Evaluation of Penetrating Sealers for Concrete

tech transfer summary

June 2022

RESEARCH PROJECT TITLE
Evaluation of Penetrating Sealers for Concrete

SPONSORS
Iowa Highway Research Board
(IHRB Project TR-765)
Iowa Department of Transportation
(InTrans Project 18-682)

PRINCIPAL INVESTIGATOR
Peter Taylor, Director
National Concrete Pavement Technology Center, Iowa State University
515-294-9333 / ptaylor@iastate.edu
(orcid.org/0000-0002-4030-1727)

CO-PRINCIPAL INVESTIGATOR
Kejin Wang, Professor
Civil, Construction, and Environmental Engineering, Iowa State University
(orcid.org/0000-0002-7466-3451)

LEAD RESEARCHERS
John T. Kevern
(orcid.org/0000-0003-0038-4107)
Goran Adil
(orcid.org/0000-0003-4515-2991)
University of Missouri-Kansas City

MORE INFORMATION
cptechcenter.org

CP Tech Center
Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-5798

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

IOWA STATE UNIVERSITY
Institute for Transportation

The results of this research include a suite of test methods that are recommended for assessing sealant products to mitigate likely concrete durability distress mechanisms.

Project Goal

Although penetrating sealers show great promise for improving joint and concrete durability, significant questions must be answered before departments of transportation (DOTs) and other concrete pavement owners can be assured of a positive cost-benefit. This research was undertaken to help address the need to establish a suite of performance criteria to define acceptability of a given concrete sealer product and a protocol for agencies to use in evaluating a product.

Problem Statement

Numerous products exist in the sealer marketplace with a range of performance claims. While sealers can be categorized based on their chemical structure, functional type, amount of active chemical, the carrier solution, and the action mechanism, they vary widely in performance. In addition, the parameters to define satisfactory performance are not agreed upon.

Research Objectives

- Evaluate recommended protocols and standards for testing the penetrating sealers with a focus on characteristics affecting the joints subjected to chemical attacks and freeze-thaw (F-T) actions
- Select, modify, or update the most appropriate testing protocols to reflect the performance of penetrating sealers
- Examine the selected sealer performance in the laboratory and extend the findings to field implementation projects in urban and/or rural areas where joint performance can be monitored long term
- Develop guidelines and protocols for investigating the short- and long-term performance of the sealers used to enhance joint durability

Phase 3 sealer application on SE 8th Street in Ankeny, Iowa, for longer term field evaluation

Background

The main factors negatively impacting concrete joint durability in Iowa are governed by moisture saturation and deleterious chloride ion reactions from de-icing salts. Penetrating sealers are a class of materials that show promise for increasing concrete durability by reducing moisture and chloride ion penetration. More specifically, extending the time to critical saturation reduces F-T exposure conditions, and limiting chloride ingress reduces the potential for oxychloride formation.

Concrete sealers can be divided into three main categories based on their mechanism of action as follows:

- **Water repellents:** Penetrate into the concrete pores and coat the pore walls, rendering them hydrophobic. In turn, water and any ions it contains cannot penetrate the pores but gases and vapors can.
- **Pore blockers:** Have a viscosity sufficiently low to allow penetration into the concrete pores, sealing them while leaving little or no measurable coating on the exterior surface of the concrete.
- **Barrier coatings:** Too viscous to penetrate inside the concrete pores but form a thick barrier layer on the surface that blocks the pores. Due to the potential effects on pavement skid resistance and the fact that these easily wear off under traffic, barrier coatings were not considered within the scope of this research.

Research Description

The work for this project was undertaken in the following three phases after the literature review was completed:

- Effect of sealers on concrete durability (a wide suite of tests was conducted on a single concrete mixture treated with a range of different products)
- Effect of sealers with different modes of action on the durability of concrete susceptible to selected durability distresses
- Field applications

The Literature Review that the researchers conducted at the beginning of this project helped define the basis of this investigation. That review has been published as a standalone document on the research project page here: **https://cptechcenter.org/research/in-progress/evaluation-of-penetrating-sealers-for-concrete/**.

Phase 1: Effect of Sealers on Concrete Durability

The objective of Phase 1 was to investigate the effects of different sealer types as post-construction treatments applied to the vertically sawn faces of highway concrete specimens to mimic real practices in the field. Performance and durability were assessed via laboratory test procedures to investigate enhancing extra protection against cold, harsh weather conditions. A suite of tests was conducted to identify which tests provided information about the efficacy of the products being tested.

Phase 2: Effect of Sealers on Concretes with Different Failure Modes

To evaluate the effect of sealers on the performance of non-durable concrete, the objective of Phase 2 was to conduct a laboratory investigation on specimens made using three different concrete mixtures. Each concrete was designed to include susceptibility to durability issues, as follows:

- **Marginal air-void system**: An otherwise durable mixture with a Super Air Meter (SAM) number higher than 0.45
- **Oxychloride susceptible:** An otherwise durable mixture that contained a paste susceptible to CaOXY formation
- **D-cracking susceptible:** An otherwise durable mixture made with known poor-quality aggregate

Phase 3: Field Evaluation

To complement the laboratory investigations carried out in Phases 1 and 2, sealers were applied to concrete pavement joints at three sites in late summer and fall 2021 for the purpose of long-term field evaluation. The sodium tartrate, potassium methyl siliconate (SoTa) and reactive alkyltrialkoxysilane (40% silane) sealers were selected for use in the field investigation. Sites included newly-constructed pavements in rural and urban areas, as well as an existing urban pavement that was undergoing rehabilitation due to joint deterioration.

Given that these field applications were completed only shortly before the end of this study, no testing has been performed on these sections to date. However, each site will be monitored to evaluate the long-term performance of the joints in the sealed areas. Cores will also be extracted over both sealed and unsealed joints from these sites to provide samples for follow-up laboratory testing using the same methods as Phases 1 and 2.

Key Findings

The evidence is clear that sealers can help improve the longevity of concrete surfaces and that they can, to an extent, compensate for mixtures at risk for premature deterioration.

Key findings from the Phase 1 and Phase 2 laboratory tests are included in the final report for this project. The findings include details about what the research results indicated about the effectiveness of each of the tests conducted, which will also be useful to practitioners.

Study Recommendations

A limited family of chemical sealer families are available, as detailed in the final report for this project along with details on the sealants used in this research. The various types of sealers act in different ways on the concrete mixtures. The information in Table 1 ties the action of the type of sealer product to the performance needed.

The test methods listed in Table 2 are recommended for assessing products as a function of the likely distress mechanisms, as indicated.

Implementation Readiness and Benefits

Guidance was developed on how the action of the sealant should be tied to the potential failure mechanism and on which tests should be conducted on new products to ensure that they meet the needs. This guidance can be used by agencies when reviewing the products available to them for a range of applications.

Again, detailed findings from the Phase 1 and Phase 2 laboratory tests are included in the final report for this project. And, the findings include details about what the research results indicated about the effectiveness of each of the tests conducted, which will also be useful to practitioners.

Significance of Ongoing Phase 3 Field Evaluation

Relatively little work has been reported on the efficacy of sealants to reduce joint deterioration directly, with most laboratory tests aiming to measure their influence on the following:

- Ion penetration
- Fluid permeability
- Water sorption
- Surface abrasion and skid resistance
- F-T resistance
- Microstructural phase changes

However, penetrating sealers evaluated in the laboratory are usually tested under accelerated conditions, while the efficacy of sealers applied in the field is only expected to yield results after several years. To validate any testing protocol, the field investigation program is also needed to compare the results observed in the field to those from the accelerated laboratory program.

Ultimately, the field evaluation (Phase 3 research) should provide further insights into the performance of these sealers by characterizing the performance of the sealed joints over time compared to each other, compared to the unsealed control joints, and compared to the results of the laboratory testing.

Table 1. Sealer family/application for different distress mechanisms

	Marginal air-void system	Oxychloride susceptible	D-cracking susceptible	Permeable
Densifier	✓	✓		✓
Pore liner, hydrophobic	✓	✓	✓	✓
Pore blocker, hydrophobic	✓	✓		✓
Barrier coating	✓	✓		✓

Table 2. Recommended test methods

	Marginal air-void system	Oxychloride susceptible	D-cracking susceptible	Permeable
Absorption capacity	✓	✓	✓	✓
Wettability	✓	✓	✓	✓
Desorption			✓	
LT-DSC		✓		

LT-DSC = low temperature differential scanning calorimetry