Long Life Concrete Pavement Joint Performance
Background and Mechanisms

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The problem?

• Some joints are deteriorating faster than we would like
Outline

• Mechanisms of Failure
• Why Now, What’s New?
• Current Recommendations

What Do We Know?

• Cold states
• Water
• Not all the same
Outline

• Mechanisms of Failure
  • Saturation / Freezing and Thawing
  • Chemical Attack
  • Incremental Cracking
  • Others

Saturation of the Paste
**Typical Symptoms**

- Shadowing
- Thin flakes

**The Symptoms**

- The aggregate is polished
Saturation

• Damage occurs where the concrete does not dry out

Saturation

• Bottom-Up Moisture
Saturation

• Bottom Up Moisture

Saturation

• Tunneling – water trapped in saw-cut
Saturation

- Tunneling – water trapped in saw-cut

Saturation

- Top-Down
The Symptoms

• Water again

Purdue Work

• Damage depends on degree of saturation

Relative Dynamic Modulus (N=6)

Jason Weiss
Salts increase saturation

Purdue Work

- Some salts prevent drying
An Example

- Draining base dries in rain
- Same joints stay wet with salt treatment
Purdue Work
• Saturation rate influenced by air and w/c

Outline
• Mechanisms of Failure
  • Saturation / Freezing and Thawing
  • Chemical Attack
  • Incremental Cracking
  • Others
Salts can cause chemical attack

• Calcium oxychloride is formed
  ➢ Calcium from cement
  ➢ Chlorides from salts
  ➢ Expands
  ➢ At 40°F

• Rates and amount are limited though

Salts can cause chemical attack

• Friedel’s Salt – Calcium-chloro-aluminate
  ➢ Calcium and aluminates from cement
  ➢ Chlorides from salts
  ➢ Also expands
Salts can cause chemical attack

- Ettringite Deposition
  - Calcium sulfo-aluminate
  - Indicates abundant water
  - Compromised air void system?

Other mechanisms

- D-Cracking
  - An aggregate problem
Other mechanisms

• Alkali silica reaction
  ➢ An aggregate problem
• Needs:
  ➢ Alkalis
  ➢ Water
  ➢ Reactive silica
• Makes
  ➢ Expansive gel

Outline

• Mechanisms of Failure
  • Saturation / Freezing and Thawing
  • Chemical Attack
  • Incremental Cracking
  • Others
Incremental Cracking

The Symptoms

- Not typical freezing and thawing
  - No thin flakes
Interfacial Zone

IFZ likely dissolved in salt solutions at low temperatures
Outline

- Mechanisms of Failure
  - Saturation / Freezing and Thawing
  - Chemical Attack
  - Incremental Cracking
  - Others

Other Causes

- Traffic
  - Unlikely – stress is ~50psi
  - Unless it is very early…
Other Causes

• Sawing
  ➢ Unlikely (Kevern)
  ➢ Except maybe at crossing points

Other Causes

• Early Entry Sawing
Other Causes

- Not all “shadowing” is doomed
- Sawing slurry

Other Causes

- Not all “shadowing” is doomed
- Tracks from the saw
Absorption Results

Other Causes

• Chert
Mechanisms Summary...

- Many things contribute
  - Water
  - Salts
  - Air void system
  - Chemical
  - Loading
  - Sawing

Outline

- Mechanisms of Failure
- Why Now, What’s New?
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Questions

- Why now?
  - Salting / Brines
  - Marginal air in situ
  - Changing system chemistry
  - Lack of inspection

Freeze - thaw cycles

Des Moines, IA 2005-2006

http://www.weather.gov
What’s in your salt?

• Read the labels

Questions

• Why in some joints
  • Batch variability
  • Drainage
  • Salt treatment
  • Hand placed
Ames, IA

- Non-distressed joint
  - Spacing factor: 0.007 in
  - w/cm: 0.40 to 0.45
- Distressed joint
  - Spacing factor: 0.005 in
  - w/cm: 0.42 - 0.47

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

Outline

• Mechanisms of Failure
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So...

- The game has changed
  - Water has to be prevented from saturating the concrete
  - Permeability of the concrete should be as low as practical
  - The air void system in the in-place concrete must be adequate

Consider the System

- Where does water come from?
- Where can it go?
- What about the joints?
- And the mixture?
Design

- Drainage
  - Avoid bathtubs
- Drainage
  - Make sure surface water can get away
  - Not much should get through
- Drainage
  - Where is the water table?

Seal?

- Avoid joint details with reservoirs
- Maintain them
Sealant Has To be Maintained

Debonded and Damaged  Bonded and Undamaged

Masten Moulzof

Seal?
- Avoid joint details with reservoirs
- Maintain them
**MN Road**

Unsealed Joints  
46% cracked panels

Sealed Joints  
5% cracked panels

*T. Burnham, Mn/DOT 2011*

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**Joints**

- Not too close
  - Some don’t crack
- Not too far
  - Curling and warping
- Longitudinal shallower than transverse?
The Mixture

- 5% minimum behind the paver
- 0.40 max w/cm
- Use appropriate SCMs

Why 0.4?

- Keep the water out
  - Connectivity of capillaries increases with higher w/cm
How Do SCMs Work?

Cement + Water + SCM = more C-S-H

SCMS – Lower Permeability

Sorptivity of 15% MgCl₂ into Different 0.45 w/c Concrete Mixtures
**Workmanship**

- Curing (poly-alpha-methylstyrene)
- Consider topical surface sealants
- Choose salts carefully
- Maintain drainage systems

**Inspection**

- w/c – Microwave test (AASHTO T 318)
- Air – Calibrate for losses in the machine
- Curing – VOCs, Spray rates, Color?

- Warm bodies…
Review

- Life is getting more complicated
- Checklists may not be adequate
- Think through the system
- Ensure you get what you pay for