Understanding Penetrating Sealers for Concrete Pavements

Better Concrete Conference
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IOWA STATE UNIVERSITY
Institute for Transportation

National Concrete Pavement Technology Center
Tech Center

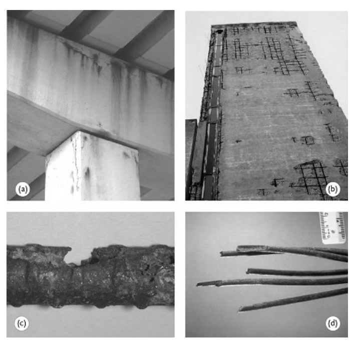
For More Information

- Xiao, D., Kevern, J.T., Wang, H., Owusu-Ababio, S., and Shi, X. "**Evaluating the Impact of Anti-Icing Solutions on Concrete Durability**," Wisconsin Highway Research Program, 10/1/20-9/30/22.
- Taylor, P. and Kevern, J.T. "**Evaluation of Penetrating Sealers for Concrete**," Iowa Highway Research Board, 01/01/19-12/31/21.
- Taylor, P., Wang, K., and Kevern, J.T. "**NCHRP 18-17 Entraining Air Void System for Durable Highway Concrete**," Transportation Research Board, 1/1/2017-03/31/19.
- Xiao, D., Kevern, J.T., Owusu-Ababio, and Schmitt, R. "**Evaluation of Penetrating Sealers Applied to Saw Cut Faces in Concrete Pavement Joints**," Wisconsin Highway Research Program, 10/01/17 - 3/31/20.
- Crovetti, J. and Kevern, J.T. "**Joint Sawing Practices and Effects on Durability**," Wisconsin Highway Research Program, 11/1/2015 - 3/31/18.

*** No company paid for any product names intentionally or unintentionally mentioned in this presentation

Concrete Deterioration

- Saturation
- Chlorides



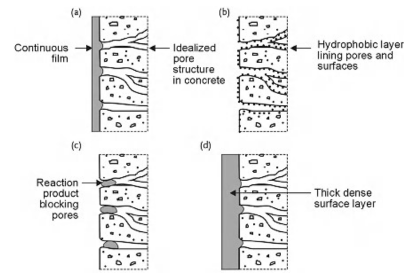
Deicing salt usage

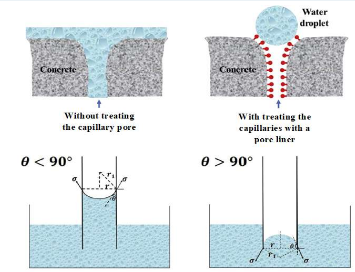
Making Durable Concrete -- First

- Proper drainage → Prevent moisture from remaining in contact with the concrete.
- Reduce permeability of the concrete.
  - Low w/cm ratio
  - Use of supplementary cementitious materials (SCMs)
  - Well graded aggregates
  - Curing
  - Penetrating sealer
- Adequate air-void system → reduce F/T damage
- Best practice of sawing and sealing joints.

Reference: Taylor, et al., *Guide for Optimum Joint Performance of Concrete Pavements*, National Concrete Pavement Technology Center, 2012

Penetrating Sealers





Liu and Hansen 2016

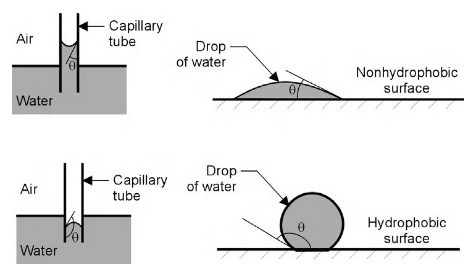
Schematic representation of the different types of surface treatment of concrete:
(a) organic coating, (b) pore-lining treatments,
(c) pore-blocking treatments,
(d) thick cementitious coating, shotcrete or rendering

Common Penetrating Sealers

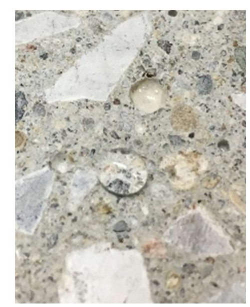
Sealer Type	Common Name(s)	Mechanism of action	Description
Continuous Film	Acylics and Vinyls	Physical barrier [ii]	Polymers or copolymers of acrylic acid
	Epoxies	Physical barrier [i]	Thermoset polymers
	Urethanes and Polyesters	Physical barrier [iii]	Reactive resins; Synthetic resins
Pore Blocking	Linseed or soybean oil	Physical barrier; water repellent	Vegetable oils
	Stearates	Physical barrier; water repellent	Soaps or metallic salts from fatty acids
	Sodium Tartrate; silica gel	Physical barrier	Absorptive crystalline structures
Pore Refining	Sodium/lithium silicate; colloidal silica	Pore size reduction	Silicon based with no organofunctional group
Pore Lining	Silane, Siloxane, XX Siliconates	Water repellent	Silicon based with organofunctional group(s)

[i] Acting as pore blocker when less than 50% active ingredient
[ii] Pore blocking if low concentration, barrier coating if high concentration
[iii] Pore blocking if diluted and barrier coat if not diluted

Hydrophobic Treatments



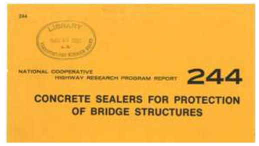
Interaction between water and a nonhydrophobic or hydrophobic material; illustrated for a capillary (left) and a concrete surface (right).



Water repellent sealer

So What?

- So someone walks in your door selling magic juice, how do I?
  - Know if it's real?
  - If it's there
  - If it's still working
  - How can I quantify with mortal testing?


NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT 244
CONCRETE SEALERS FOR PROTECTION OF BRIDGE STRUCTURES

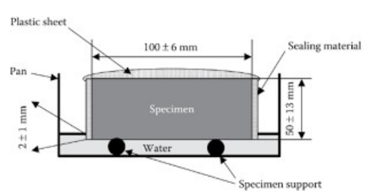
Wait, What? NCHRP 244 isn't a test standard or specification?

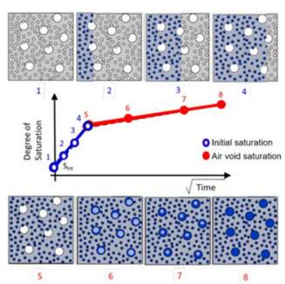
So What Do We Want?

- Reduce water movement in
  - To maintain a lower degree of saturation
- Reduce chloride movement in
  - To extend time to critical chloride threshold
- Not impede water movement out
  - To not cause unintended FT issues
- Not degrade quickly
  - To minimize vulnerable window/reapplications

Step 1) Let's look at water in

- Absorption capacity /degree of saturation (ASTM C 1585, formation factor)





FHWA air entrainment tech brief, HIF-17-009

Basic Results

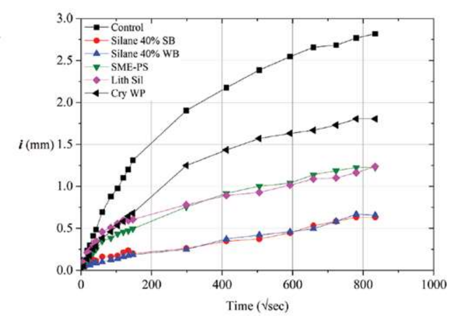


Fig. 2—Absorption results for initial penetrating sealer products for full-coverage application.

- **Adil., G., Kevern, J.T., and Xiao, D. "The Influence of Penetrating Sealers on the Performance of Concrete Joints," ACI Materials Journal, V. 118, No. 5, September 2021, 10 pgs.**

Results cont. (Control = 2.8mm)

Absorption Day 8 Results: SME-PS

sq. ft. / gal	"Hurry"	"Regular"	"Double"
100	.89 mm	.98 mm	.53 mm
200	.89 mm	1.22 mm	.47 mm
400	1.27 mm	1.15 mm	.74 mm

Absorption Day 8 Results: Silane, water-based

sq. ft. / gal	"Hurry"	"Regular"	"Double"
100	.42 mm	.58 mm	.19 mm
200	.48 mm	.98 mm	.31 mm
400	.64 mm	1.32 mm	.36 mm

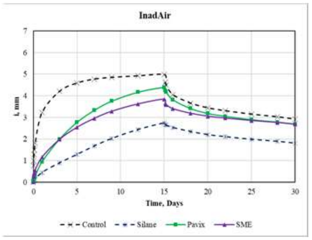
Absorption Day 8 Results: Raw LiSi

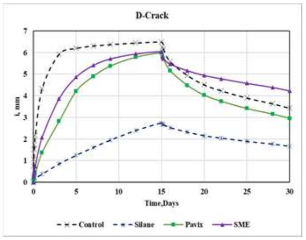
sq. ft. / gal	"Hurry"	"Regular"	"Double"
100	1.57 mm	1.40 mm	1.17 mm
200	1.36 mm	1.24 mm	1.24 mm
400	1.53 mm	1.32 mm	.91 mm

Absorption Day 8 Results: Silane, solvent-based

sq. ft. / gal	"Hurry"	"Regular"	"Double"
100	.41 mm	.30 mm	.12 mm
200	.51 mm	.64 mm	.19 mm
400	.49 mm	.41 mm	.28 mm

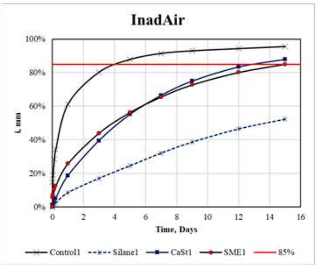
Step 1.5) Absorption/Desorption

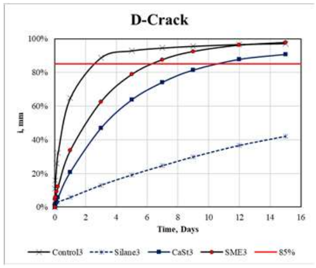




- Pore size/distribution matters, you can prevent drying

Degree of Saturation





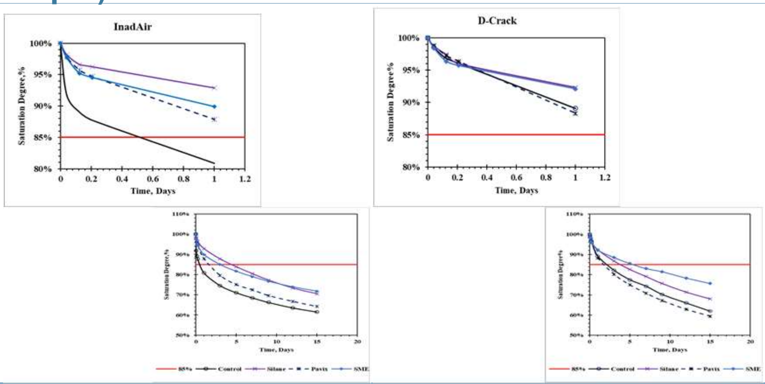
- Significant increases to time to critical saturation

Concrete and Critical Saturation

Treatment	Final Degree of Saturation	Days to 85% Saturation	Lifespan Increase (x)
Untreated Control	100%	28	NA
40% silane applied after 7 days	62%	221	6.9
40% silane applied 30 min. after sawing	69%	210	6.5
10% Siloxane mixture applied after 7 days	89%	62	1.2
7% Siloxane mixture applied after 7 days	86%	84	2.0
SME-PS applied after 7 days	63%	279	9.0
Lithium Silicate mixture applied 30 min. after sawing	100%	10	-0.6
PAM applied 30 min. after sawing	100%	19	-0.3

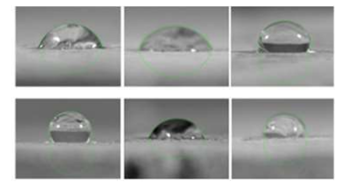
- While water in is only one piece, measurement is low cost and a good indicator of concrete performance

Step 2) Desaturation



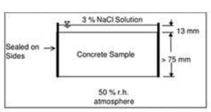
Step 3) Contact Angle

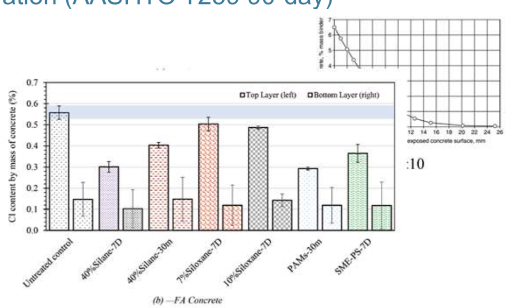
Treatment	θ°	CV	Classification
Control	NA	NA	Hydrophilic
LS	76	13%	Hydrophobic
SC	74	19%	Hydrophobic
40% silane	105	6%	Over-hydrophobic
CaSt	120	15%	Over-hydrophobic
Acrylic	83	9%	Hydrophobic
SME	100	10%	Over-hydrophobic



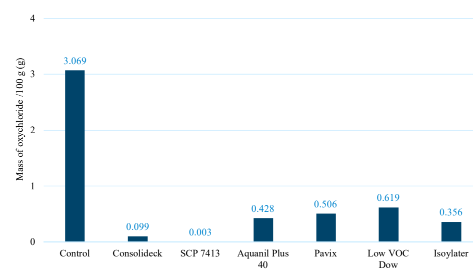
Step 4) Chloride Penetration

- Chloride penetration (AASHTO T259 90-day)





Last Interesting Parting Thought



$$M_{CaOXY} = \frac{\Delta H}{L_{CaOXY}} \times 100$$

where: M_{CaOXY} is the mass in g of CaOXY per 100 g of cementitious paste, g/100g; ΔH is the latent heat absorbed during CaOXY phase transition, J/g; and L_{CaOXY} is the specific latent heat associated with pure CaOXY phase transition, 186 J/g.

Conclusions, Thoughts, and Recommendations

- A wide variety of chemicals and products exist which fall into the category of penetrating sealers.
- They DO NOT function along the same pathways, some are good early, some late, some good for deteriorated concrete, some terrible for certain concrete….meeting NCHRP 244 does NOT mean anything and real tests exist
- Absorption/Desorption; Desaturation; contact angle; chloride penetration should be the minimum…
- Corrosion initiation, scaling, 1D Freeze-thaw, and oxychloride could also be beneficial

Conclusions, Thoughts, and Recommendations

- The body of research strongly supports the use of penetrating sealers to improve deicer salt scaling and reduce chloride penetration on horizontal surfaces
- The value proposition, technology, and test methods are here
- However, penetrating sealers are not a panacea for bad concrete, make good concrete first, then make good concrete even better

Questions?

MnROAD sealer and anti-icer testing install 11/1 by UWP

About the Presenter

John T. Kevern, PhD, PE, FACI, LEED AP, Chair of the Department of Civil & Mechanical Engineering at the University of Missouri-Kansas City. He is an internationally recognized expert on pervious concrete, concrete durability, and non-traditional concrete applications. Dr. Kevern has been named one of the top five most influential people in the concrete industry by concrete construction magazine. He chairs AKM50 Advanced Concrete Materials and Characterization committee at the National Transportation Research Board.

John received his BS from the University of Wisconsin-Platteville and his MS and PhD degrees from Iowa State University.

Some of his current research topics include improving water quality using cement-based filters, improving concrete lifespan using hydrophobic coatings, internal curing concrete, techniques to reduce cost and improve performance of soil structures in sub-Saharan Africa, and eliminating joints in concrete pavements.