deterioration mechanisms that occur as a result of treatment.

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2. MATERIALS AND METHODS

The Interstate 49 pavement was cast in 1998 near Fayetteville, Arkansas. The concrete contains Arkansas River sand from Van Buren, Arkansas and crushed limestone coarse aggregate from West Fork, Arkansas. The concrete also contains a high alkali cement that was produced in Pryor, Oklahoma and a Class C fly ash from Muskogee, Oklahoma. The cement was found to contain between 0.4 and 1.0 percent alkalis.

The concrete pavement is 30 cm thick and 7.3 m wide. The pavement has a tine finish and the original surface is still exposed. The pavement is two lanes with a center joint and transverse joints every 3.7 m. The section of pavement diagnosed with ASR is 19.25 km in length. The pavement section selected for evaluation is 21 panels in length, of which 12 were instrumented for evaluation. The pavement has discoloration at the joints, which occurs in a pattern similar to D-cracking (Figure 1A, 1B). In addition, there has been some joint failure, as seen in Figure 1C, which has required patching.

The fine aggregate is moderately alkali-silica reactive, with accelerated mortar bar (AMBT, ASTM C1260) and concrete prism (CPT, ASTM C1293) tests confirming that the aggregate is reactive. The pavement began showing signs of deterioration in 2012, with the majority of the deterioration occurring near joints. Core samples were sent for petrographic examination in 2012, which was conducted by CTLGroup. The core samples had short cracks near the surface, penetrating between 0.2 and 2 inches. There were also alkali-silica gel deposits and reacted fine aggregate particles, indicating minor amounts of ASR. There was no evidence of freezing and thawing distress in the core samples, and air entrainment was estimated at between 2.5 and 5 percent. Additional core samples were extracted from the pavement for laboratory testing. The samples were prepared for damage rating index (DRI) testing and potential for further expansion (PFE) testing [7].

2.1. Instrumentation and Monitoring

The pavement was instrumented for strain and internal RH monitoring. Each pavement panel was instrumented with a grid of four strain measuring points. Pins were placed at the corners of a 0.5 m square, the pins were 75 mm long and 8 mm in diameter with a 1 mm indentation drilled into the exposed surface of the pin (Figure 1D, 1F). Strain was measured by matching the points of the detachable mechanical (DEMEC) strain gage with the indentation on two pins. Length change was recorded to the nearest .001 mm, and then converted to strain. Strain was measured along all four faces of the grid, providing two measurements in the travel and transverse directions. In each direction the strain was averaged to provide a single measurement for the travel and transverse directions.

Much of the drying, after treatment with silane, will occur through the exposed surface. This will introduce a moisture gradient within the concrete that will make it difficult to assess the relative humidity within the concrete. Measuring RH at a single depth within the concrete does not convey the state of moisture within the concrete [8]. However, it may be used to compare the level of drying that has occurred in treated samples as compared to the control. A port for measuring internal RH was drilled into each panel. The port was placed along outside edge of the pavement to limit the amount of traffic (Figure 1E). Each port was 12.5 mm in diameter and 150 mm in depth. The ports were capped with PVC and epoxied into place to prevent water from entering the port. During measurements, the cap was removed and a RH probe inserted. The probe was allowed to equilibrate with the air in the port for 1 hour prior to measuring RH and temperature. The method for measuring RH was changed about 1.5 years into the research program due to difficulties. The ports were capped between measurements, but remained empty. This caused moisture to precipitate within the port and lead to highly inaccurate measurements. Therefore, a new method was adopted, which involves drilling fresh ports to a depth of 75 mm at each site visit. The port was cleaned with a vacuum and then the RH probe was inserted and sealed in place with silicon. The probe remained in the port for 4 hours before RH and temperature were recorded. This method has proven repeatable and accurate.

Measurements were conducted in the spring and fall, on days when the temperature was near 21 °C and the skies were overcast. However, lane closures were scheduled with advanced warning, so the weather was not always as expected. The measurements were conducted between 9:00 and 12:00 to limit temperature fluctuations and thermal stresses. During site visits, the humidity probes were inserted at the beginning of the day to allow 4 to 5 hours of equilibrating. Strain measurements were then recorded for all the pavement panels, which took approximately 1 hour. After a two-hour break, an additional set of strain measurements were recorded, before recording the RH and temperature for each panel. There was approximately a 5 to 10 °C difference in temperature from the time of the initial and final strain measurements. The additional set of strain measurements was used to calibrate the temperature correction applied to strain measurements.

2.2. Treatments

Silane was selected as a mitigation method because it is a hydrophobic penetrant, which binds to the concrete and is resilient to traffic wear for several years. The silane limits water from entering the concrete, but remains breathable and allows water vapor to escape. When the RH outside the concrete is lower than that of the concrete, moisture is drawn out of the concrete. By treating the exposed surface of the pavement, drying will occur over an extended period of time. If the drying is sufficient to reduce the RH of the concrete below 80 percent [9, 10], then ASR related expansion will cease. In addition, reducing the moisture within the concrete will improve the freezing and thawing durability of the concrete, which may have been reduces due to ASR gel and microcracking within the concrete [11].

Three commercial silane treatments were selected for evaluation. The first two, BASF Enviroseal 40 and Sika Sikagard 740w, contain 40 percent silane. The third, Euclid Baracade Silane 100 contains 100 percent silane. Each treatment was applied to three test panels using hand sprayers. Each treatment was applied according to manufacturer recommendations, and then allowed to dry for 8 hours before the pavement was opened to traffic (Figure 1G, 1H). Each treatment was applied to three pavement panels, and three additional pavement panels remained untreated as control sections.

2.3. Specimens

Core samples were extracted from the pavement in August 2014. The core samples were 100 mm in diameter and 300 mm in length. The cores were first cut axially to produce half sections with a 100 mm by 300 mm flat surface. The surface was then polished using an air powered polisher with diamond impregnated rubber pads. The surface was polished down to a 3000 grit polishing pad, with imperfections no greater than 10 microns. A grid of 1 cm squares was then drawn on the surface with indelible ink. A 5 mm gap was left outside the grid along the edges of the sample to avoid measuring defects produced during coring. The grid was therefore 90 mm by 290 mm, leaving 261 cm^2 of polished surface. A polished and prepared sample is shown in Figure 3A.

The sample was inspected under 15X stereoscopic magnification [12, 13]. Each grid cell was inspected and petrographic features were counted, the types of petrographic features are listed in Table 3. The features were weighted and summed for all of the cells and then normalized to a surface area of 100 cm^2. The results were plotted in a bar graph to show the occurrence of each damage type. This process reveals the mechanism of deterioration within the concrete, and is used to compared samples collected at different times, which may have additional deterioration.

2.4. Test Methods

After samples are prepared for the DRI method, the sample is analyzed under stereoscopic magnification. A magnification of 15X allows one 10 mm cell to be observed through the stereo microscope lens. Petrographic features of deterioration are counted within the cell and logged as one of the categories included in Table 3. Each petrographic feature is assigned a weight based on the mechanism of deterioration which is attributed to the feature. The weighted sum off all the petrographic features is then counted for all the cells along the surface. The results are then summarized in a stacked bar graph, which conveys the quantity of each petrographic feature. The graph can be used to quickly determine the deterioration mechanisms present within the concrete and to compare the deterioration between samples. By collecting core samples before, during, and after the monitoring period, the change in deterioration mechanism can be used to assess the rate of deterioration. In addition, the core samples from treated sections can be compared to the control, to determine the effects of treatment on deterioration rate and mechanism.

3. RESULTS AND DISCUSSION

3.1. Strain Monitoring

In January of 2014, silane treatment was applied to nine test panels of Interstate 49 pavement. The panels were instrumented for strain and RH monitoring at the time of treatment. Strain measurements have been collected intermittently over a 1.5-year period. Strain was measured in both the travel direction and the transverse direction, the strain rates were higher in the transverse direction because there is less restraint. Internal RH was also measured along with strain, although with some difficulty. Preliminary findings for some of the silane treatments show that silane can decrease the rate of deterioration in concrete pavements.

The travel direction strain results for sections treated with Enviroseal 40 are summarized in Figure 2A. The sections treated with Enviroseal 40 had a decrease in strain rate for the travel direction (Table 1) as compared to the control sections. As summarized in Figure 2A, sections Enviroseal 1 and Enviroseal 3 had less strain in the travel direction toward the end of the monitoring period. The remaining section, Enviroseal 2, had a higher strain but lower strain rate as compared to the control. The results indicate that Enviroseal 40 has benefited the pavement during the monitoring period. The stain in the transverse direction for the

Enviroseal sections are provided in Figure 2B. All three of the treated sections are expanding, and sections Enviroseal 1 and 3 are expanding at a strain rate higher than the average control (Table 2). This indicates that Enviroseal has not provided a benefitial reduction in expansion as compared to the control.

In the travel direction Enviroseal 1 and 3 have a strain rate of -0.0012 (%/yr.) and 0.0023 (%/yr.), respectively. The average control section has a strain rate of 0.0039 (%/yr.) while section Enviroseal 2 is expanding at 0.0037 (%/yr.). In the transverse direction sections Enviroseal 2 and 3 had a strain rate of 0.0019 (%/yr.) and 0.0035 (%/yr.) as compared to 0.0034 (%/yr.) in the average control. Section Enviroseal 1 had a higher strain rate of 0.0059 (%/yr.) than the control sections.

The sections treated with Euclid Baracade 100 do not show as much improvement in the travel direction, but are performing better in the transverse direction. In the travel direction, the strain in sections Baracade 1 and 2 have a higher strain than the average control. However, the strain rate in all three Baracade sections is lower than that of the control (Table 1). The sections Baracade 1 and 3 have contracted in the transverse direction, while section Baracade 2 is expanding similarly to the control. Overall, the Baracade treatment is slowing expansion as compared to the control sections (Figure 2C).

Travel direction strain rates for the three Baracade treated sections were -0.0006, 0.0040, and 0.0021 (%/yr.), respectively. Section Baracade 2 is expanding faster than the average control. In the transverse direction, the strain rates are -.0017, 0.0034, and -0.0018 (%/yr.), respectively. Therefore, sections Baracade 1 and 3 are expanding slower than the control and section Baracade 2 is expanding at the same rate as the control (Figure 2D).

The Sikagard 740w had little effect on the treated sections. As shown in Figure 2E, all of the sections have continued to expand in the travel direction at a similar rate of strain as the control (Table 1). The sections Sikagard 2 and 3 have expanded more than the control section, while section Sikagard 1 has expanded less and at a slower rate. In the transverse direction, all of the Sikagard treated sections have expanded more than the control (Figure 2F). Section Sikagard 3 is also expanding at a faster rate than the control (Table 2).

The Sikagard is underperforming, and in the travel direction sections Sikagard 2 and Sikagard 3 are expanding at 0.0060 and 0.0040 (%/yr.) as compared to 0.0039 (%/yr.) for the control. Section Sikagard 1 is expanding slower than the control, but on average the Sikagard is performing worse than the average controls. In the transverse direction the Sikagard sections are expanding at a rate of 0.0063, 0.0038, and 0.0093 (%/yr.) as compared to 0.0048 (%/yr.) in the average control. Therefore, the Sikagard has provided no benefit to the pavement.

3.2. Relative Humidity Monitoring

At 1.5 years the strain results are preliminary and will continue to change as moisture in the pavement is lost. Along with expansion measurements, RH has been monitored at each site visit. Unfortunately, there has been some difficulty in measuring accurate and consistent RH data. The ports for measuring RH were drilled to a depth of 150 mm, half the thickness of the pavement. This depth was selected to best gage the change in humidity in the full depth of the pavement, rather than the surface layer. The ports were capped with PVC to prevent water from entering. However, the port remained empty between site visits, which allowed moisture to condense within the port. This resulted in RH values between 97 and 100 percent at each site visit. The data is not reported herein because it does not reflect the true RH of the concrete, while the expansion measurements convey the efficacy of silane.

Due to the difficulties in measuring RH, the research team has switched to drilling new RH ports at each site visit. The ports are 75 mm in depth and are cleaned using a vacuum before the RH probe is inserted and sealed in place with silicon. The probe remains in the port for 4 hours, with measurements every 30 minutes. This method has provided more consistent results but requires one RH probe for each pavement panel. LabJack probes were selected because they are inexpensive and accurate. Each probe was calibrated over a range of RH values to increase the accuracy. At this point there is not enough data to report in this paper, but RH will be monitored in this manner over the next 1.5 years.

3.3. DRI

Core samples were collected from three locations along the Interstate 49 pavement. The cores were collected from lane mile 46, 47.5, and 48 to determine the deterioration along the length of the pavement. The silane treatment test sections are at lane mile 46 and the DRI results from this location will be used to assess the progression of deterioration in the treated and control sections. The DRI results are summarized in Figure 3B, and include 3 test locations. The core samples from lane miles 46 and 47.5 were taken from the corner of the test panel, while the only core available from lane mile 48 was from the middle of the panel.

The sample from LM 46 had a majority of closed cracks in the aggregate, which could be due to aggregate processing when the limestone was crushed. The concrete pavement contained a river sand fine aggregate, which was categorized as potentially deleteriously reactive in laboratory testing. Evidence of ASR was also noted in the petrographic examination of core samples collected from the pavement. The DRI method can be used to observe deterioration originating from the fine aggregate, although the deterioration may have a lesser effect on the DRI number. There were also open cracks in the aggregate and cracks in the cement paste, which propagated parallel to the pavement surface and extended across the entire sample. There were some open cracks with alkali-silica gel, and some corroded aggregate particles. The corroded aggregate particles were found within the coarse fraction of the fine aggregate, and had been broken down by ASR. Gel was also present in the larger air voids within the sample. The DRI for the sample was 510 (Figure 3B), indicating some deterioration.

The core sample from LM 47.5 had a similar amount of closed cracks in the aggregate. However, the presence of open cracks in the aggregate and cement paste was higher. There were also debonded coarse aggregate particles and corroded aggregate particles, similar to the sample from LM 46 (Figure 3B). Another core from the middle of a pavement panel at LM 48, had very little deterioration, with a DRI less than 100. Surprisingly, there were far fewer closed cracks in the aggregate, indicating that the cracks found in samples from LM 46 and 47.5 have additional deterioration beyond what was caused by aggregate processing. There were some open cracks in the aggregate and gel present within some of the cracks indicating that ASR is ongoing within the pavement at LM 48. Throughout the pavement, the concrete near the joints is deteriorating much more rapidly than the concrete near the center of the panel. This is due in part to additional loading near the joints and additional moisture, which enters the concrete through the joint.

4. CONCLUSIONS

The research program is ongoing, and will require another 18 months of monitoring to assess the efficacy of silanes in mitigating ASR in concrete pavements. Strain measurements have provided preliminary conclusion on the efficacy of different silane products. Two of the products have provided a beneficial reduction in strain rate over the monitoring period, slowing the progression of expansion. However, the remaining product was less effective.

Additional monitoring is required to measure the state of moisture present within the concrete slabs. Initial measurements were unusable due to moisture collecting within the measuring ports, which caused artificially high RH. A new method for measuring RH is now in place, and will provide internal RH values for the concrete at a depth of 75 mm. The results will be used to compare the state of moisture within the silane treated panels to that of the untreated control sections.

The DRI test method was useful for quantifying the state of deterioration within the pavement at the time of treatment. In addition, the DRI was used to assess the different deterioration along the length of pavement, and at different locations within the slabs. The results indicate that much higher deterioration is occurring near the joints as compared to the middle of the slab.

5. ACKNOWLEDGEMENTS

The authors would like to acknowledge the Arkansas Highway and Transportation Department for funding and supporting the research program. Several graduate researchers from the University of Arkansas were invaluable in setting up the research project and conducting site visits.

6. REFERENCES

[1] Bérubé, M.-A., Chouinard, D., Pigeon, M., Frenette, J., Rivest, M., & Vézina D. (2002a). "Effectiveness of sealers in counteracting alkali–silica reaction in highway median barriers exposed to wetting and drying, freezing and thawing, and deicing salt". *Canadian Journal of Civil Engineering*, 29, pp. 329-337.

[2] Drimalas, T., Folliard, K.J., Thomas, M.D.A., Fournier, B., & Bentivegna, A. (2012). "Study of the effectiveness of lithium and silane treatments on field structures affected by ASR". Proceedings of the 14th International Conference on Alkali-Aggregate Reaction (ICAAR), Austin, Texas.

[3] Folliard, K.J., Thomas, M.D.A., Fournier, B., Resendez, Y., Drimalas, T., & Bentivegna, A. (2012). "Evaluation of mitigation measures applied to ASR-affected concrete elements: preliminary findings from Austin, TX Exposure Site". Proceeding of the 14th International Conference on Alkali Aggregate Reaction (ICAAR), Austin, Texas.

[4] Thomas, M.D.A., Folliard, K.J., Fournier, B., Drimalas, T., & Rivard, P. (2012). "Study of Remedial Actions on Highway Structures Affected by ASR". Proceedings of the 14th International Conference on Alkali-Aggregate Reaction (ICAAR), Austin, Texas.

[5] Stark, D. C., Morgan, B., Okamoto, P., & Diamond, S. (1993). "Eliminating or minimizing alkali-silica reactivity (Report No. SHRP-C-343)." Strategic Highway Research Program (SHRP), National Research Council, Washington, DC, 266 pp.

[6] Thomas, M.D.A., Folliard, K.J., Fournier, B., Rivard, P., and Drimalas, T. (2013). "Methods for Evaluating and Treating ASR-Affected Structures: Results of Field Application and Demonstration Projects" (Report No. FHWA-HIF-14-0002). Federal Highway Administration, U.S. Department of Transportation, Washington DC, 80 pp.
[7] Berube, M.A., Frenette, J., Pedneault, A., Rivest, M. (2002c). "Laboratory Assessment of the Potential Rate of ASR Expansion of Field Concrete". *Cement, Concrete and Aggregates*, 24(1), 13-19.
[8] Rust, C. (2009). "Role of Relative Humidity in Concrete Expansion due to Alkali-Silica Reaction and Delayed Ettringite Formation: Relative Humidity Thresholds, Measurement Methods, and Coatings to Mitigate Expansion." M.S. Thesis, The University of Texas at Austin, Austin, TX
[9] Berube, M.A., Chounard, D., Boisvert, L., Frenetter, J., and Pigeon, M. (1996). "Influence of wetting-drying and freezing-thawing cycles, and effectiveness of sealers on ASR". Proceedings of the 10th International Conference on Alkali-Aggregate Reaction (ICAAR), Melbourne, Australia, August 18-23, 1056-1063
[10] Stark, D. (1990). "The moisture condition of field concrete exhibiting alkali-silica reactivity". *CANMET/ACI International Workshop on Alkali-Aggregate Reaction in Concrete*, Halifax, Nova Scotia, 19 pp.
[11] Bérubé, M-A., Chouinard, D., Pigeon, M., Frenette, J., Boisvert, L., & Rivest, M. (2002b). "Effectiveness of sealers in counteracting alkali–silica reaction in plain and air-entrained laboratory concretes exposed to wetting and drying, freezing and thawing, and salt water". *Canadian Journal of Civil Engineering*, 29, pp. 289-300.
[12] Crisp, T. M., Waldron. P., Wood. J. G. M. (1989). "Development of a non-destructive test to quantity damage in deteriorated concrete". *Magazine of Concrete Research*, 45, 165.
[13] Sanchez, L. (2014). "Contribution to the assessment of damage in aging concrete infrastructures affected by alkali-aggregate reaction". Doctoral Thesis, Université Laval, Quebec, Canada, 401 pp.

TABLE 1: Strain rate results strain in the travel direction (percent per year).

Strain Rate (%/Year)	Enviroseal	Baracade	Sikagard	Control
1	-0.0012	-0.0006	0.0020	0.0067
2	0.0037	0.0040	0.0060	0.0008
3	0.0023	0.0031	0.0040	0.0043
Ave	0.0016	0.0021	0.0040	0.0039

TABLE 2: Strain rate results strain in the transverse direction (percent per year).

Strain Rate (%/Year)	Enviroseal	Baracade	Sikagard	Control
1	0.0059	-0.0017	0.0063	0.0047
2	0.0019	0.0034	0.0038	0.0007
3	0.0035	-0.0018	0.0093	0.0048
Ave	0.0038	-0.0001	0.0065	0.0034

TABLE 3: DRI petrographic features and weighing factors [10].

Petrographic Feature	Weighing factor
Closed crack in the coarse aggregate (CCA)	0.25
Open crack in the coarse aggregate (OCA)	2
Open crack in the coarse aggregate with reaction product (OCAG)	2
Coarse aggregate debonded (CAD)	3
Corroded aggregate particle (DAP)	2
Crack in the cement paste (CCP)	3
Crack in the cement paste with reaction product (CCPG)	3

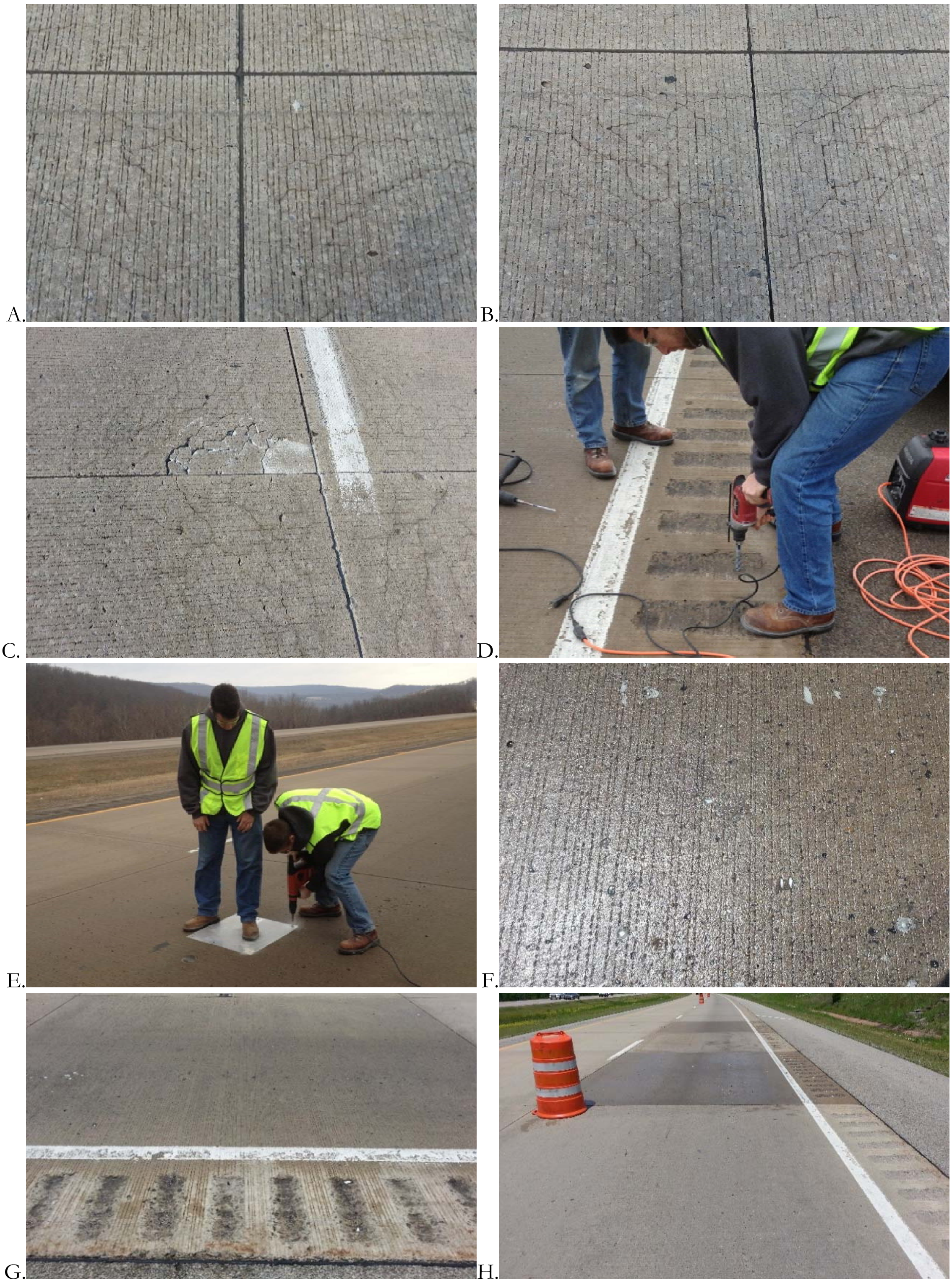


FIGURE 1: A. Interstate 49 pavements with discoloration and cracking near the joint. B. Similar discoloration and cracking at all joints along the pavement. C. The strain grid was placed near the center of the pavement panel, with pins placed at the corners of a 0.5 m grid. D. The humidity port was placed along the shoulder and capped with PVC. E. Other joints have begun to fail and show crushing, which must be patched. F. Pavement panel with gage pins installed for strain monitoring. G. Treated pavement panel before the silane is completely dry. H. Three treated pavement panels, treated with different silane treatments, dry at different rates.

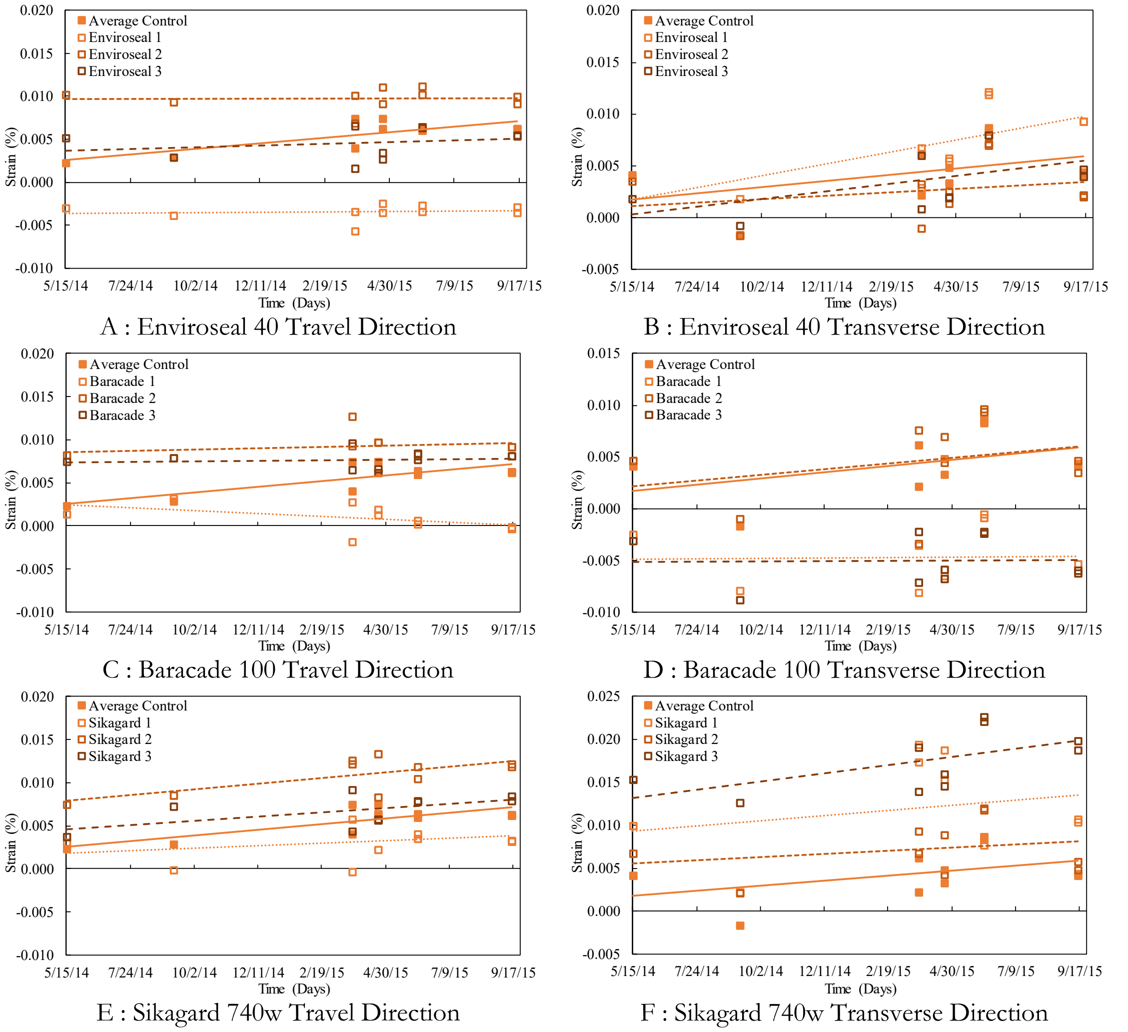
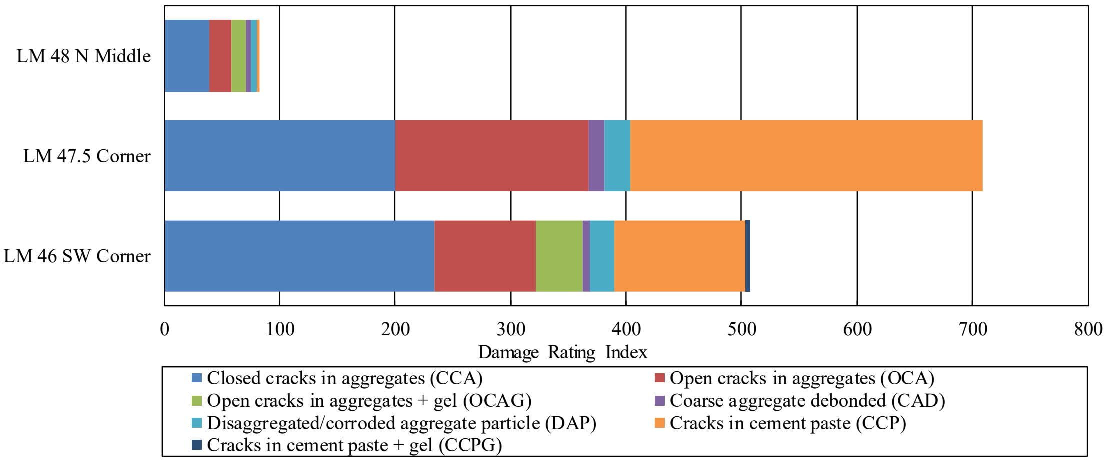


FIGURE 2: A. Travel direction strain data for Enviroseal 40 treated panels. Temperature normalized strain (%) with respect to time (days). The Average Control is the average of three control panels within the test section. B. Transverse direction strain data for Enviroseal 40 treated panels. C. Travel direction strain data for Baracade 100 treated panels. D. Transverse direction strain data for Baracade 100 treated panels. E. Travel direction strain data for Sikagard 740w treated panels. F. Transverse direction strain data for Sikagard 740w treated panels.

A : Typical surface of polished DRI sample with grid



B : DRI test results for core samples from Interstate 49 pavement

FIGURE 3: A. Polished core sample from Interstate 49 pavement, with a 1 cm square grid drawn over the surface. B. DRI test results for core samples from the Interstate 49 pavement at LM 46, 47, and 48.