Types of Pavement Issues: Why and Prevention

2013 Municipal Streets Seminar
November 13, 2013

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How and Why Do We Keep Shooting Ourselves in the Foot?

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Long Lasting Concrete Pavement

Design

Carries the Design Traffic

1300 bushels on **1** axel !!

Plant

Fresh Properties

Q_C

Placement

Construction

Q_C

Results

Harden Properties (Durability)

Q_A

ESAL => 18k
This wagon => 73k !!

What are the Challenges to Achieve Durability Pavements

Hardened Properties (Durability)

Permeability
- W/C Ratio
- Gradation
- Curing

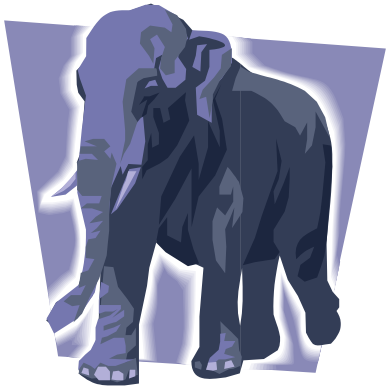
Crack Resistance
- Shrinkage
  - Temperature
  - Moisture

Frost Resistance
- Air Void System
- Salt Scaling
- Pop Out

Sulfate Resistance
- Minimize Sulfate
- Water

Material Reaalted Resistance
- ASR
- D-Cracking

What's not on that list? Strength!



Permeability

- Keep stuff out
  - Water
  - Chlorides
    - Deicing salts
  - Sulfates
- Mix design
- How to measure it

Basic Mix Proportioning

9 - 15%
Cement

15 - 16%
Water

Paste
(cement + water)

25 - 35%
Fine aggregate

Mortar
(paste + fine aggregate)

30 - 45%
Coarse aggregate

Concrete
(mortar + coarse aggregate)

Optimized Combined Gradation

- What will it do for me?
  - Improved workability
  - Reduce segregation potential
  - Reduced cementitious content for equal strength

Less paste=> **Less permeable**

  - Normally reduce cost

Gradation

Gap Graded

Well Graded

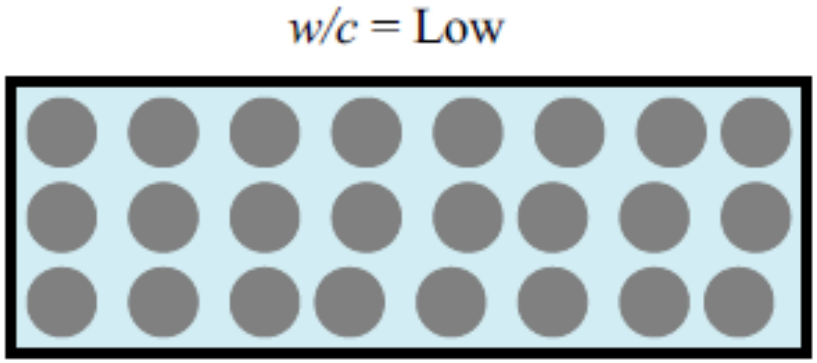
Water/Cement Ratio

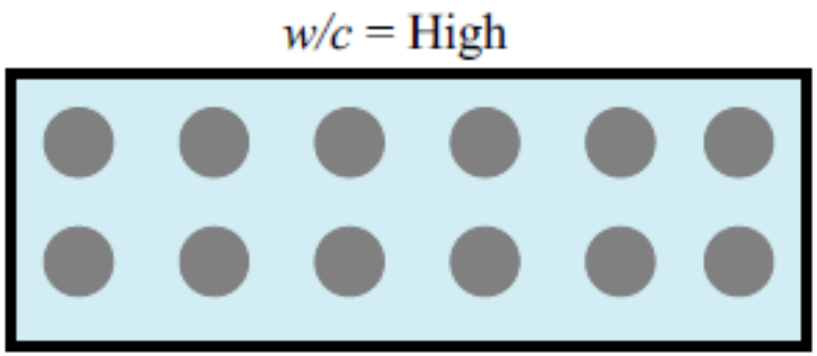
- Weight of water divided by weight of cementitious (cement, fly ash, GGBFS)
- Direct relationship permeability

$$= W/Cm$$

Permeability

- Controlled by W/Cm





How SCM's Work

Cement

Calcium Silicates + **Water** → **CSH** + **CH**

Calcium
Silicate
Hydrate

Calcium Hydroxide

Secondary Reaction

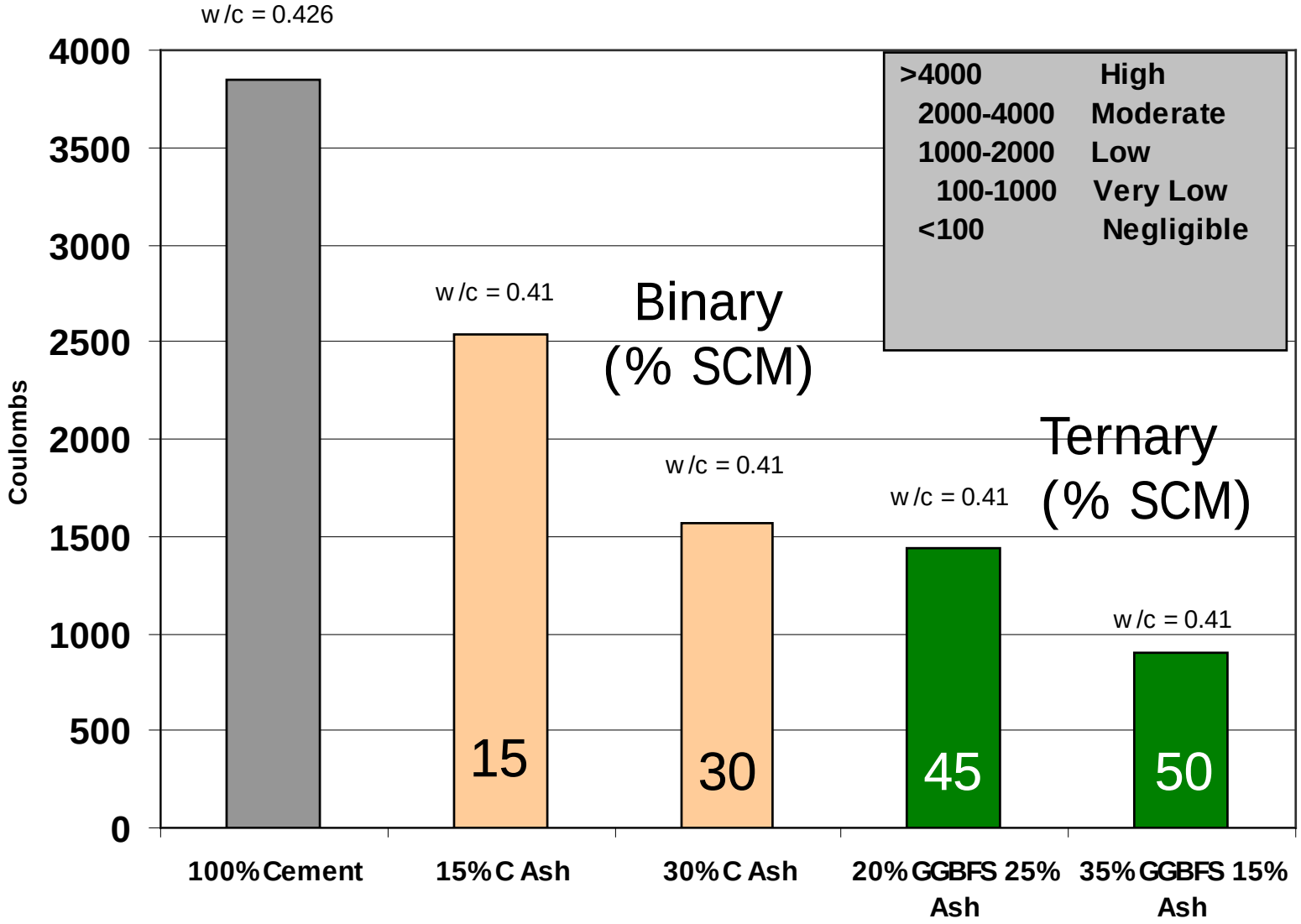
Begins after the cement reaction

Fly Ash / Slag

Supplemental Cementitious Material + **Water** + **CH** → **CSH**

Ternary Mix Design - Lab Study

Permeability AASHTO T277 - Virginia Cure Method

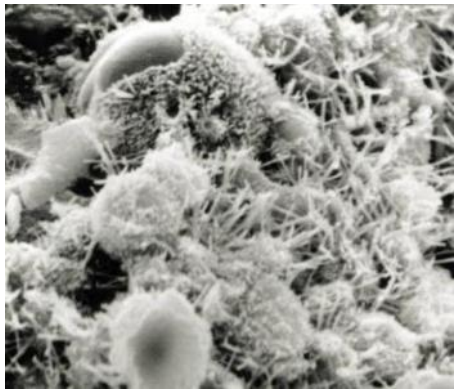


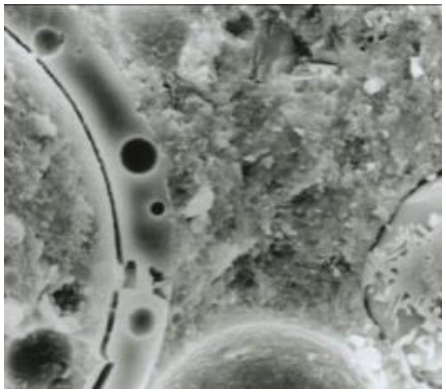
Curing

- Hydration continues as long as water is present

Permeability

- The ease with which fluids can penetrate concrete
- Minimize durability damage by
  - Minimize paste volume
  - Use low W/Cm
  - Use SCMs
  - Curing
  - Minimize cracking

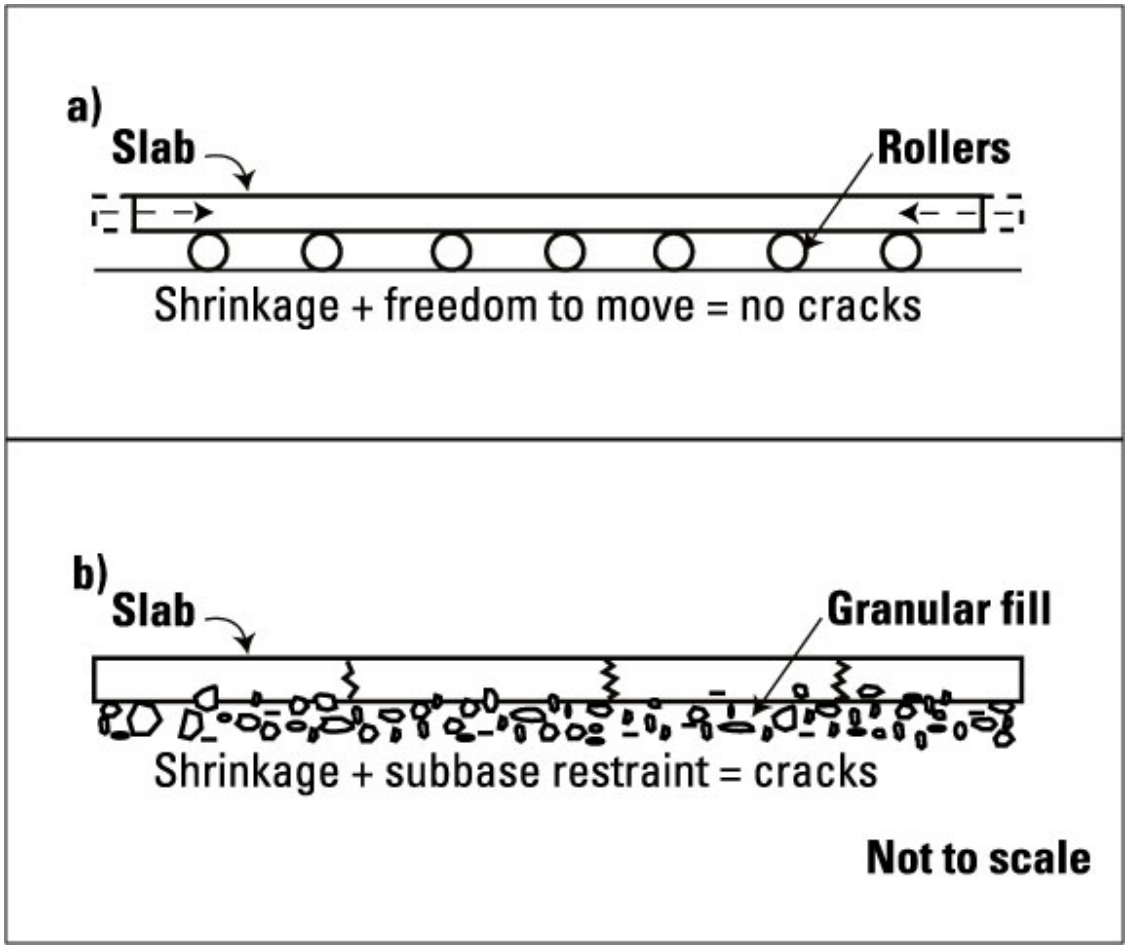




Factors Affecting Early-Age Cracking

- Volume shrinkage
- Strength
- Curling/warping
- Early loading

Restraint Cracking

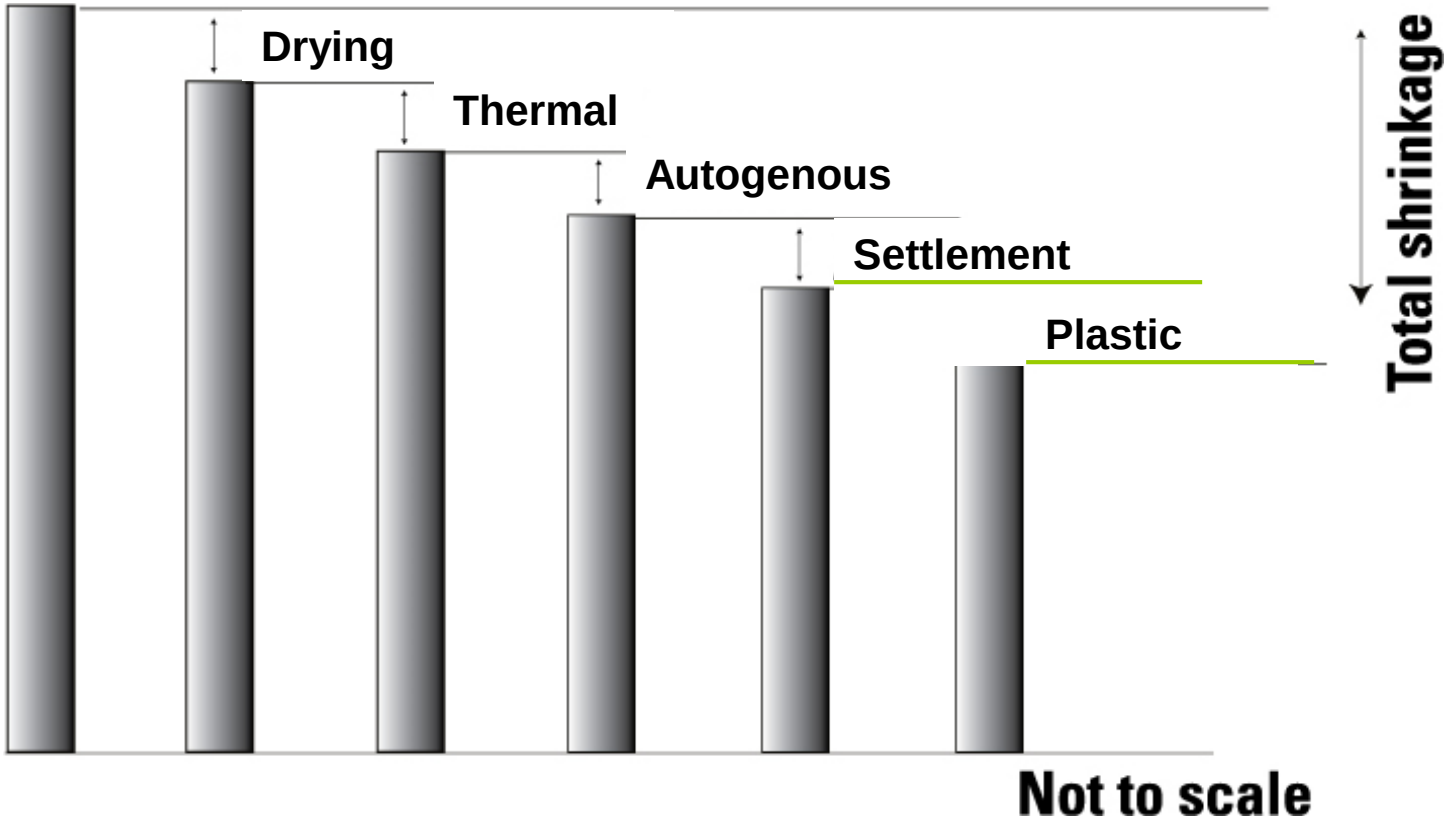


(a) Cracks generally do not develop in concrete that is free to shrink.

(b) Slabs on the ground are restrained by the subbase, creating tensile stresses that result in cracks.

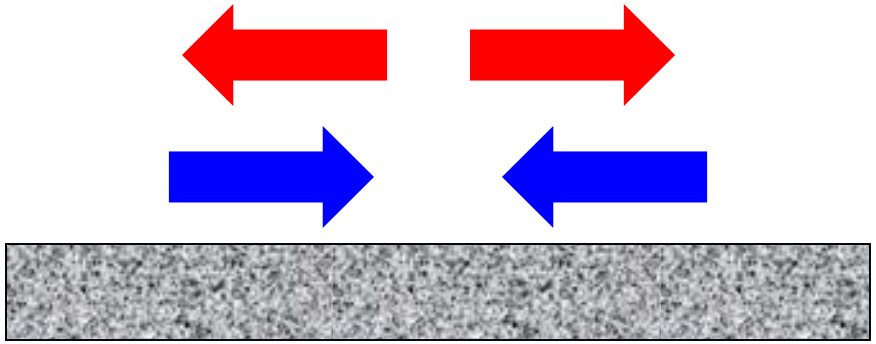
Volume Shrinkage

Total shrinkage is the sum of individual shrinkage mechanisms. Minimizing any or all mechanisms will reduce the risk of cracking.



Primary Factors of Early-Age Cracking

- Concrete expands as **temperature** rises and contracts as **temperature** falls



- Concrete expands as **moisture** increases and contracts as **moisture** decreases

Optimized Combined Gradation

- What will it do for me?
  - Reduced cementitious content for equal strength

Less water =>

Less cement => **Less shrinkage**

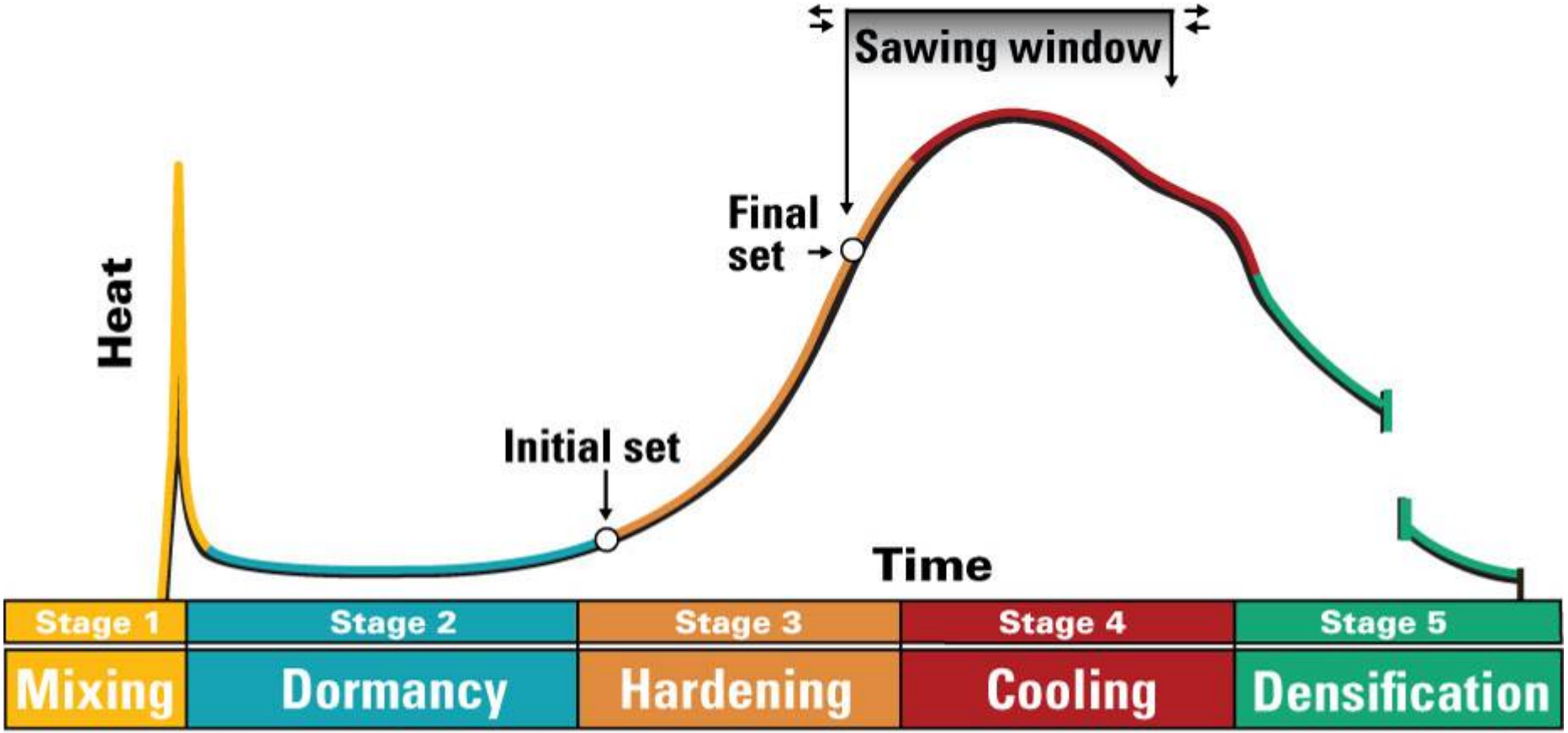
Less heat =>

  - Less potential for cracking

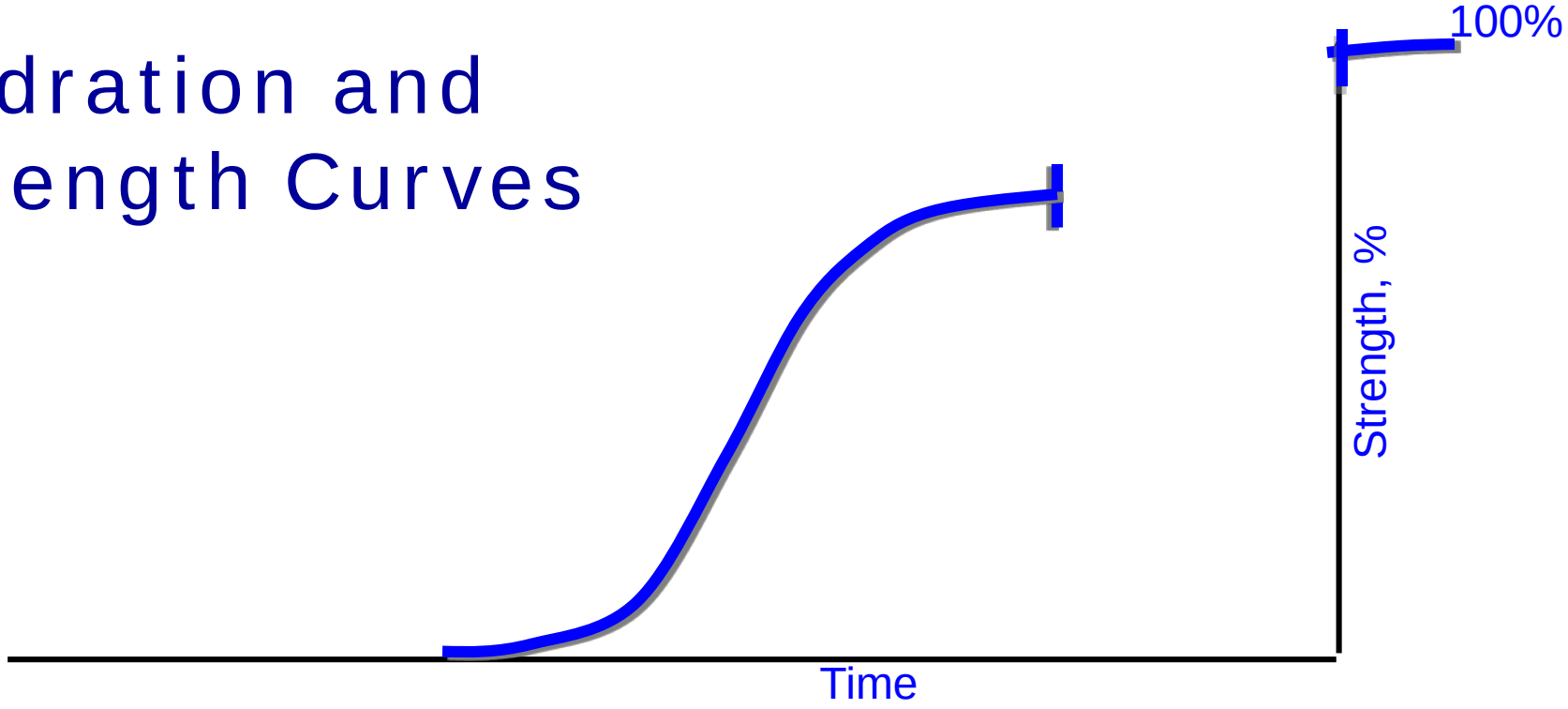
Drying Shrinkage

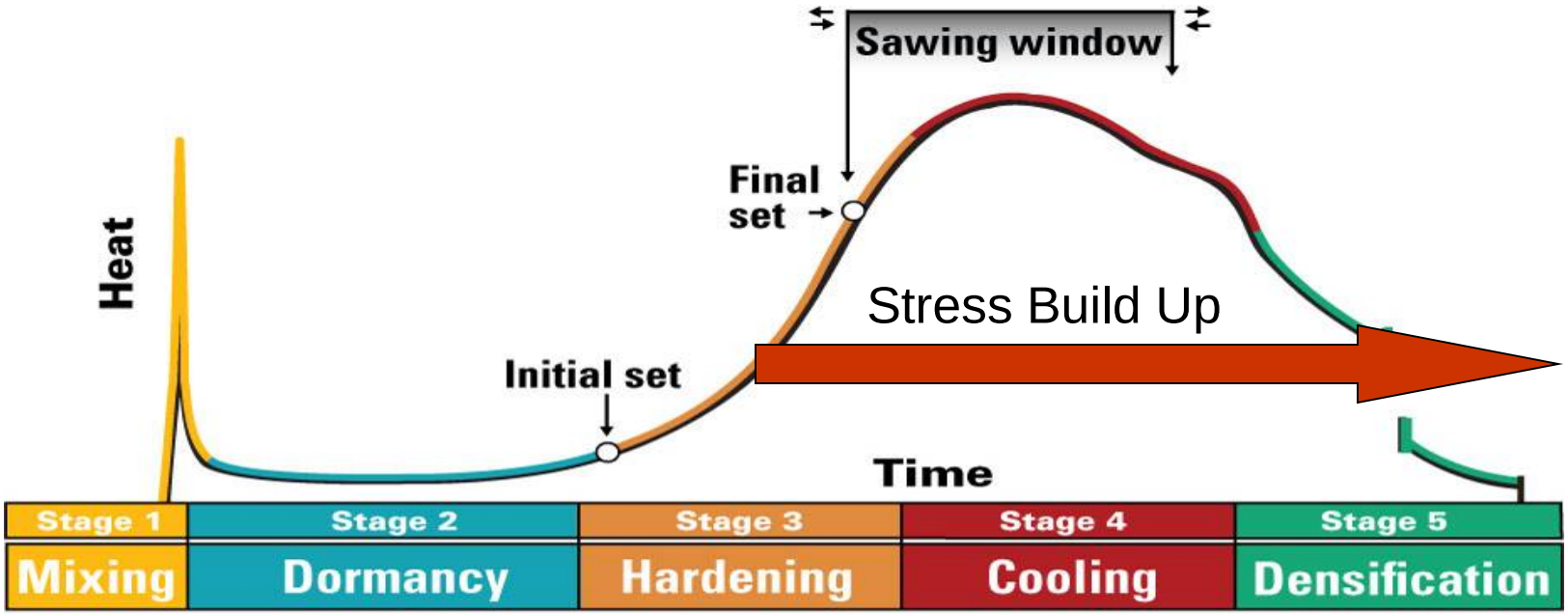
- Loss of mixing water through hydration and evaporation
  - Overall volume contracts
  - Greater paste content => greater drying shrinkage => higher tensile stress
  - Low relative humidity of air can affect shrinkage diffusion-curing is critcal!

Five Stages of Hydration



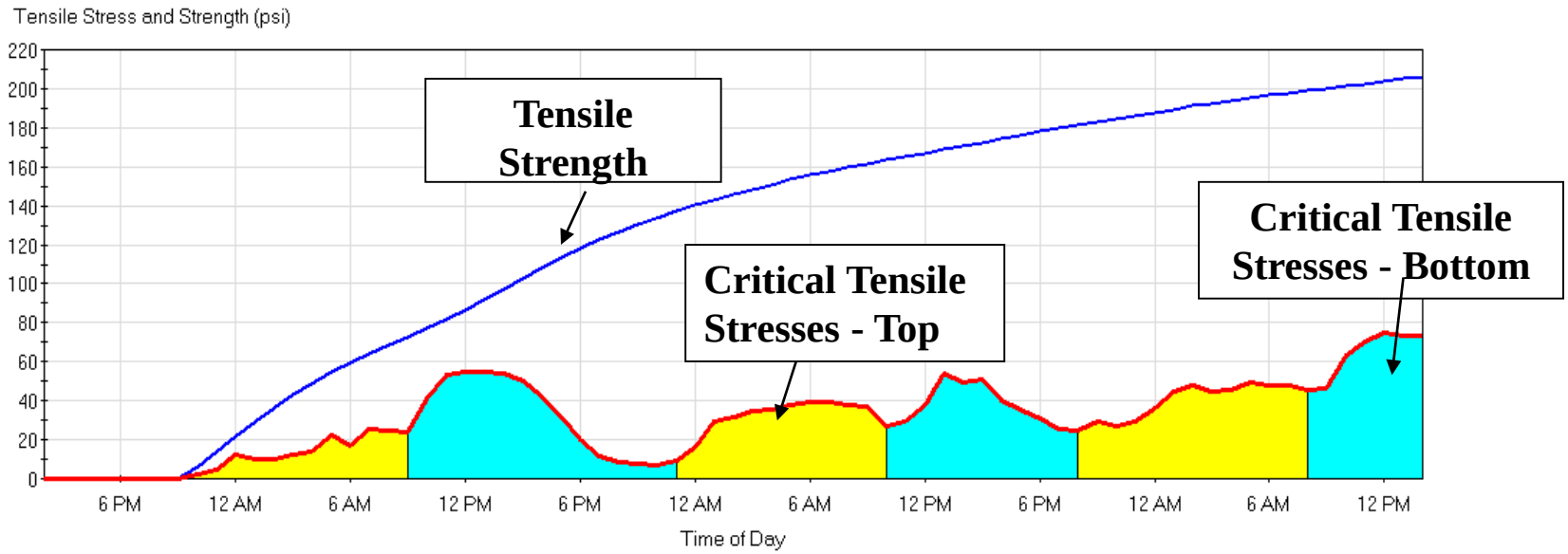
Hydration and Strength Curves

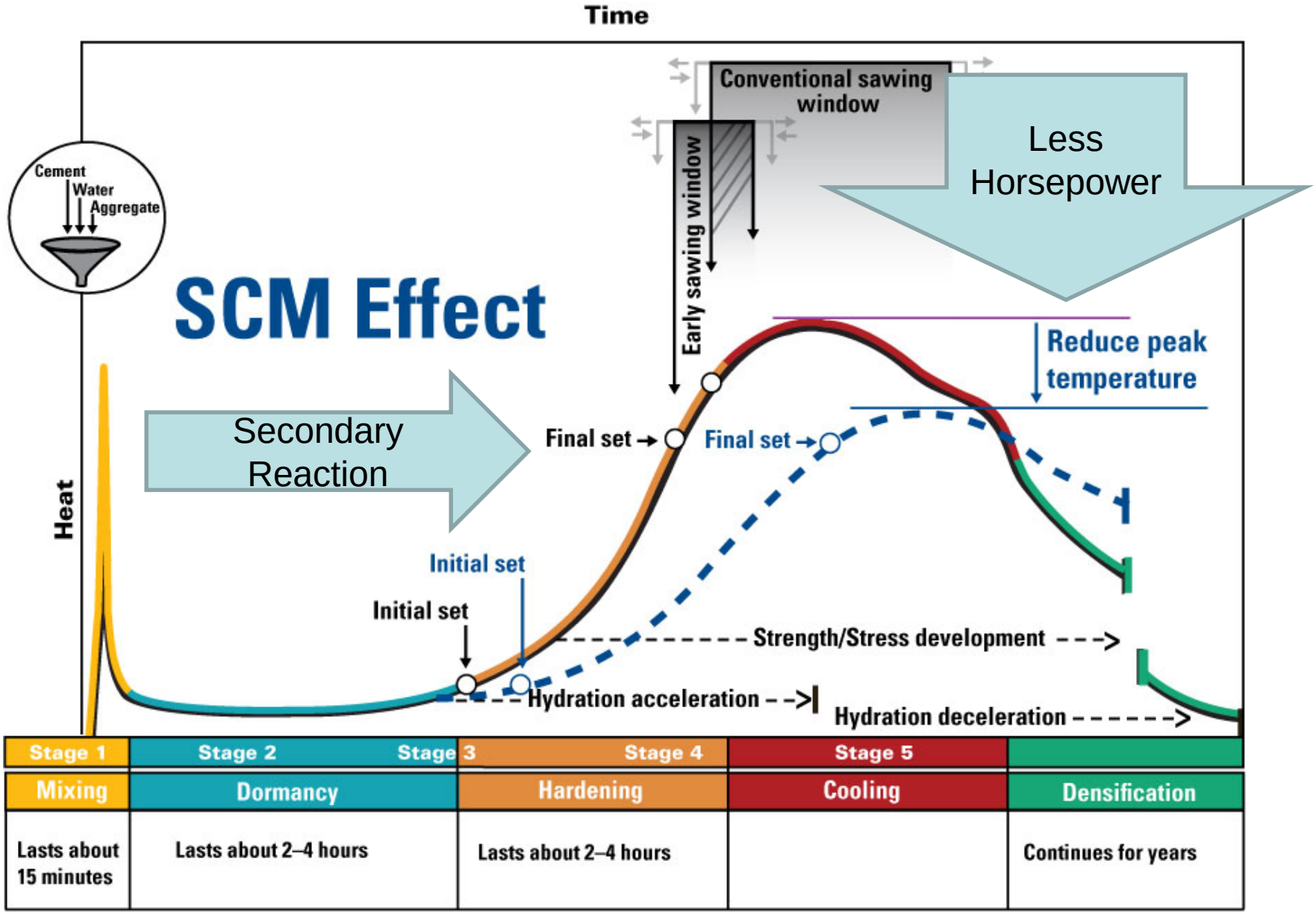




HIPERPAV

- Software tool for assessing cracking risk




Time
Cement
Water
Aggregate
SCM Effect
Conventional sawing window
Early sawing window
Less Horsepower
Reduce peak temperature
Secondary Reaction
Heat
Final set
Final set
Initial set
Initial set
Strength/Stress development
Hydration acceleration
Hydration deceleration
Stage 1
Stage 2
Stage 3
Stage 4
Stage 5
Mixing
Dormancy
Hardening
Cooling
Densification
Lasts about 15 minutes
Lasts about 2–4 hours
Lasts about 2–4 hours
Continues for years

Factors Affecting Thermal Properties

- Cement fineness
- Amount of Pozzolans
  - Class F fly ash heat of hydration
    - Typically 50 percent of cement
  - Class C fly ash heat of hydration
    - Typically 70 to 90 percent of that of cement
- Pozzolans are a secondary reaction
  - Reduce the maximum temperature

Factors Affecting Thermal Properties

- Aggregate types
  - Account for about 60 to 75 percent of concrete by volume
  - Coefficient of Thermal Expansion (CTE) of aggregates dominates CTE of concrete

Restraint

External Restraint: A bonding or friction between a slab and the base or an abrupt change in the slabs cross-section.

Internal Restraint: The outer concrete shrinks or expands and the core does not.

Curling and Warping

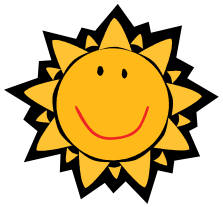
- Variations in contraction and expansion cause differential, non-uniform movements

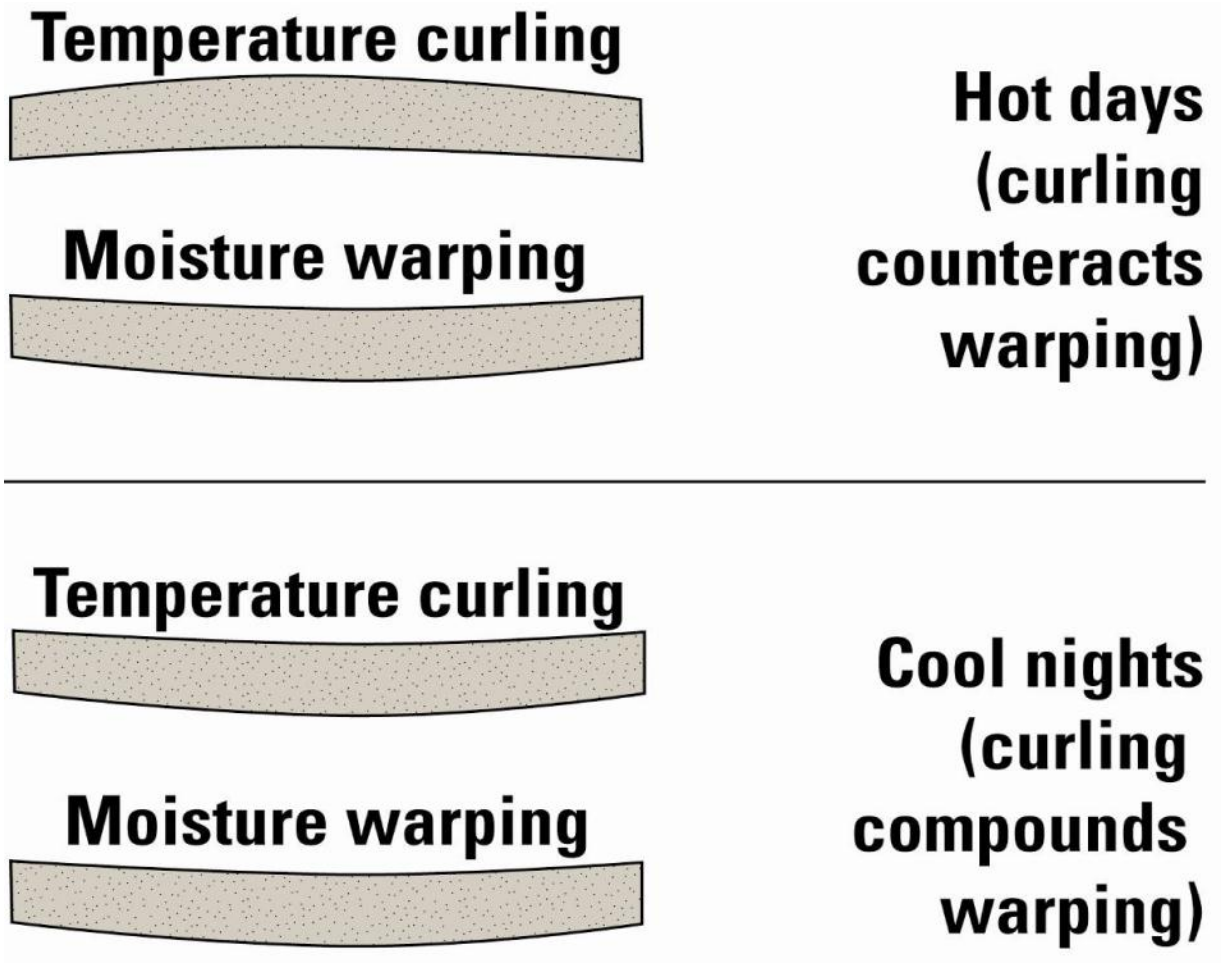
Curling => Change in **Temperature**

Warping => Change in **Moisture**

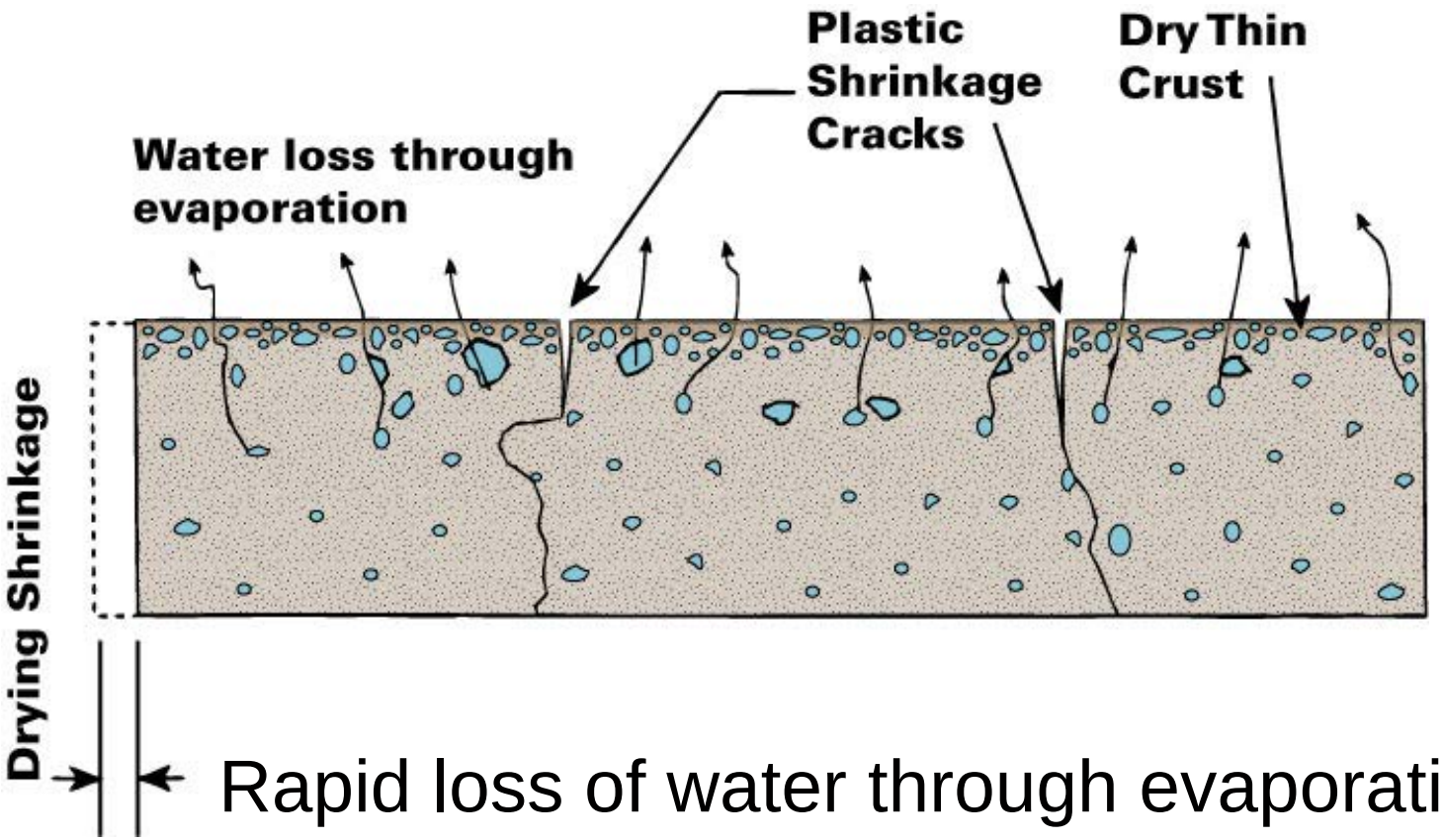
- These movements, especially when restrained, can cause cracking

Curling and Warping of Slabs



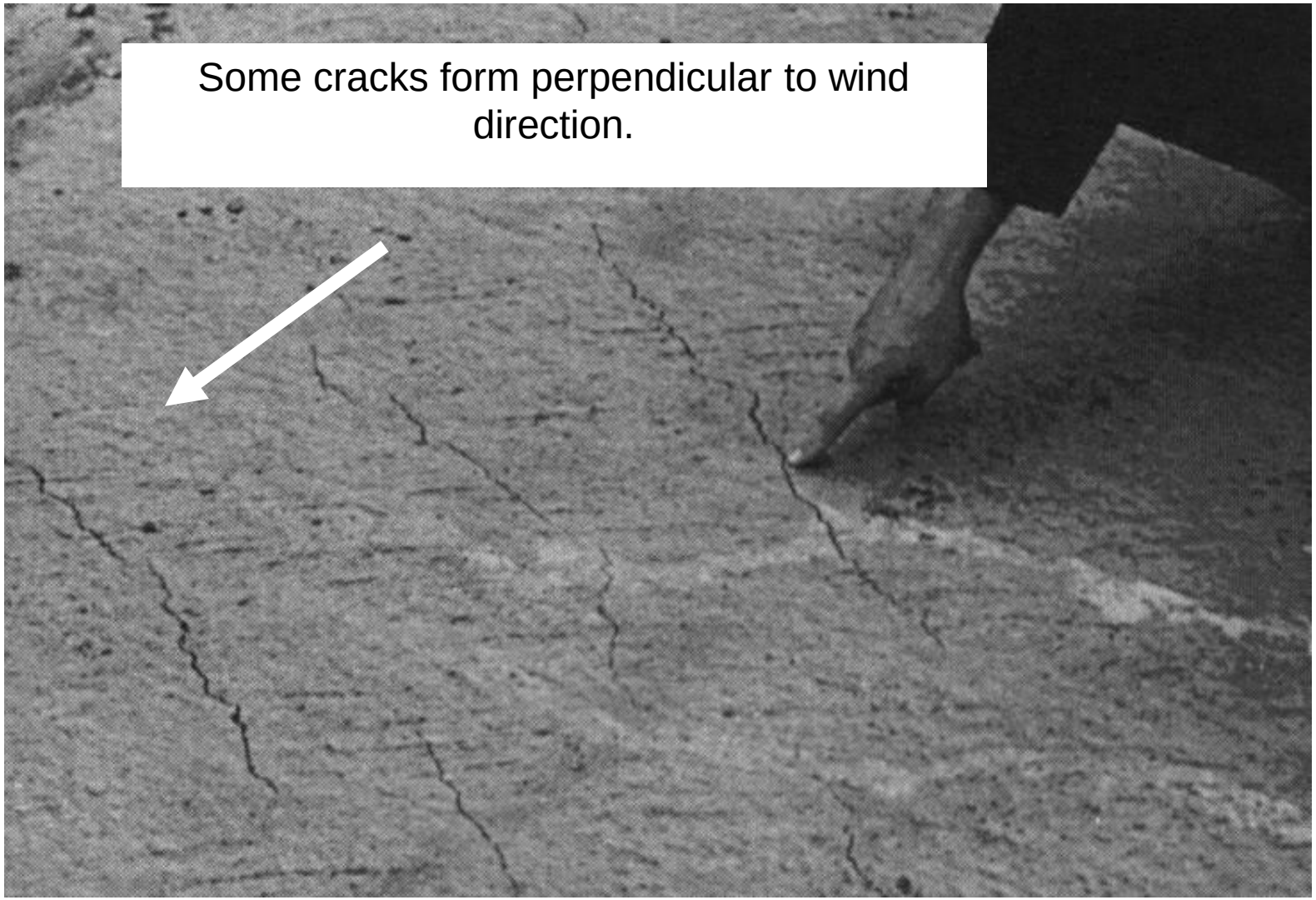


Plastic Shrinkage



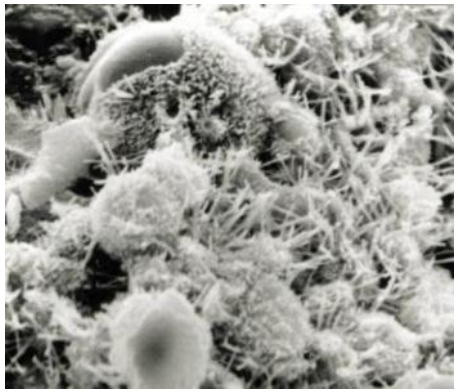
Rapid loss of water through evaporation causes concrete **on the surface** to shrink. If shrinkage is restrained, tension develops, which may cause cracking.

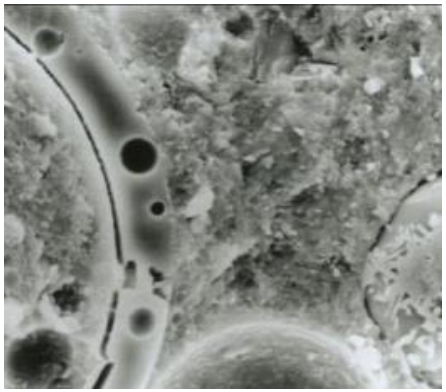
Plastic Shrinkage Cracks



Cracking

- Minimize durability damage by
  - Minimize paste volume
  - Use low w/cm
  - Use SCMs
  - Curing
  - Minimize cracking





Early Joint Deterioration

- A new problem
  - Not D-cracking
  - Not freeze/thaw damage

Early Joint Deterioration

- Deterioration stops at the edge of the traveled lane

Incremental Cracking

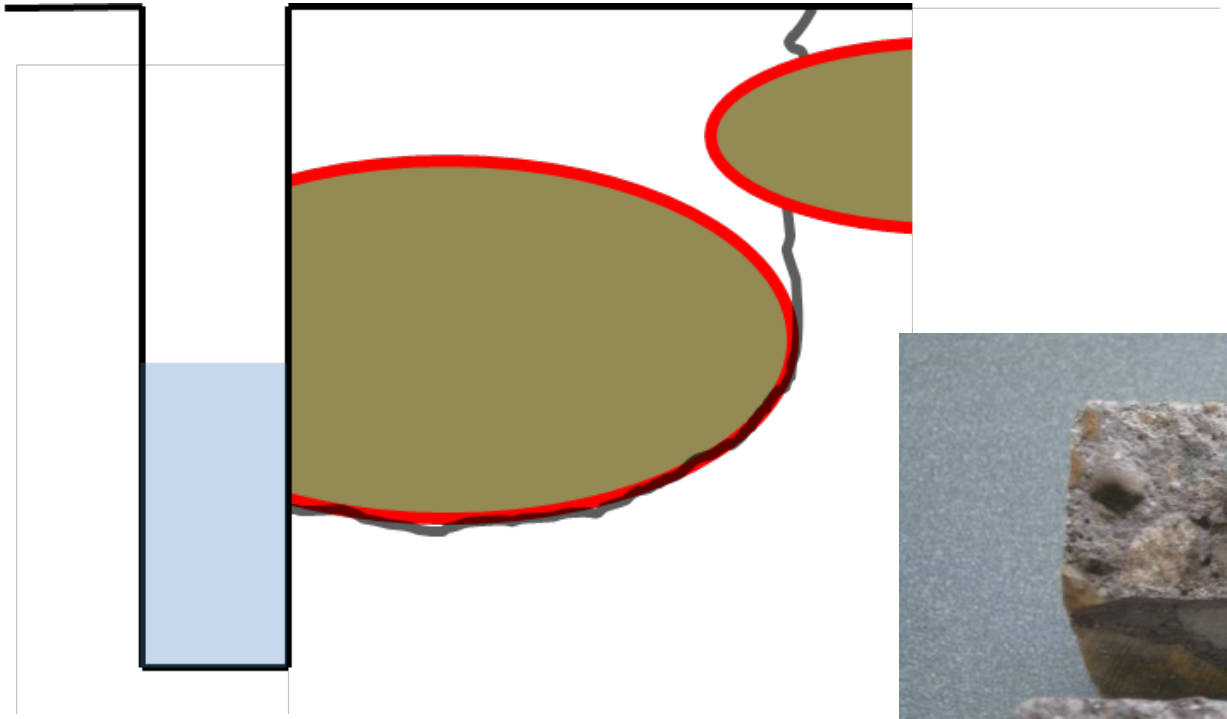
The Symptoms

- Not typical freezing and thawing
  - No thin flakes

The Symptoms

- The aggregate is polished

Interfacial Zone

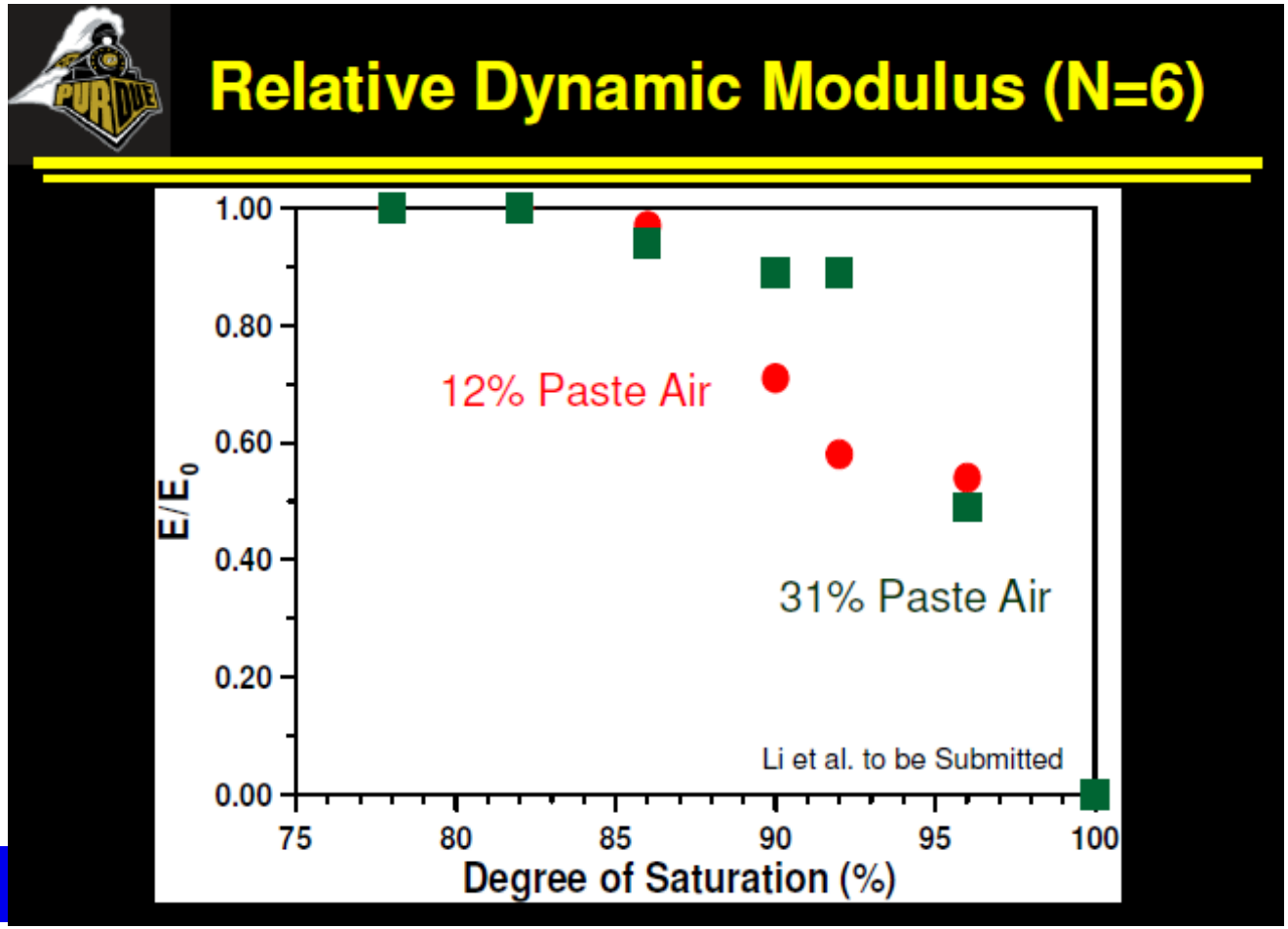


Saturation

- Tunneling – water trapped in saw-cut

Purdue Work

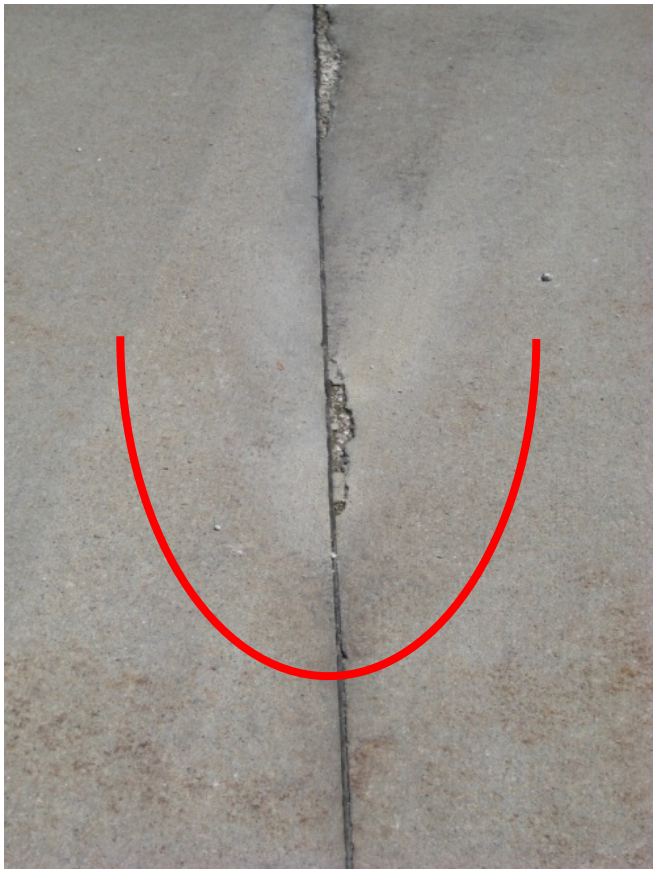
- Damage depends on degree of saturation

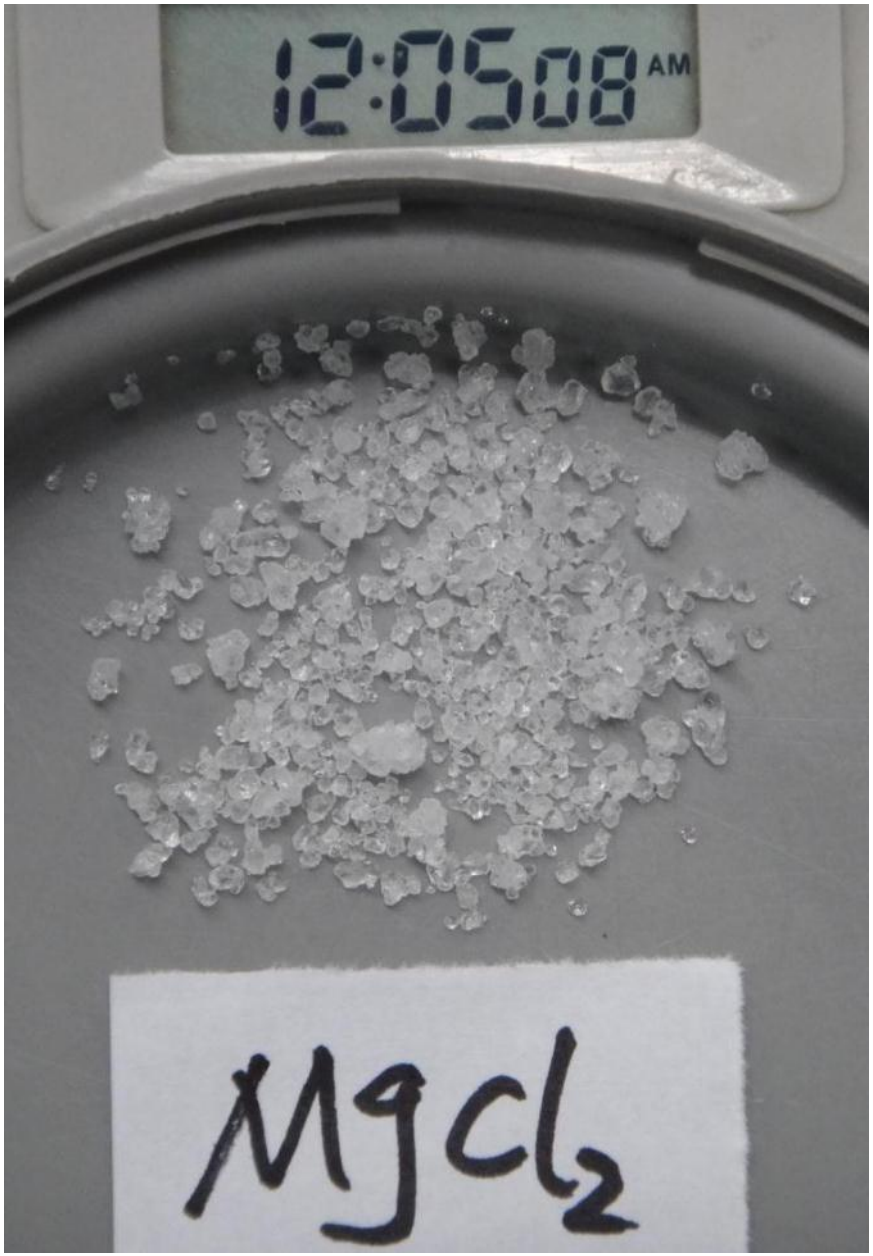


Jason Weiss

Saturation

- Bottom-Up Moisture

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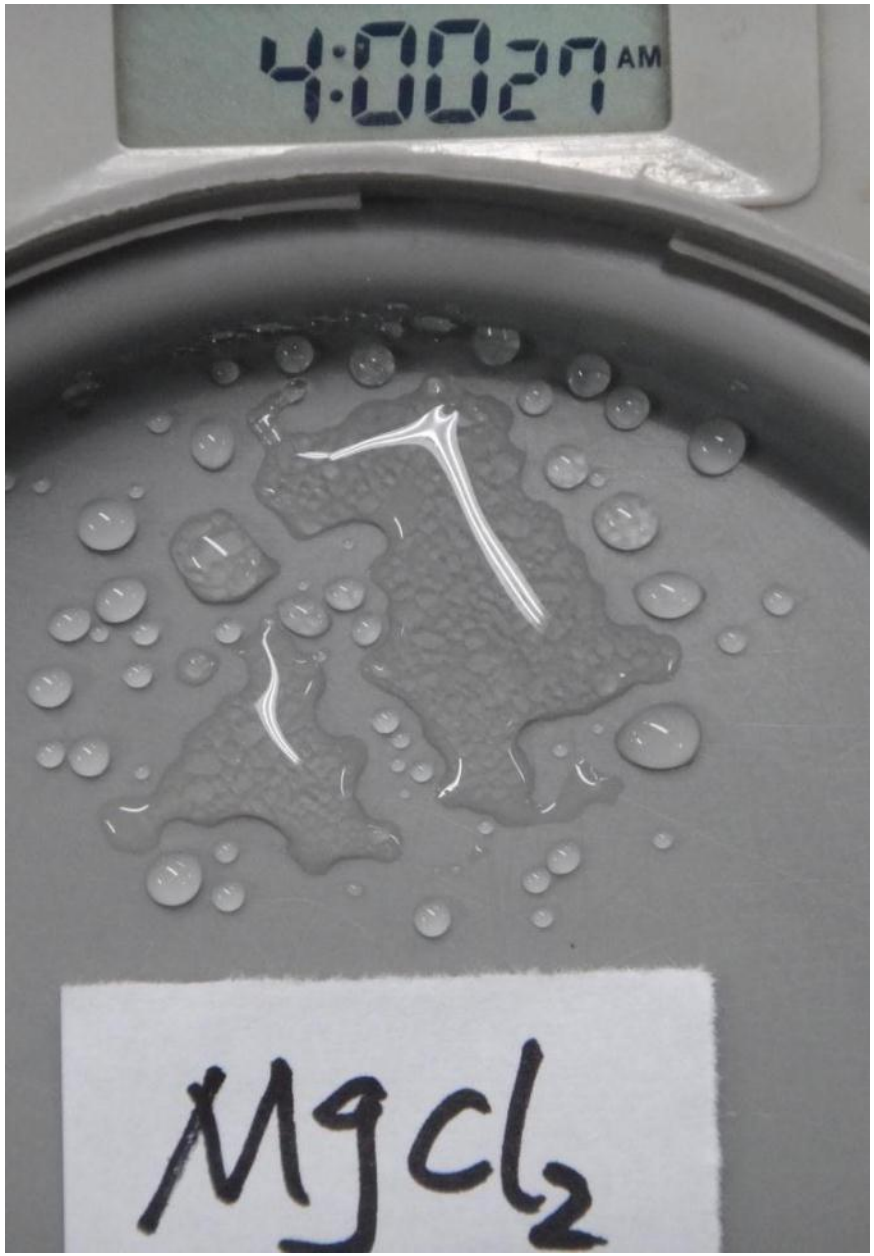
MgCl2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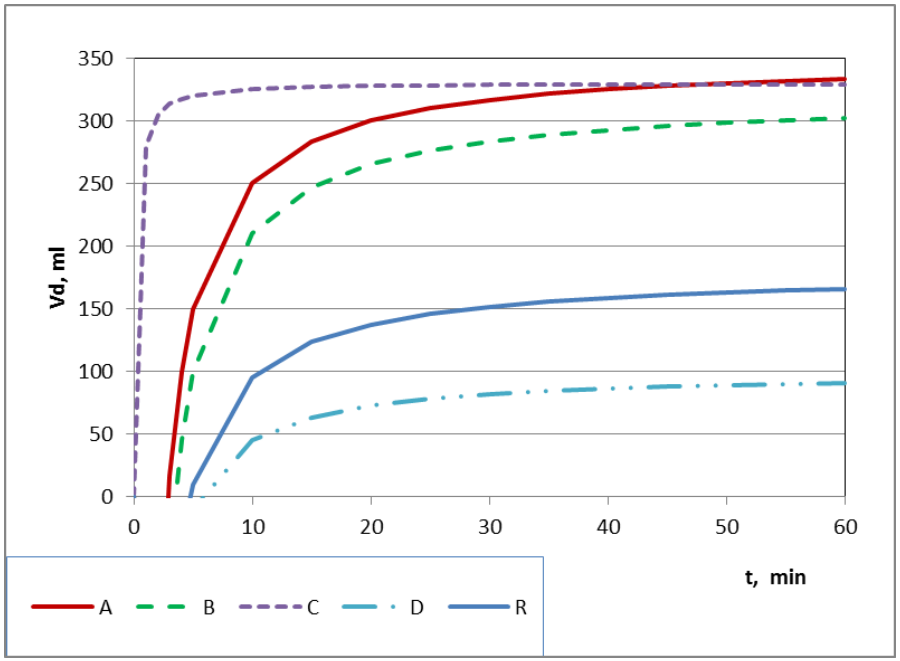
MgCl2

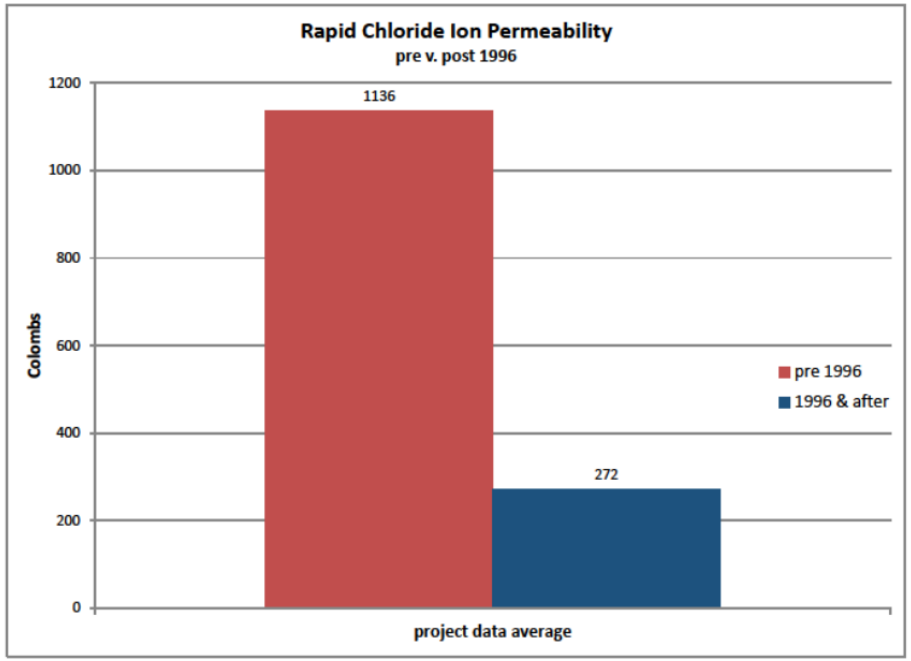
An Example

- No sealant-joints dry first
- If they don't drain, salts collect

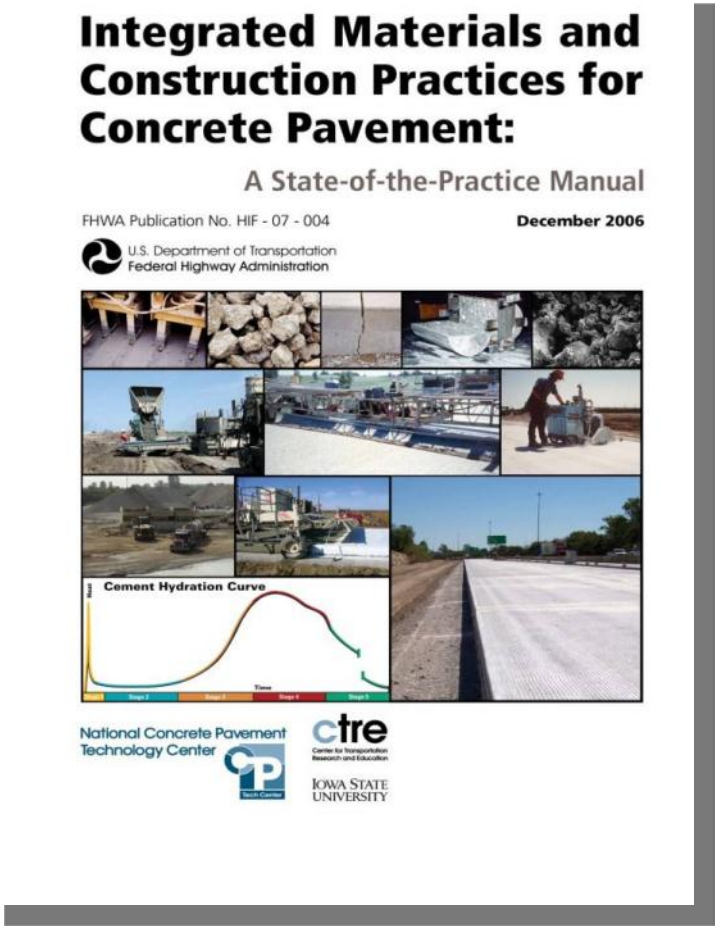
The Mixture

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





The IMCP Manual



Integrated Materials and Construction Practices for Concrete Pavement:

A State-of-the-Practice Manual

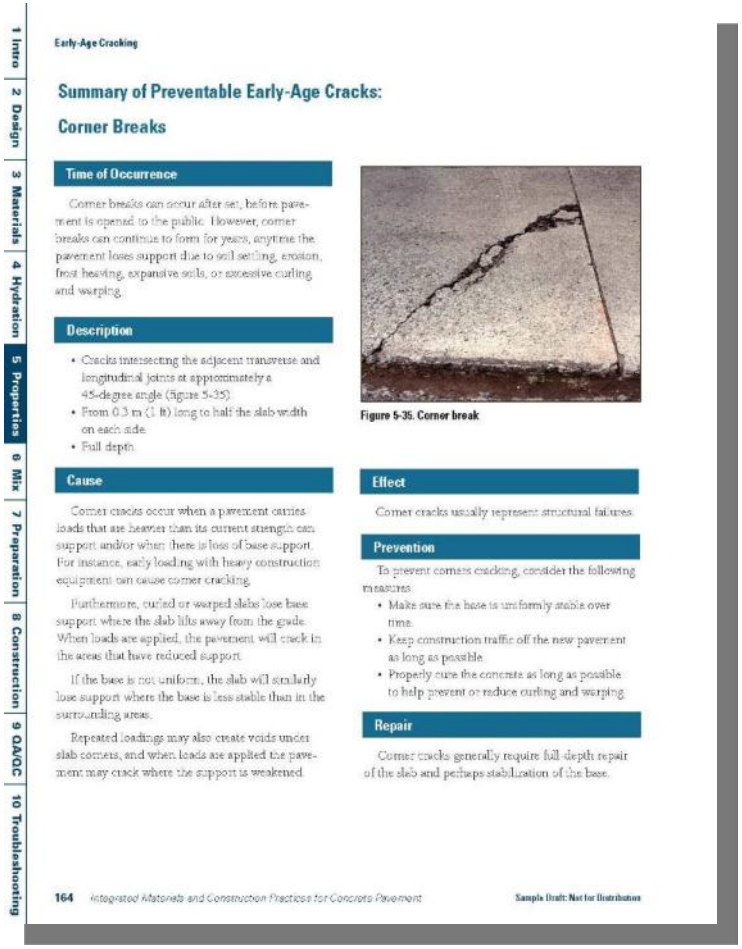
FHWA Publication No. HIF - 07 - 004 **December 2006**

U.S. Department of Transportation
Federal Highway Administration

National Concrete Pavement Technology Center

ctre Center for Transportation Research and Education

Iowa State University



1 Intro | 2 Design | 3 Materials | 4 Hydration | 5 Properties | 6 Mix | 7 Preparation | 8 Construction | 9 QA/QC | 10 Troubleshooting

Early-Age Cracking

Summary of Preventable Early-Age Cracks:

Corner Breaks

Time of Occurrence

Corner breaks can occur after set, before pavement is opened to the public. However, corner breaks can continue to form for years, anytime the pavement loses support due to soil settling, erosion, frost heaving, expansive soils, or excessive curling and warping.

Description

- Cracks intersecting the adjacent transverse and longitudinal joints at approximately a 45-degree angle (figure 5-35).
- From 0.3 m (1 ft) long to half the slab width on each side.
- Full depth.

Cause

Corner cracks occur when a pavement carries loads that are heavier than its current strength can support and/or when there is loss of base support. For instance, early loading with heavy construction equipment can cause corner cracking.

Furthermore, curled or warped slabs lose base support where the slab lifts away from the grade. When loads are applied, the pavement will crack in the areas that have reduced support.

If the base is not uniform, the slab will similarly lose support where the base is less stable than in the surrounding areas.

Repeated loadings may also create voids under slab corners, and when loads are applied the pavement may crack where the support is weakened.

Figure 5-35. Corner break

Effect

Corner cracks usually represent structural failures.

Prevention

To prevent corners cracking, consider the following measures:

- Make sure the base is uniformly stable over time.
- Keep construction traffic off the new pavement as long as possible.
- Properly cure the concrete as long as possible to help prevent or reduce curling and warping.

Repair

Corner cracks generally require full-depth repair of the slab and perhaps stabilization of the base.

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Rocky asks:
Any Questions?

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