Evaluation of Penetrating Sealers Applied to Saw Cut Faces in Concrete Pavement Joints

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Outline

- Mechanisms of failure
- Solutions
- Do they work?
Outline

- Mechanisms of Failure
  - **Saturated** Freezing and Thawing
    - Commonly associated with marginal air system
  - Chemical Attack
    - De-icing salts result in oxychloride formation
- Combined
Saturation of the Paste

- Water is trapped
- Air may be marginal
- Paste gets saturated
- Flakes formed (near surface)
Effect of salts

• Typical deicing salts
  ➢ NaCl-based – fewer worries
  ➢ MgCl<sub>2</sub>-based – the most complicated
  ➢ CaCl<sub>2</sub>-based – relatively simple, the worst
  ➢ Others: calcium magnesium acetate, potassium acetate

• Some salts prevent drying
Mechanism of Deterioration

- **MgCl$_2$ (10 to 28% by mass; ~10°C)**
  - Primary deleterious phases: Calcium or Magnesium oxychloride
  - Other phases: brucite, gypsum, M-S-H, Friedel’s salt

- **CaCl$_2$ (10 to 28% by mass; 38°C)**
  - Primary deleterious phase: Calcium oxychloride
  - Other phases: Friedel’s salt
Chemical attack

- Calcium/Magnesium oxychloride
  - Calcium hydroxide (CH) from cement hydration
  - Chlorides from MgCl₂ and CaCl₂
  - 30% expansion of oxychloride itself
  - Severity: wet/dry > immersion > F/T
  - Shows as flaking or incremental cracking
Recommendations

• Drainage
  ➢ Avoid joint details with reservoirs
  ➢ Ensure the water can get away

• The mixture

• Consider penetrating sealers
The Mixture

- 5% air minimum behind the paver
- 0.42 max w/cm
- Use appropriate SCMs
  - May need 35% to control oxychloride
- Guidance in AASHTO PP 84
Sealers

• Which ones work?
• How much?
• When?
• Where?
Products Available

- Linseed oil
  - Dried seeds from flax plant
  - Effective at reducing salt water absorption and surface scaling

- Silane / siloxane
  - Lines the pores
  - Depth of penetration ~12 mm
  - Siloxananes are bigger molecules
Products

• Soy-methyl esters (SME)
  ➢ Oils extracted from soybeans
  ➢ Slows water penetration up to 95%
  ➢ Admixture or surface application
• Lithium or sodium silicate
  ➢ Densifies surface
Products

• Crystalline
  ➢ Two types of crystals and water repellency
  ➢ Hygroscopic and hydrophilic properties
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)
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 in$^2$
Evaluation

- Drop test calibration (56 days)

![Graph showing absorption time for different mixtures with categories: Good, Fair, Bad]
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

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

Joint cores
Mid-span cores
Iowa Program – Off Joint

- Drop-absorption test
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% MgCl\textsubscript{2} and CaCl\textsubscript{2} solution at 40°F for 8 weeks
4% MgCl₂ @ 40°F for 28 days

20% CaCl₂ @ 40°F for 28 days
Sealer Evaluation

- Paste Expansion
  - 4% MgCl₂ – paste expansion with a thin film formed
Sealer Evaluation

• Paste Expansion
  ➢ 20% CaCl₂ – scaling failure type
  ➢ 4% CaCl₂ – no sign of deterioration/paste expansion

Visual rating of the surface after 28, 56, 84, and 112 days of soaking @40F in accordance with the following scale:

<table>
<thead>
<tr>
<th>Rating</th>
<th>Condition of Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>no scaling</td>
</tr>
<tr>
<td>1</td>
<td>very light scaling, about 10% aggregate surround mortar scales with minor edge breaking</td>
</tr>
<tr>
<td>2</td>
<td>slight to moderate scaling, about 20% aggregate surround mortar scales with moderate edge breaking</td>
</tr>
<tr>
<td>3</td>
<td>moderate scaling, about 40% aggregate surround mortar scales and tears off, moderate edge breaking and expansion</td>
</tr>
<tr>
<td>4</td>
<td>moderate to severe scaling, about 60% aggregate surround mortar scales and tears off, severe edge breaking and expansion</td>
</tr>
</tbody>
</table>
Sealer Evaluation

- Chemical reaction assessment
  - LT-DSC – quantitatively measure oxychloride formation
    - Grind topically treated slices mix with 20% CaCl\textsubscript{2}
    - Measure the enthalpy between 25 - 45°C
    - Target: <0.15 g CaOXY/g paste (AASHTO PP84)
Sealer Evaluation

- Typical LT-DSC result

![Graph showing LT-DSC results with Enthalpy, Onset Temperature, and Eutectic/Ice Formation temperatures.](image)
Evaluation

- Test results
  - Comparison between paste expansion and LT-DSC
Closing

• Reactions are complex
• Drop test and paste expansion test appear to identify sealer performance
• Some sealers appear to be reducing the risk of expansion