Surface Sealers: Concrete Pavement Applications

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*Special Thanks to Xuhao Wang*
Surface Sealers

• Joint performance today
• The role of sealers
• Lab studies and field trials
Surface Sealers

JOINT PERFORMANCE TODAY
Moisture

• The issue revolves around moisture entering, and lingering in, the concrete matrix at the joints and random cracks
Distress

- Two causes of distress resulting from moisture penetration
  - Saturation of concrete that leads to freeze/thaw deterioration
  - Chemical reaction of certain de-icing chemicals with products of cement hydration
Freeze/Thaw Deterioration

- Saturation above 85%
  - Concrete will perform through decreasing number of freeze/thaw cycles
    - Regardless of having specified air content

- De-icing chemicals draw moisture to the joint
  - Moisture drains from the pavement surface

- Design plays an important role
  - Allow the joint to dry out!
Saturation

• Dr. Jason Weiss
  – Now at Oregon State University

• At 100% saturation
  – Air voids are full!
  – Moisture has no room for expansion

• >85% saturation
  – Diminishing ability to withstand F/T
Chemical De-icers & Saturation

• Dr. Jason Weiss
• Some de-icers pull moisture from the air
  – Causing greater saturation of the matrix
  • Especially around joints and cracks

Drying of Concrete With Salt Solutions

• One-sided condition, 50 +/- 2% RH, 23 +/- 1°C
• Lower or no water loss or gain with higher salt concentrations
• Drying behavior explained by differences in solution and environmental RH

Spragg et al 2010

Tech Center
Design for Drying of Joints

- Design the joints to allow some period of drying to occur
  - No backer rod
    - Fill all joints with hot pour sealant
    - Do not fill joints
      - Must then design the entire pavement system to drain
- Consider drainage beneath the slab
  - In either of the case
Oxychloride Formation

- Calcium Hydroxide (CH) is a product of the cement hydration process
  - The less important of the two products
- CH can react with de-icers to form Oxychloride
  - Magnesium Chloride
  - Calcium Chloride
Oxychloride Expansion

- Oxychloride formation is accompanied by 30%
  - Expansion of the oxychloride
  - At temps above freezing
- Water expands by 9%
  - When freezing
- Worst joint deterioration is a result of both
How Do We Limit Oxychloride Formation?

- Limit the amount of CH exposed
  - Moisture transports the MgCl2 & CaCl2
    - Minimize permeability
  - SCMs react with CH
    - Tie up the CH
    - Create more CSH

- Cement hydration produces CH and CSH
  - Causes Stuff to Harden
Prevention is the Best Solution

- Design and build pavement >5% air behind the paver
- Design and build pavement with a system that allows drying of the joints
  - Drainage
  - No backer rod
- Design and build with less permeable concrete
  - Low w/c ratio (<0.42)
  - Use of SCMs for less permeability
- Design and build for less oxychloride formation
  - Use SCMs to tie up Calcium Hydroxide (CH)
Nothing Wrong Here!
What if?

• Existing concrete is showing issues…
• Greater protection of new concrete is desired…
Surface Sealers

THE ROLE OF SEALERS
Decreasing Permeability

- Minimize the transport of chlorides to proximity of the CH
  - Less internal expansion due to oxychloride formation
  - Keep the two apart

- Minimize the transport of moisture into the concrete matrix
  - Less internal expansion due to freezing of moisture
  - Keep the water out
Decreasing Permeability

Remove the bad actors

Let it freeze outside
Jerod’s Driveway
Surface Sealers

LAB STUDIES & FIELD TRIALS
Are Sealers the Answer?

• Is moisture penetrating the pore structure within the joint after applying a surface sealer?
• Is moisture prevented from freezing within the pore structure?
• Are the “bad actors” kept out?
• Is the deterioration stopped, slowed, or altered in any way?

How can we tell?
Challenges

• Joint deterioration is a slow process
  – About ten years in the field
• Freeze/thaw deterioration is not typically tested on the faces of joints
• Testing for oxychloride formation is a relatively new process
• Much of the moisture entering a slab is from the bottom
Challenges

• Costs are very difficult to estimate
  – The adequate application rates are difficult to know for each product

• Frequency of application is difficult to know
  – Accelerated testing or long-term field trials would need to be done to develop for each product

• An application process did not exist for each product for this particular issue
  – One product supplier actually developed equipment specific to this application
Tests and Trials

- Conducted specifically for this issue
  - Iowa Field Trials
    - Photo log
      - Attempting to monitor visible deterioration
    - Drop test
      - Attempting to measure moisture penetration
  - Paste Expansion Test (ISU)
    - Attempting to measure expansion due to oxychloride formation
Types of Penetrating Sealers

• Linseed oil
  – Decades of use in Iowa on pavements & bridges

• Silane/siloxane based sealers
  – Very widely used outside of the pavement world

• Soy-methyl Esters
  – Soy bean oil

• Lithium or Sodium Silicate
  – Densifiers

• Crystalline
  – Both hydrophylic and hygroscopic
Iowa Program

• Funded by ICPA

• 4 Sites
  – Site 1: Des Moines (Siloxane)
  – Site 2: Davenport (Crystalline)
  – Site 3: West Des Moines (a) (Crystalline)
  – Site 4: West Des Moines (b) (Silane-Siloxane)

Credit: Xuhao Wang, National CP Tech Center
Iowa Program

- Approach
  - Pre-application evaluation
  - Application by the manufacturer
  - Re-evaluation periodically

- Detailed Photo-log

- Extract cores – two over good joints, two over bad joints, two off joints
  - Drop-absorption test on sawn face and on top surface
Evaluation

- Test
  - Drop test (ISU) - assess the quality of paste in an exposed surface at a local scale of less than 0.5 in²
Evaluation

- Drop test calibration (56 days)
Proposed Field Investigation

View A
- Saw cut
- Applied sealers
- Air-void system analysis and petrographic examination

View B
- Saw cut face
- Crack face
- Location of drop test

Joint cores
- Mid-span cores

Tests:
- Surface resistivity test
- Paste expansion test
- Water absorption
- Paste expansion test

Credit: Xuhao Wang, National CP Tech Center
Iowa Program – Off Joint

• Drop-absorption test

Credit: Xuhao Wang, National CP Tech Center
Iowa Program – On Joint

- Drop-absorption test
Iowa Program

- Site 3 photo-log (control)

Initial Year (2014)  Second Year (2016)
Iowa Program

- Site 3 photo-log (test)

Initial Year (2014)

Second Year (2016)
Sealer Evaluation

• Test
  – Chemical reaction assessment
    • Paste expansion test (ISU) – assess the ability to resist oxychloride formation
      – Topically treated slices
      – Immerse in 4%, 20% MgCl₂ and CaCl₂ solution at 40°F for 8 weeks

Credit: Xuhao Wang, National CP Tech Center
4% MgCl₂ @ 40°F for 28 days

20% CaCl₂ @ 40°F for 28 days

Credit: Xuhao Wang, National CP Tech Center
Sealer Evaluation

- **Paste Expansion**
  - 4% MgCl₂ – paste expansion with a thin film formed
  
  For comparison to control
  
  ONLY
  
  (inhibit oxychloride formation)
Answers

• Drop test indicates less permeability
• Paste expansion test (ISU) indicates less expansion
Questions?