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Investigation of Deterioration of Joints in Concrete Pavements: Field Study of Penetrating Sealers

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Abstract
The objective of this research was to assess the efficacy of various waterproofing sealers applied to pavement joints with respect to limiting water ingress. The measure of water ingress was the chloride concentration profile as measured by scanning electron microscopy and energy dispersive spectroscopy. The fieldwork was conducted at the MnROAD facility. Cores were retrieved from pavements to assess the before condition. Various silane- and siloxane-based sealers were applied in 2013, and the pavements were exposed to service for two years. After two years, cores were retrieved. The chloride profiles for various pavement sites were compared before and after application of the sealer. No appreciable differences were noted. The lack of measured differences is attributed to the short time span allowed for ingress. The older pavements measured had a considerable degree of chloride ingress and, as such, small changes were difficult to detect. The newer pavement analyzed also showed no appreciable change, but it would be worth re-analyzing after more time has elapsed (e.g., two more years).

Keywords
Chloride, Joint sealing, Pavement joints, Portland cement concrete, Sealing compound, Silane, chloride profile, joint deterioration, MnROAD testing, Siloxane

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The mission of the National Concrete Pavement Technology Center is to unite key transportation stakeholders around the central goal of advancing concrete pavement technology through research, tech transfer, and technology implementation.

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tech transfer summary

The use of penetrating sealers on portland cement concrete pavements may improve freeze-thaw durability by reducing the amount of water permeating the concrete.

Background and Problem Statement

Over the past 10 to 15 years, state, county, and local agencies in wet freeze-thaw environments have seen a significant increase in premature joint distress in portland cement concrete (PCC) pavements. This distress has been attributed to a number of chemical and physical mechanisms, and the evidence is strong that ingress of water and deicers at the joints is integral to the problem. Research indicates that keeping the water and deicers from penetrating the concrete at the joints will reduce or eliminate the observed joint distress.

Objective

The objective of this research was to assess the efficacy of various waterproofing sealers applied to PCC pavement joints with respect to limiting water ingress.

Research Approach/Description

The fieldwork performed for this study was conducted at the Minnesota Department of Transportation (MnDOT) MnROAD facility on I-94 40 miles northwest of Minneapolis/St. Paul, Minnesota (near Albertville). The mainline section used is located on a 3.5 mile section of westbound I-94 and comprises a number of different evaluation cells with various pavement materials and designs that were placed between 1992 and 2011.

The operating premise for this evaluation was that permeation of water can be inferred by measuring the ingress of chloride ions, which are carried by deicing chemicals in the winter months and require water for transport into the concrete. The chloride concentration profile was measured by scanning electron microscopy and energy-dispersive spectroscopy (EDS).

Cores were retrieved from pavements to assess the before condition. Six-inch cores were extracted immediately adjacent to the selected joints. All cores were extracted from the approach side of each joint, with respect to traffic. Cores were positioned so the edge of the expansion joint just intersected the perimeter of the core. Five cores were taken from different joints in each cell, with one joint to serve as the control and the other four to have different sealers applied.

Various silane- and siloxane-based sealers were applied in 2013 to study the protection of joints, and the pavements were exposed to service for two years. After two years, cores were retrieved.

Sample core retrieved in 2013 showing the relationship to Joint 105 Cell 9

Sample core retrieved in 2013 showing the relationship to Joint 4241 Cell 505 with its fabric bond-breaker

The cores were cut into 1/2 in. thick slabs, and the slabs were cut in a pattern to produce billets for chloride profiling in planes normal to (vertical) and parallel with (horizontal) the wear surface. The chloride profiles for various pavement sites were compared before and after application of the sealers.

A form of Fick's second law of diffusion incorporating a background concentration term was used to fit a curve to the measured profiles. This form of the law was used because EDS measures total chlorine signal and cement paste natively contains a small but detectable concentration of chlorine that must be accounted for.

While obtaining cores in 2015, a visual inspection of all three cells and digital-image documentation of all joints was performed.

Key Chloride Profiling Findings

All of the chloride diffusivities are the same order of magnitude, indicating no measurable difference between 2013 and 2015.

In general, the horizontal profiles from the older pavement in Cells 8 and 9 (23 years old as of the time of coring in 2015) demonstrate a noisy concentration gradient only poorly fit using Fick's second law. The uniformly lower initial concentration of chloride in the horizontal profiles compared to their vertical counterparts suggests a more diluted salt solution is present in the joint than is present on the wearing surface. This may indicate the seal system mitigates the flow of water/salt solution into the joint, even when compromised.

The chlorine concentration gradients in the vertical direction in the 23 year old pavement are generally nicely fit by Fick's second law, with inflection points uniformly occurring at a depth of approximately 50 mm.

Both the horizontal and vertical profiles in the four-year-old unbonded concrete overlay in Cell 505 are nicely fit by Fick's second law. Inflection occurs in both the vertical and horizontal directions at a distance of approximately 20 mm from the exposed surfaces. These profiles are predictably steep and uniformly have higher initial concentrations than those found in the pavement in Cells 8 and 9.

In contrast to the 23 year old pavement, the initial concentration in the horizontal direction of Cell 505 is the same as that found in the vertical direction, suggesting the dilution evident in the older pavements does not take place in Cell 505. The joints in Cell 505 were not sealed with silicone or hot pour asphalt, and the concrete overlay was placed over a separation fabric. The lack of sealing permits free entry of salt solution and debris from the wear surface into the joint.

The low diffusivities mean that very little change in the concentration profile has taken place even over the two years separating the collection of cores evaluated in this study, regardless of the age of the pavements or whether sealer was applied.

The younger concrete overlay in Cell 505 should be more sensitive to changes in diffusivity given the greater driving force resulting from a higher concentration gradient, but no clear difference is apparent in the profiles. Further exacerbating analysis of the data is the small sample population. The apparent variations are likely stochastic.

Conclusions

- The older pavements measured had a considerable degree of chloride ingress and therefore small changes were difficult to detect.
- The method employed for generating chlorine profiles appears to be effective. The premise that determining chloride diffusivity as a proxy for measuring water permeation is theoretically sound, even though the results from this limited study are inconclusive.
- Because there is no clearly apparent difference in the chlorine concentration profiles between 2013 and 2015, it is not possible to determine with any certainty the performance of the various waterproofing sealers applied for this study. This is as much due to the short timeframe of the study as to any other reason.
- The difference in initial concentration between the vertical and horizontal profiles of the 23 year old pavements may indicate that silicone joint seals mitigate the joints' exposure to water from the wear surface. This is especially apparent considering that the horizontal and vertical profiles from the four-year-old concrete overlay, which had no joint seals, showed no difference in initial concentration. Therefore, the results suggest that joint seals are effective at limiting water ingress into the concrete.

Sample core retrieved in 2013 showing the relationship to Joint 105 Cell 9

Implementation Benefits

The use of penetrating sealers on PCC pavements may improve freeze-thaw durability by reducing the amount of water permeating the concrete. This may be particularly beneficial in concrete immediately adjacent to joints, where two perpendicular surfaces permit water to enter simultaneously and where freeze-thaw distress tends to be concentrated.

Implementation Readiness/Future Research

- Given the limited time and scope of this project, the results should not be seen as absolutely conclusive with respect to the performance of penetrating sealers. The newer pavement analyzed showed no appreciable change, but it would be worth re-analyzing after more time has elapsed.
- Given the significant level of chloride ingress observed in Cells 8 and 9, further measurements of chloride ingress would likely not yield any conclusive results. However, extraction of cores from Cell 505 in 2017, after another two seasons' of exposure, may provide data indicating a trend.
- Future research should focus on developing the means to directly measure water ingress by some means other than chloride ingress. Ideally, the moisture content at any time could be determined in situ, using a non-destructive test, allowing for continual monitoring of moisture content. Such measurements could provide a rapid way to monitor sealer or sealant efficacy.

Sample core retrieved in 2013 showing the relationship to Joint 4241 Cell 505 with its fabric bond-breaker