Joint Deterioration Cause & Mitigation

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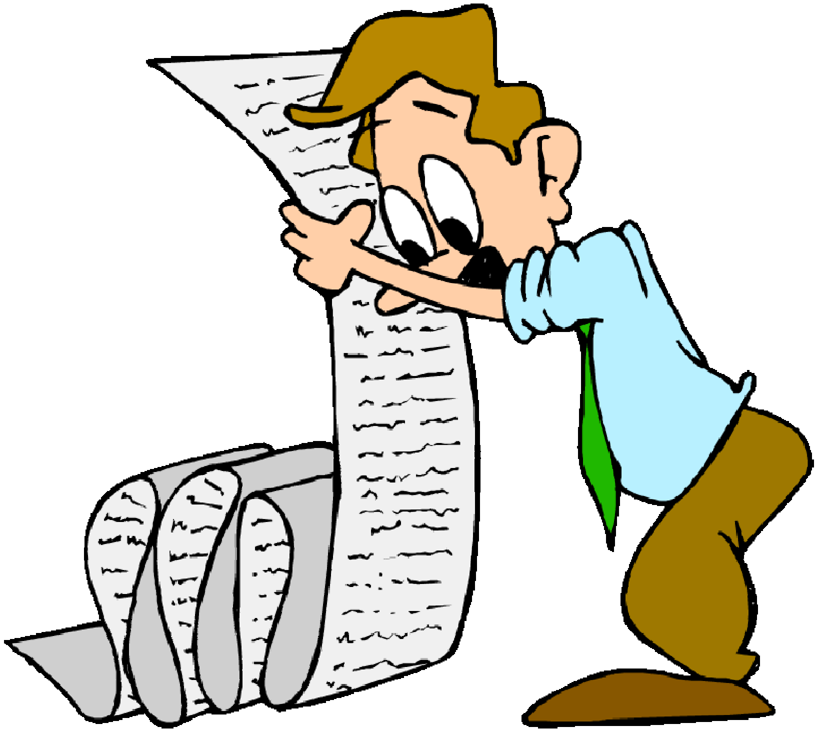
Iowa State University
Institute for Transportation

Steven L. Tritsch, P.E.
stritsch@iastate.edu

Outline

- A Little History
- Challenge
- Types and Mechanisms
- Saturated Freeze-Thaw
- Oxychloride Formation
- Sawing Practice
- Seal or Fill
- In-Short
- References



A Touch of Iowa History

Early pavements were built with gravels until the late 30's.

Original slabs were 18' wide, 20' starting in 1935, 22' in 1949, and 24' in 1971.

D-cracking was researched extensively and poor aggregate sources identified. In 1952, air entrainment was required to mitigate freeze-thaw damage.

Early 1990's saw the advent of "early joint deterioration" leading to more research into vibration, air content, saturation levels, and expansion of paste via calcium oxychloride.

Built in 1914, 18' wide, no longitudinal joint, 25' formed transverse joints

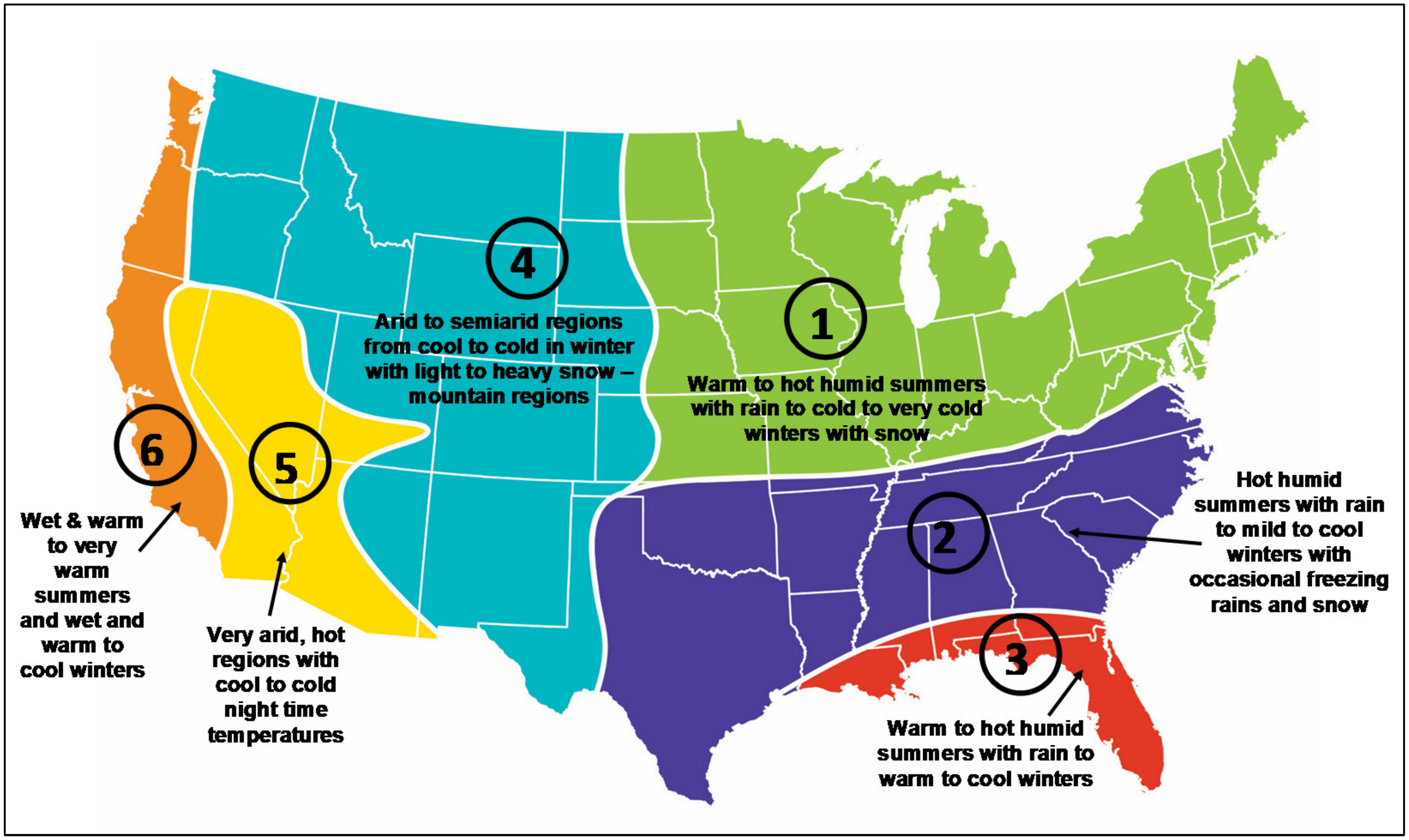
Moscow Road 2014

The Challenge

The Challenge

The Clues

Predominately in cold, wet places

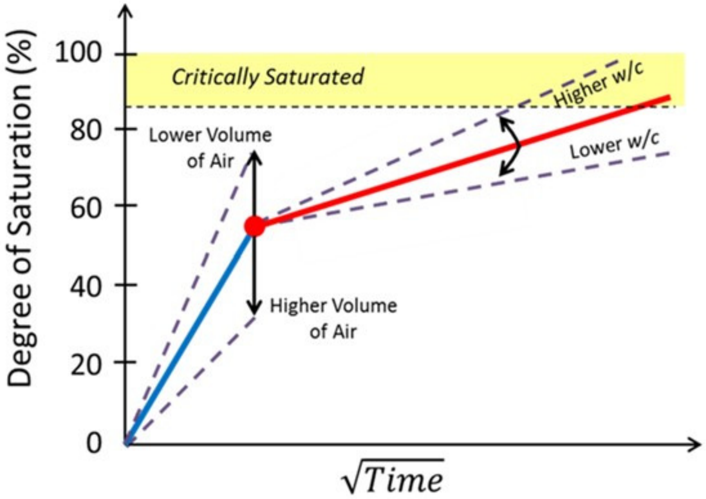


Types and Mechanisms of Joint Deterioration

Saturated Freeze-thaw Damage

- Volume of pores
  - ➢ Measure mass change from oven dry to vacuum saturated
- Degree of saturation
  - ➢ Compare mass of sample with oven dry and saturated masses
- Sorption / Saturation
  - ➢ ASTM C 1585 (modified)

Jason Weiss



Types and Mechanisms of Joint Deterioration

Calcium Oxychloride Formation, Expansion, and Damage

- Chemical Reaction

  Calcium chloride and calcium hydroxide forms calcium oxychloride – cracking due to volume change

- Mitigate
  - Use SCMs
  - Reduces calcium hydroxide
  - Use low w/c ratios to reduce fluid transport
  - Proper entrained air-void system

The Causes

Saturated freeze thaw

Oxychloride formation

Sawing practice

Saturated freeze thaw

Marginal w/cm

Marginal air

Poor local drainage

Leads to rapid saturation

Shadowing

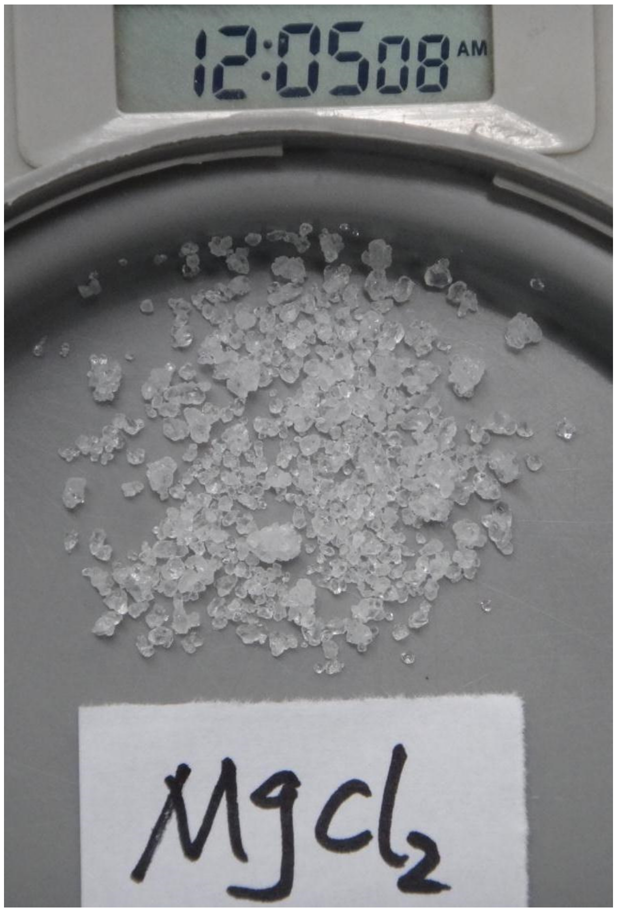
Thin flakes

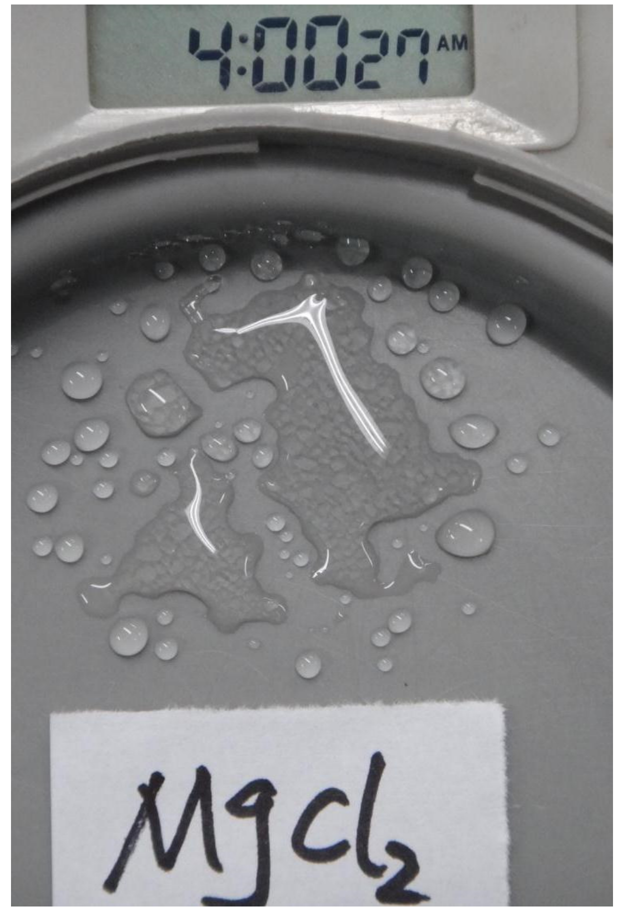
Saturation

Damage occurs where the concrete does not dry out

Water needs space to expand into

Saturation





The Causes

Saturated freeze thaw

Oxychloride formation

Sawing practice

Salts can cause chemical attack

Calcium oxychloride

- Calcium hydroxide
- Chlorides from salts ($MgCl_2$ and $CaCl_2$)
- Expands >30%
- At ~40°F

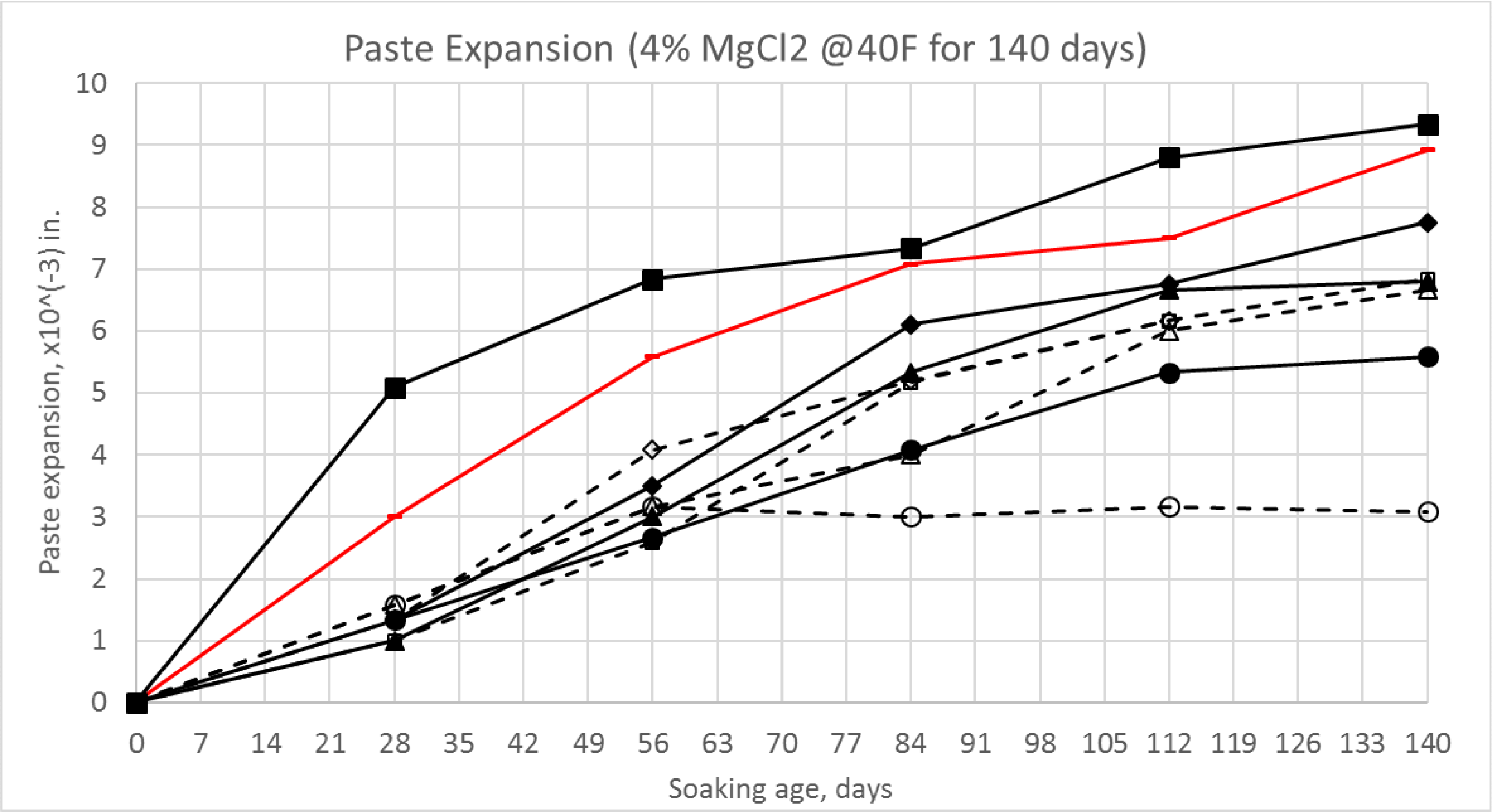
- Use SCMs to reduce CaOH

$CaCl_2$ @ 40°F

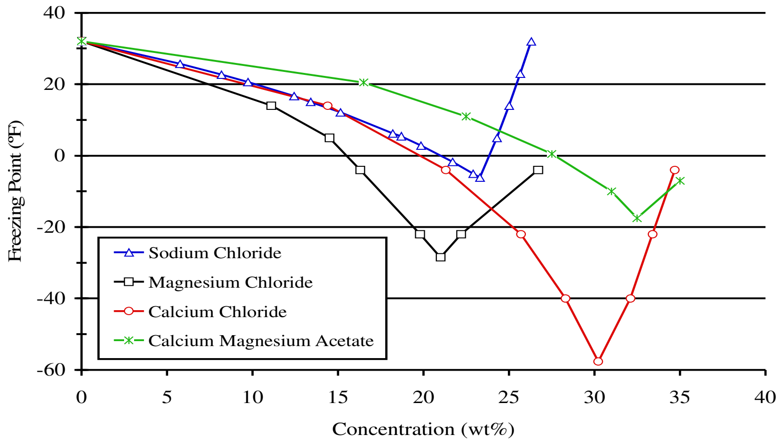
Sutter

Salts can cause chemical attack

Calcium oxychloride - Sealers can help



How Much is Enough



Salt	Concentration (wt%)	Freezing Point (F)
Sodium Chloride	23.30	-6.16°
Magnesium Chloride	21.00	-24.50°
Calcium Chloride	30.22	-57.60°
Calcium Magnesium Acetate	32.50	-17.50°

The Causes

Saturated freeze thaw

Oxychloride formation

Sawing practice

What is the common denominator

The Objective

Preventing Joint Deterioration in New Pavements

Soil, Subgrade, and Base systems

- Stabilized subgrade
- Granular subbase
- Drainage of pavement system

Concrete Mixture Recommendations

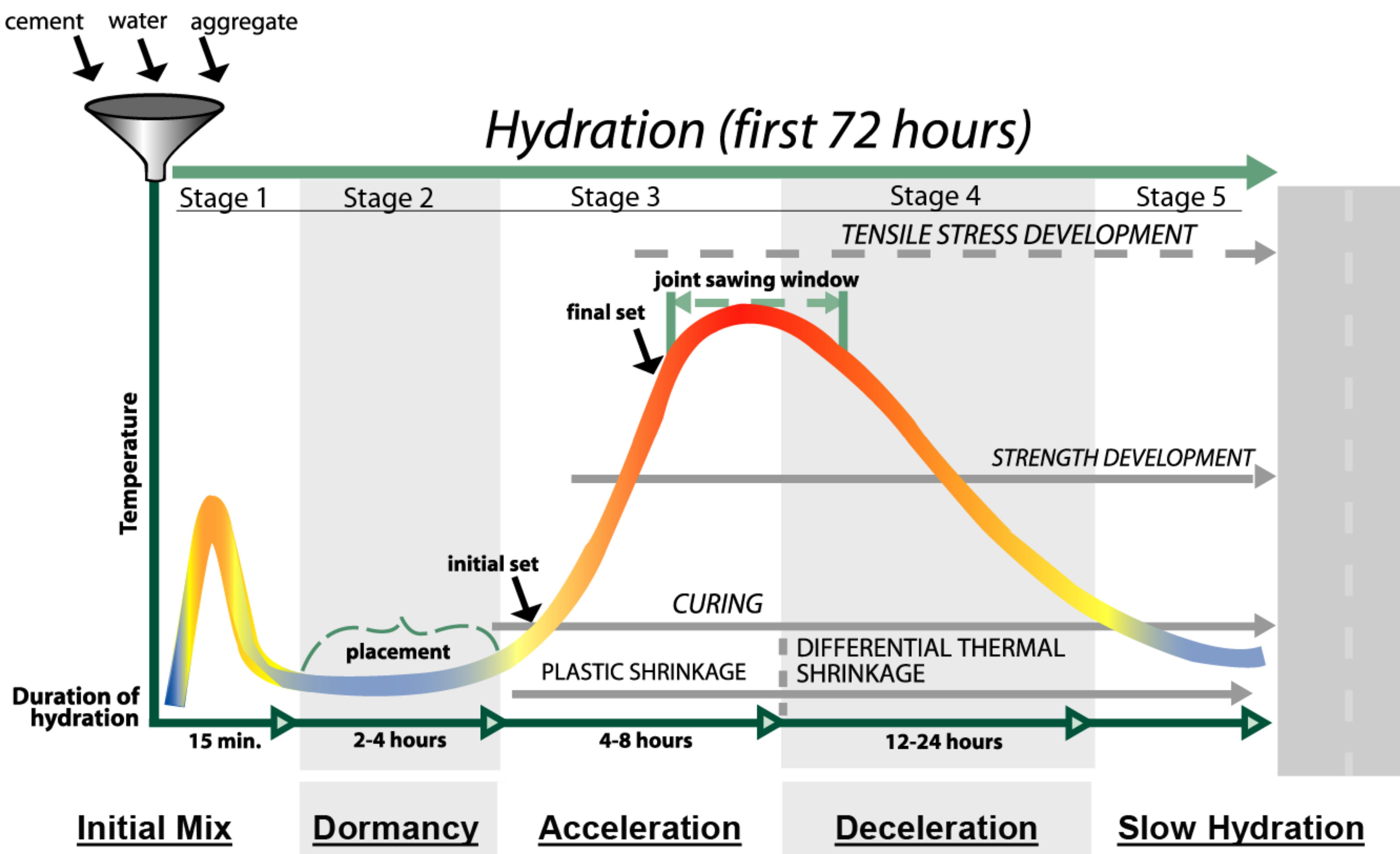
- Low water-cement ratio
- Supplementary cementitious materials
- Well-graded aggregates
- Air-void system

Preventing Joint Deterioration in New Pavements

Construction Practices

- Curing
  - Ensure adequate coverage and application rate
- Sawing joints
  - Sawing window and proper depth
- Sealing joints
  - If seal, have to maintain the seal
  - Consider drainable base
- Surface Sealers
  - If use, consider high solids content
  - Research is ongoing

Sawing Window



Seal or Not to Seal – or "Fill"

Built in 1921, 18' wide, 7-8-7 slab, no jts

Old US 20, Woodbury County, 2014

Type of construction
- New
- Overlay
- Panel size

Foundation
- Natural subgrade
- Free draining base
- Treated base

Traffic pattern and flow

What do we want to mitigate

What do we want to mitigate

Sealant Types

Hot-pour asphalt based

Cold pour

- Silicone
- Nitrile rubber
- Polysulfide
- Polymeric low modulus

Preformed compression seals

Maintenance Activities to Reduce Joint Deterioration Risk

Routine Maintenance

- Joint cleaning and sealing
- Surface sealers
- Drainage

Winter Maintenance

- Deicing/anti-icing chemicals – 13,472 lane miles
  - DE averaged 463,333 gallons of NaCl brine application in the last three years - #1 state was IA 20,209,040 gal, 19,279 ln mi
  - DE averaged 46,781 tons of NaCl in last three years - #1 state was NY 920,866 tons, 43,603 ln mi
  - Calcium chloride and magnesium chloride are more detrimental to cement paste than sodium chloride
- Do not expose concrete to salt for at least 30 days after placement

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

The Lessons

Significant change seems to be deicing salt selections

Concrete ingredient changes may have contributed

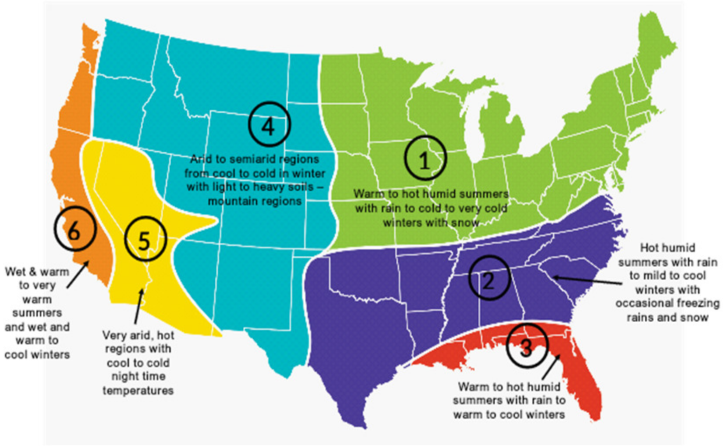
Acknowledging that safety is paramount, we need to make better concrete to resist these salts

- Air void system
- w/cm
- SCM dose

A Better Specification

Require the things that matter

- Transport properties (everywhere)
- Aggregate stability (everywhere)
- Strength (everywhere)
- Cold weather resistance (cold locations)
- Shrinkage (dry locations)
- Workability (everywhere)



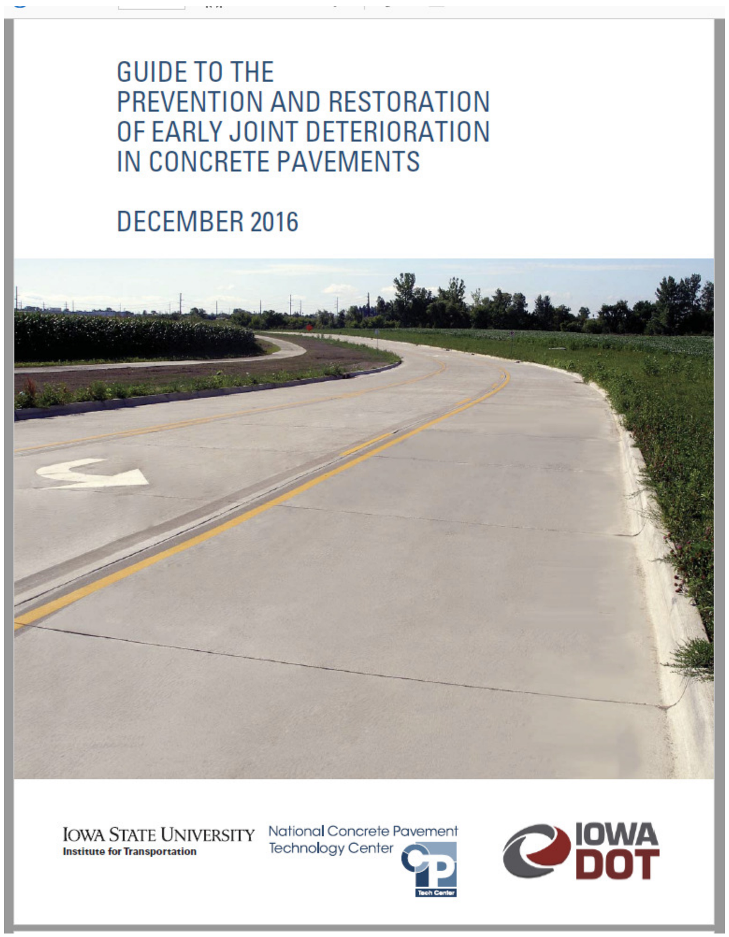
AASHTO PP 84-17

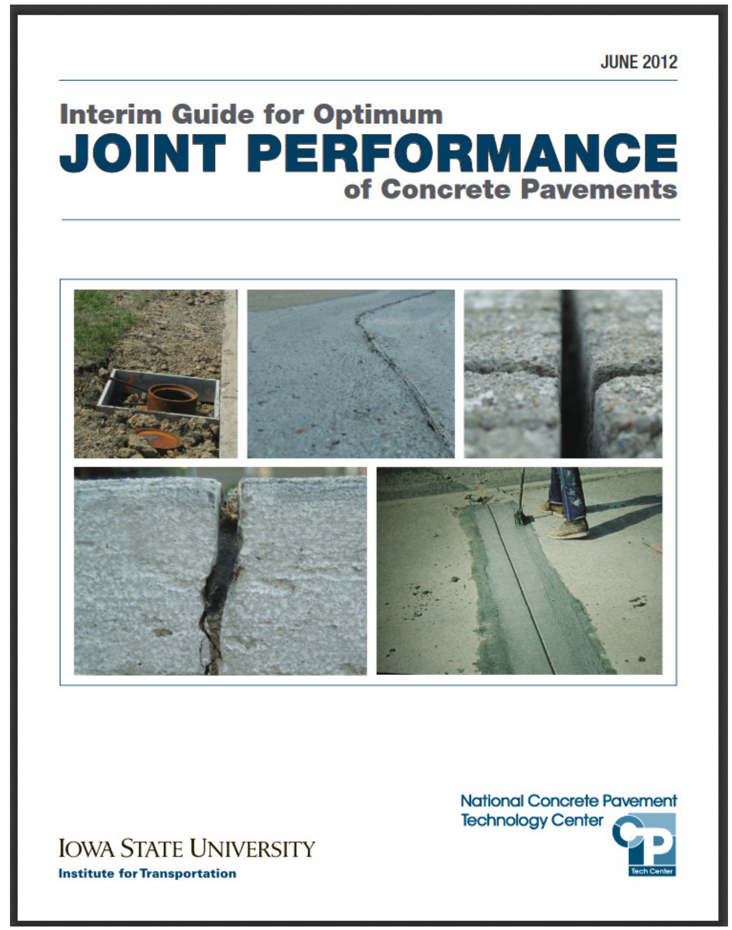
Section	Property	Specified Test	Specified Value		Mixture Qualification	Acceptance	Selection Details		Special Notes
6.3 Concrete Strength									
6.3.1	Flexural Strength	AASHTO T 97	4.1 MPa	600 psi	Yes	Yes	Choose either or both		
6.3.2	Compressive Strength	AASHTO T 22	24 MPa	3500 psi	Yes	Yes			
6.4 Reducing Unwanted Slab Warping and Cracking Due to Shrinkage (If Cracking is a Concern)									
6.4.1.1	Volume of Paste		25%		Yes	No	Choose only one		
6.4.1.2	Unrestrained Volume Change	ASTM C157	420 με	at 28 day	Yes	No			Curing Conditions
6.4.2.1	Unrestrained Volume Change	ASTM C157	360, 420, 480 με	at 91 days	Yes	No			
6.4.2.2	Restrained Shrinkage	AASHTO T 334	crack free	at 180 days	Yes	No			
6.4.2.3	Restrained Shrinkage	AASHTO TP XXX	σ < 60% f'r	at 7 days	Yes	No			Dual ring test is currently under consideration as an AASHTO Provisional Test Method
6.4.2.4	Probability of Cracking	Appendix X1	5, 20, 50%	as specified	Yes	No			
Commentary	Quality control check	~	~	~	No	Yes			Variation controlled with mixture proportion observation or F Factor and Porosity Measures
6.5 Durability of Hydrated Cement Paste for Freeze-Thaw Durability									
6.5.1.1	Water to Cementitious Ratio	~	0.45	~	Yes	Yes	Choose Either 6.5.1.1 or 6.5.2.1		
6.5.1.2	Fresh Air Content	AASHTO T 152, T 196, TP 118	5 to 8	%	Yes	Yes		Choose only one	
6.5.1.3	Fresh Air Content/SAM	AASHTO T 152, T 196, TP 118	≥ 4% Air; SAM ≤ 0.2	%, psi	Yes	Yes			
6.5.2.1	Time of Critical Saturation	Bucket Test, Specification	30	Years	Yes	No	Note 1	Note 2	Variation controlled with mixture proportion observation or F Factor and Porosity Measures
6.5.3.1	Deicing Salt Damage	~	35%	SCM	Yes	Yes	Choose one		Are calcium or magnesium chloride used
6.5.3.2	Deicing Salt Damage	AASHTO M 224	~	Topical Treatment	Yes	Yes			Are calcium or magnesium chloride used, use specified sealers
6.5.4.1	Calcium Oxychloride Limit	Test sent to AASHTO	< 0.15g CaOXY/g paste		Yes	No			Are calcium or magnesium chloride used
6.6 Transport Properties									
6.6.1.1	Water to Cementitious Ratio	~	≤ 0.45 or ≤ 0.50	~	Yes	Yes	Choose Only One		The required maximum water to cementitious ratio is selected based on freeze-thaw conditions.
6.6.1.2	Formation Factor	Table 1	≥ 500 or ≥ 1000	~	Yes	Yes			Based on freeze-thaw conditions. Other criteria could be selected
6.6.2.1	Ionic Penetration, F Factor	Appendix X2	25 mm at 30 year		Yes, F	through 2			Determined using guidance provided in Appendix X2.
6.7 Aggregate Stability									
6.7.1	D Cracking	AASHTO T 161, ASTM C 1646	~	~	Yes	No			
6.7.2	Alkali Aggregate Reactivity	AASHTO PP 65	~	~	Yes	No			
6.8 Workability									
6.8.1	Box Test	Appendix X3	<6.25 mm, < 30% Surf. Voids			No			
6.8.2	Modified V-Kelly Test	Appendix X4	15-30 mm per root seconds			No			
Note 1: Choose Either 6.5.1.1 or 6.5.2.1									
Note 2: Choose either 6.5.1.2, 6.5.1.3 or 6.5.2.1									

In Short

- Low w/cm ratio – consider 0.4 target
- Adequate entrained air – 5% to 8% w/5% min in place
- SCMs
  - 20-25% class F fly ash
  - 30-35% class C fly ash
  - Combination 20% slag and 20% C fly ash
- Well graded aggregates
- Use chemicals appropriately
  - Salts
  - Penetrating sealers

http://www.intrans.iastate.edu/research/documents/research-reports/2016_joint_deterioration_in_pvmts_guide.pdf
http://www.cptechcenter.org/technical-library/documents/Joint-Performance-Guide.pdf





http://www.cproadmap.org/publications/MAPbriefJune2015.pdf
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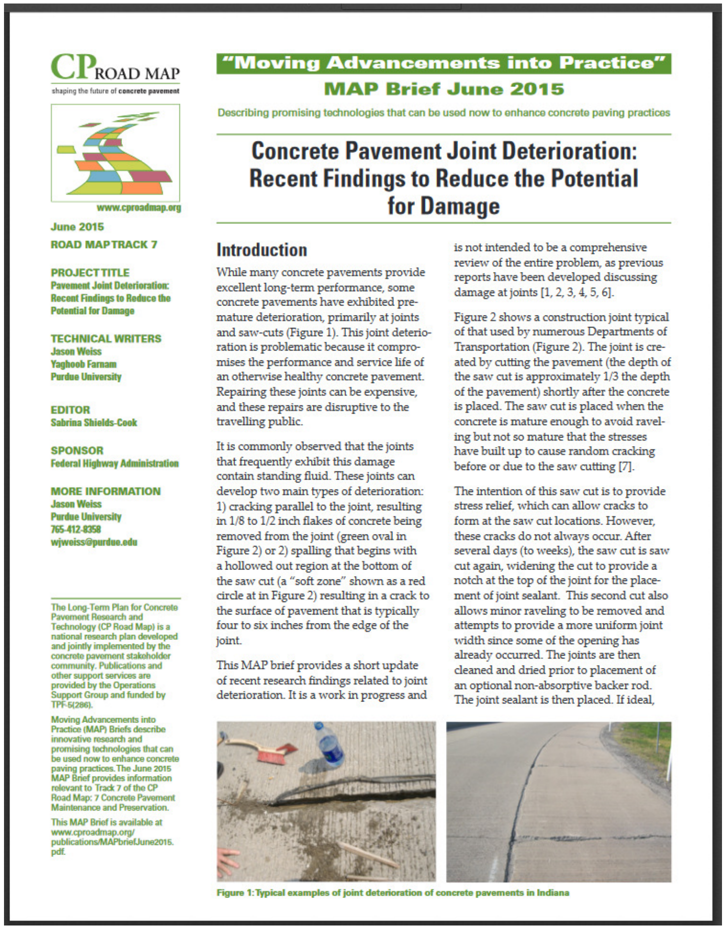

CP ROAD MAP
shaping the future of concrete pavement

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June 2015

ROAD MAP TRACK 7

PROJECT TITLE
Pavement Joint Deterioration: Recent Findings to Reduce the Potential for Damage

TECHNICAL WRITERS
Jason Weiss
Yaghoob Farnam
Purdue University

EDITOR
Sabrina Shields-Cook

SPONSOR
Federal Highway Administration

MORE INFORMATION
Jason Weiss
Purdue University
765-412-8358
wjweiss@purdue.edu

The Long-Term Plan for Concrete Pavement Research and Technology (CP Road Map) is a national research plan developed and jointly implemented by the concrete pavement stakeholder community. Publications and other support services are provided by the Operations Support Group and funded by TPF-5(286).

Moving Advancements into Practice (MAP) Briefs describe innovative research and promising technologies that can be used now to enhance concrete paving practices. The June 2015 MAP Brief provides information relevant to Track 7 of the CP Road Map: 7 Concrete Pavement Maintenance and Preservation.

This MAP Brief is available at www.cproadmap.org/publications/MAPbriefJune2015.pdf.

"Moving Advancements into Practice"

MAP Brief June 2015

Describing promising technologies that can be used now to enhance concrete paving practices

Concrete Pavement Joint Deterioration: Recent Findings to Reduce the Potential for Damage

Introduction

While many concrete pavements provide excellent long-term performance, some concrete pavements have exhibited premature deterioration, primarily at joints and saw-cuts (Figure 1). This joint deterioration is problematic because it compromises the performance and service life of an otherwise healthy concrete pavement. Repairing these joints can be expensive, and these repairs are disruptive to the travelling public.

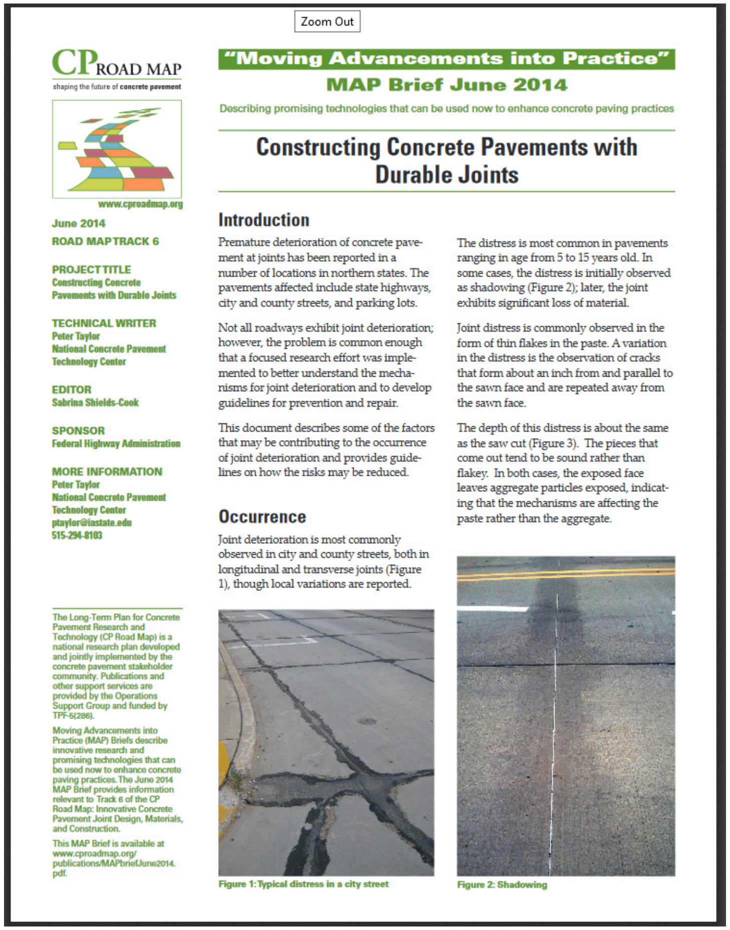
It is commonly observed that the joints that frequently exhibit this damage contain standing fluid. These joints can develop two main types of deterioration: 1) cracking parallel to the joint, resulting in 1/8 to 1/2 inch flakes of concrete being removed from the joint (green oval in Figure 2) or 2) spalling that begins with a hollowed out region at the bottom of the saw cut (a "soft zone" shown as a red circle at in Figure 2) resulting in a crack to the surface of pavement that is typically four to six inches from the edge of the joint.

This MAP brief provides a short update of recent research findings related to joint deterioration. It is a work in progress and is not intended to be a comprehensive review of the entire problem, as previous reports have been developed discussing damage at joints [1, 2, 3, 4, 5, 6].

Figure 2 shows a construction joint typical of that used by numerous Departments of Transportation (Figure 2). The joint is created by cutting the pavement (the depth of the saw cut is approximately 1/3 the depth of the pavement) shortly after the concrete is placed. The saw cut is placed when the concrete is mature enough to avoid raveling but not so mature that the stresses have built up to cause random cracking before or due to the saw cutting [7].

The intention of this saw cut is to provide stress relief, which can allow cracks to form at the saw cut locations. However, these cracks do not always occur. After several days (to weeks), the saw cut is saw cut again, widening the cut to provide a notch at the top of the joint for the placement of joint sealant. This second cut also allows minor raveling to be removed and attempts to provide a more uniform joint width since some of the opening has already occurred. The joints are then cleaned and dried prior to placement of an optional non-absorptive backer rod. The joint sealant is then placed. If ideal,

Figure 1: Typical examples of joint deterioration of concrete pavements in Indiana



Zoom Out

CP ROAD MAP
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June 2014

ROAD MAP TRACK 6

PROJECT TITLE
Constructing Concrete Pavements with Durable Joints

TECHNICAL WRITER
Peter Taylor
National Concrete Pavement Technology Center

EDITOR
Sabrina Shields-Cook

SPONSOR
Federal Highway Administration

MORE INFORMATION
Peter Taylor
National Concrete Pavement Technology Center
ptaylor@iastate.edu
515-294-8103

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Moving Advancements into Practice (MAP) Briefs describe innovative research and promising technologies that can be used now to enhance concrete paving practices. The June 2014 MAP Brief provides information relevant to Track 6 of the CP Road Map: Innovative Concrete Pavement Joint Design, Materials, and Construction.

This MAP Brief is available at www.cproadmap.org/publications/MAPbriefJune2014.pdf.

"Moving Advancements into Practice"

MAP Brief June 2014

Describing promising technologies that can be used now to enhance concrete paving practices

Constructing Concrete Pavements with Durable Joints

Introduction

Premature deterioration of concrete pavement at joints has been reported in a number of locations in northern states. The pavements affected include state highways, city and county streets, and parking lots.

Not all roadways exhibit joint deterioration; however, the problem is common enough that a focused research effort was implemented to better understand the mechanisms for joint deterioration and to develop guidelines for prevention and repair.

This document describes some of the factors that may be contributing to the occurrence of joint deterioration and provides guidelines on how the risks may be reduced.

Occurrence

Joint deterioration is most commonly observed in city and county streets, both in longitudinal and transverse joints (Figure 1), though local variations are reported.

The distress is most common in pavements ranging in age from 5 to 15 years old. In some cases, the distress is initially observed as shadowing (Figure 2); later, the joint exhibits significant loss of material.

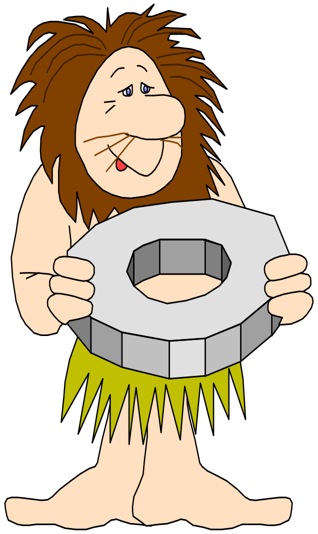
Joint distress is commonly observed in the form of thin flakes in the paste. A variation in the distress is the observation of cracks that form about an inch from and parallel to the sawn face and are repeated away from the sawn face.

The depth of this distress is about the same as the saw cut (Figure 3). The pieces that come out tend to be sound rather than flakey. In both cases, the exposed face leaves aggregate particles exposed, indicating that the mechanisms are affecting the paste rather than the aggregate.

Figure 1: Typical distress in a city street

Figure 2: Shadowing

Thanks for your time



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