Joint Distress in Portland Cement Concrete Pavements

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Background

• Significant levels of premature joint deterioration reported across northern states
  – Not all roads affected
  – Problem is significant enough to cause local agencies to reconsider portland cement concrete pavements
Wisconsin
Approach

• Research conducted at multiple universities
  – Purdue
  – Iowa State
  – Michigan Tech
Approach

• Research sponsored by
  – State DOTs
    ✓ Indiana
    ✓ Iowa (lead state)
    ✓ Michigan
    ✓ Minnesota
    ✓ New York
    ✓ South Dakota
    ✓ Wisconsin
  – Industry
    ✓ American Concrete Paving Association
    ✓ Iowa Concrete Paving Association
    ✓ Michigan Concrete Paving Association
    ✓ Wisconsin Concrete Paving Association
    ✓ Portland Cement Association
Many Suspects

- Air entraining agents
- Early entry sawing
- Curing
- Deicing practices
What Do We Know?

• Based on research to date
  – Not a single cause for the deterioration
    • Low air content
    • Compromised air-void systems
    • w/c above 0.40
    • Aggressive salt use
    • Marginal or D-cracking aggregates
  – Saturation is a key variable
Field Studies

• Sites in WI, MI, IA, & MN
  – Analysis still on-going

• Different manifestations
  – Related to type/permeability of base, sealant, & materials
Field Studies

• Sites in WI, MI, IA, & MN
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• Different manifestations
  – Related to type/permeability of base, sealant, & materials

• Top Down vs. Bottom Up vs. Inside Out…

• Commonalities
  – Entrapped water
Field Studies

• A Tale of Two Cores
  – Same slab – same joint
• Top Down vs. Bottom Up
Field Studies

• A Tale of Two Cores
  – Same slab – same joint

• Cracking parallel to the joint observed on the surface
  – Common observation

• Cracking sub-surface appears to be parallel to the deterioration front
  – F-T damage

• Results in the V-shaped top down damage
Field Studies

- A Tale of Two Cores
  - Same slab – same joint
- Also found:
- Significant chemical attack from deicers
Field Studies

• A Tale of Two Cores
  – Same slab – same joint
• Area with less distress
• Cracking emanating from the bottom up
• Core hole drained significantly slower than all other core holes on the slab
• Water trapped at the bottom but F-T?
I-275, Two Sites, Varying Performance

- Site 2 - showing deterioration at joint
- Site 4 - not exhibiting deterioration at joint
Summary

• Site 2
  – Poor air-void system
  – Alkali-silica reaction with fine aggregate particles and related **cracks extending** into hardened paste, but only within the top inch
  – Low paste density, high chloride ingress

• Site 4
  – Adequate air-void system
  – Alkali-silica reaction with fine aggregate particles, but **without cracks extending** into hardened paste
  – Higher paste density, lower chloride ingress
Pink boxes show area of automated air void analyses. Air voids visibly more abundant in bottom halves of all cores.
<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Air %</th>
<th>Paste %</th>
<th>Voids/meter</th>
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Site 2, (left) with carbonation depth of approx. 3 to 5 mm
Site 4 (right) with carbonation depth of approx. 2 to 3 mm.
Green = Cl
Red = Ca
Blue = Si
Comparison of best fit lines to Fick’s 2nd Law – chloride penetration more pronounced at Site 2 as compared to Site 4.
Field Studies

• Other Observations
  – Compromised air-void systems due to ettringite in-filling
Field Studies

• Other Observations
  – Base layer drainage

Conversion: \( k \text{ in ft/day} = k \text{ in cm/s} \times 2834.66 \)
Research on Mechanisms

• A conceptual model will be shown to relate the rate of water absorption to degree of saturation
• When concrete reaches a critical degree of saturation its freeze thaw behavior is compromised
• Salts have slower absorption; however they alter drying with a higher degree of saturation
• Sealers may be able to be used to keep out water but how do they perform in FT
Freeze-Thaw Damage and the Degree of Saturation

To Reach 88%
- 4% Conc Air – 0.4 years
- 6% Conc Air – 6 Years
- 8% Conc Air – 6 Years

Li et al. 2012
Salt Water Solutions are not the Same as Water

- Slower abs. with salt solns.
- Different phase diagram
- Different equilibrium RH
Can We Use Concrete Sealers/Pore Blockers to Reduce Saturation

- Sealers can keep out water
- FT behavior differs – new test in development

![Graph showing water absorbed and relative elastic modulus over time and cycles.](image-url)
Observations

• Absorption to saturation, then damage is instantaneous
• Proper air only delays the rate of saturation
• Salts have slower absorption & alter drying
• Recent investigations of sorption important
• Sealers appear to work but discrepancies are noticed with temperature (working hypothesis)
Conclusions

• Multiple factors are at the root of the problem
  – Materials
  – Design
  – Construction

• What worked in the past is not working now
  – Deicing practices have changed the game
  – New materials require new specifications and construction practices
Conclusions

• New maintenance practices must be examined
  – Sealants

• Marginal concrete will not survive
  – Need low permeability
  – Need good air-void systems
  – Need high quality aggregates
  – Need thoughtful deicing practices
Questions?

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