Concrete Pavement Troubleshooting

NHI Real Solutions
Presentation
Oct 23 , 2008

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Troubleshooting Concrete Pavements

- Nothing ever goes wrong…
- Right?

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Learning Objectives

The goal of this session is to understand the basic process of troubleshooting paving-related problems:

- Identifying what the problem really is
- Understanding what is causing the problem
- Developing a plan to address the problem

When Do We See the Problem?

- Before the concrete has set
- First days after placing
- Some time after construction

General Thoughts

- Make sure you look at all the information available
- Don’t assume that the first potential cause you find is the only one
- Start big, then go small – a microscope image is unlikely to tell the whole story
- Beware of the carpenter to whom all tools are hammers

Case History 1

The problem:

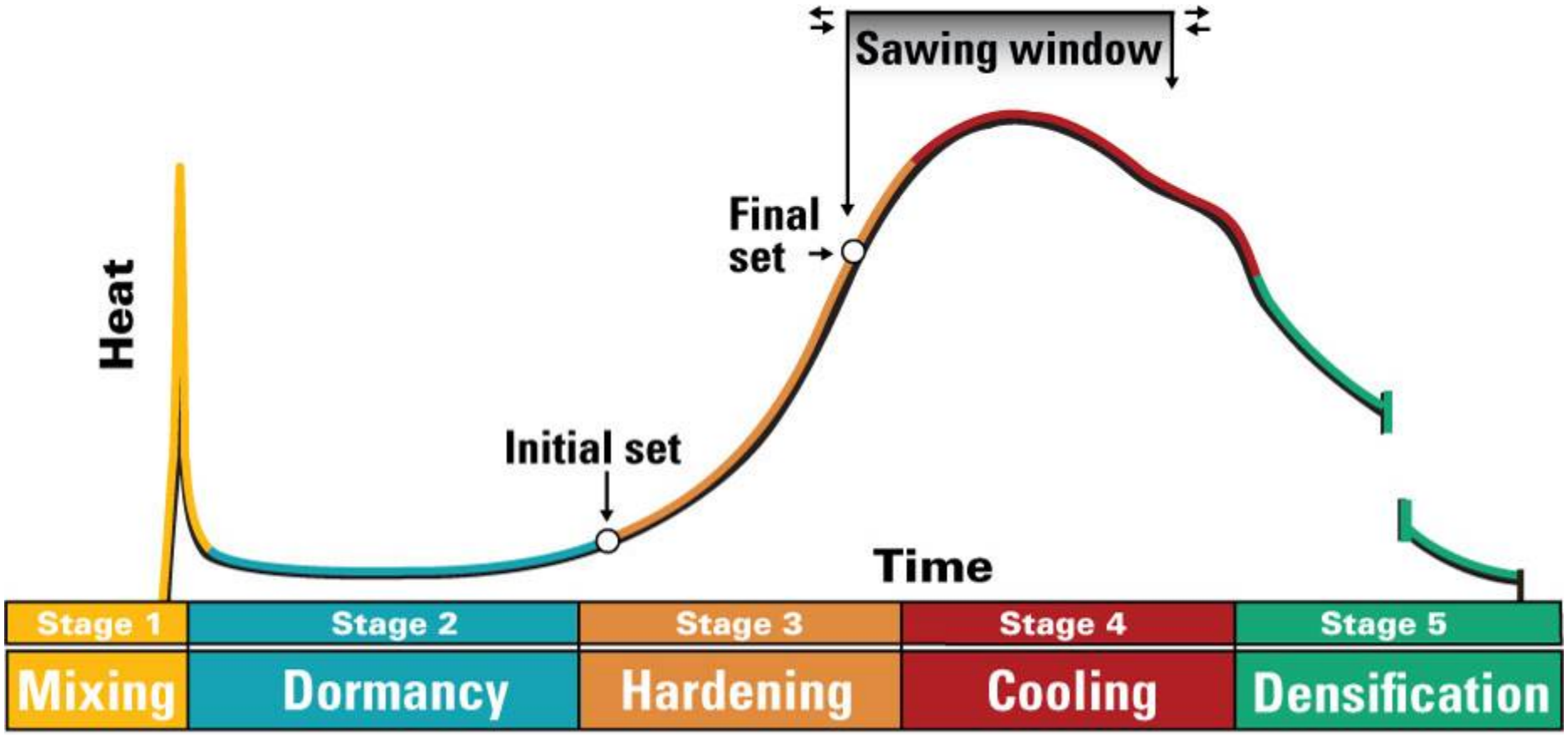
- It's August and hot
- Concrete coming out of the paver is stiff and can't be consolidated
- It looks OK when unloaded from the truck
- 10-minute haul

Case History 1

Actions taken:

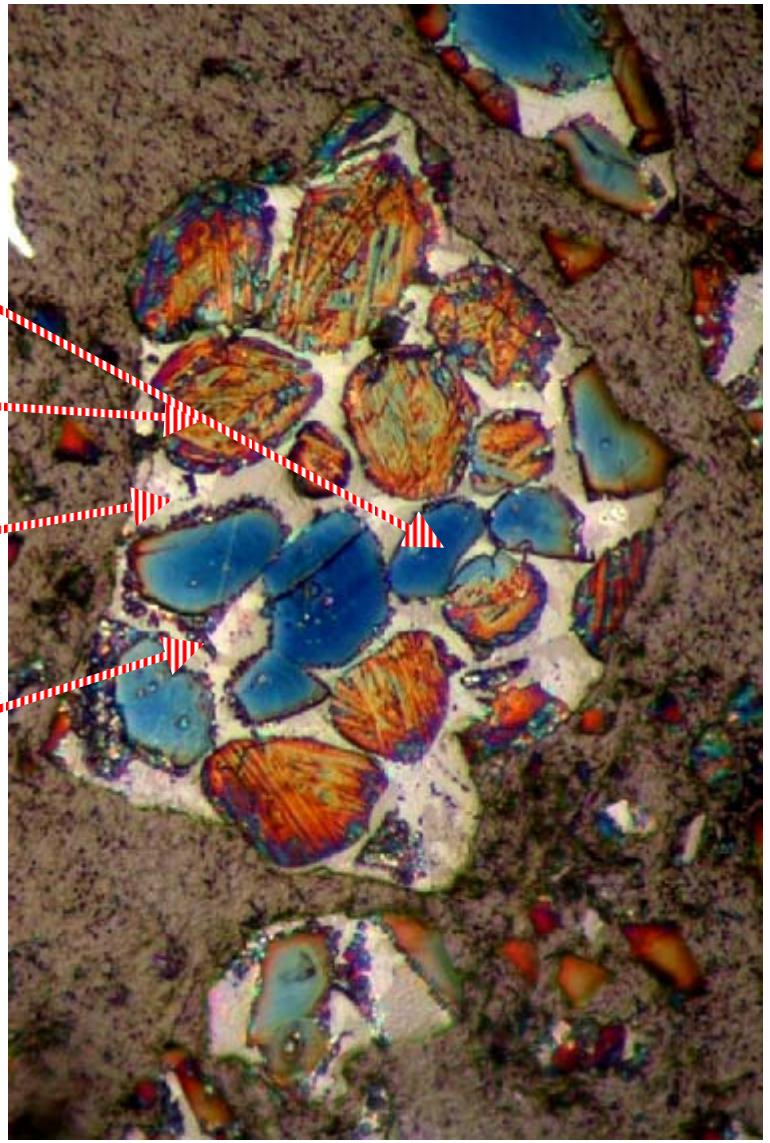
- Phoned the batch plant
  (They say the slump is in spec at loading)
- Added WRA
  (It got worse)
- Turned up the vibrators
  (The inspector complained about losing air and signs of vibrator trails)

Five Stages of Hydration



What is Cement?

- C_3S – The hare (alite)
- C_2S – The tortoise (belite)
- C_3A – The fox (calcium aluminate)
- C_4AF – … (ferrite)



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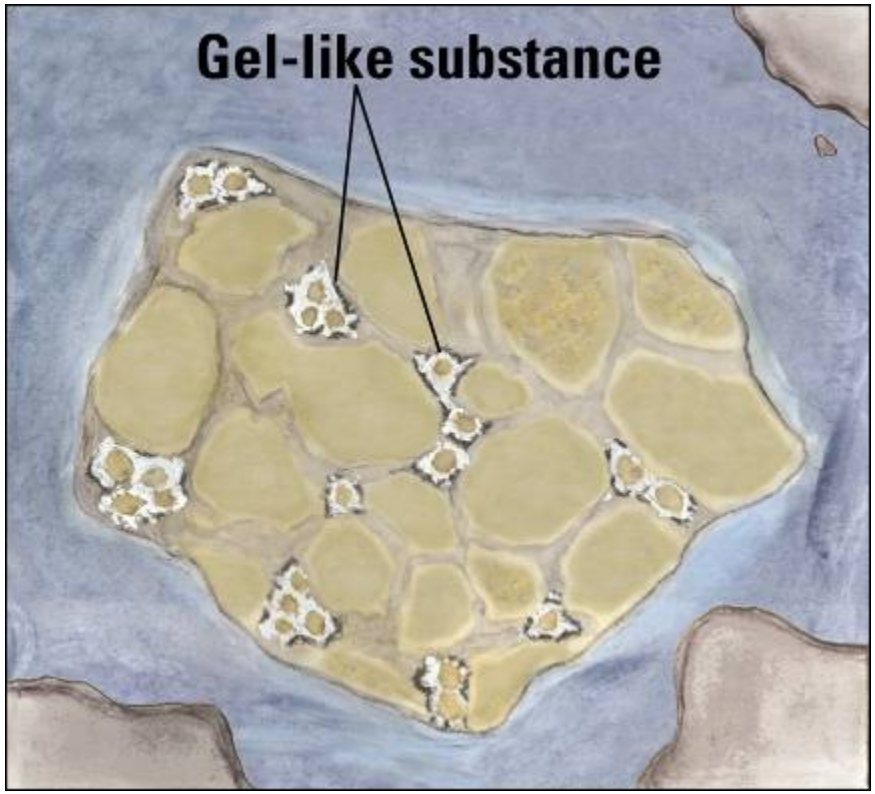
Stage 1: Mixing



- Aluminates dissolve and react quickly, with high heat. Danger: flash set.
- Sulfate (Gypsum) dissolves quickly, too. It reacts with aluminate and water, forming a gel.
- The gel limits water's access to aluminate. Reactions slow. Heat drops. Flash set averted.

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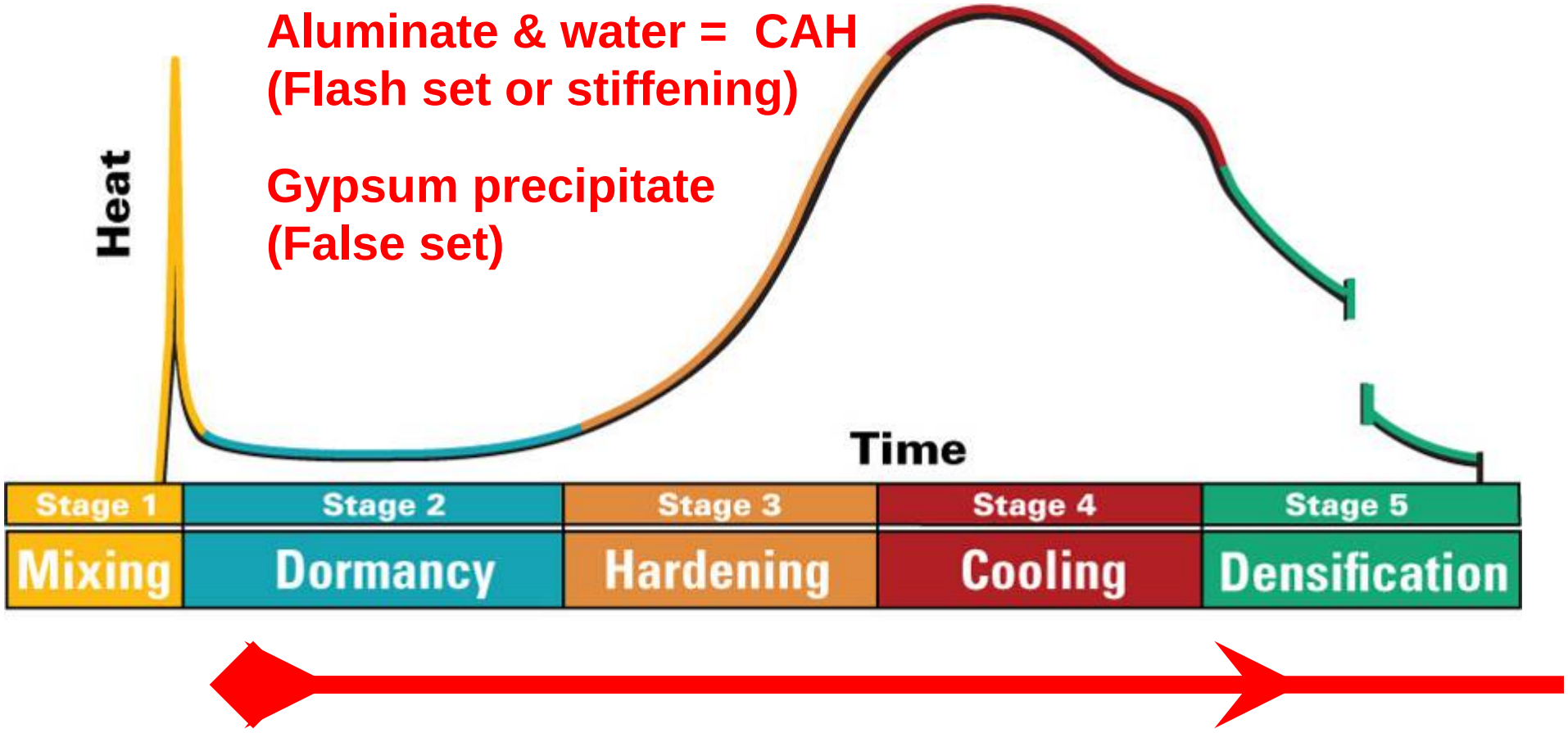
Gypsum and Aluminates

Aluminate & Sulfate & water = Ettringite (Normal)

Aluminate & water = CAH (Flash set or stiffening)

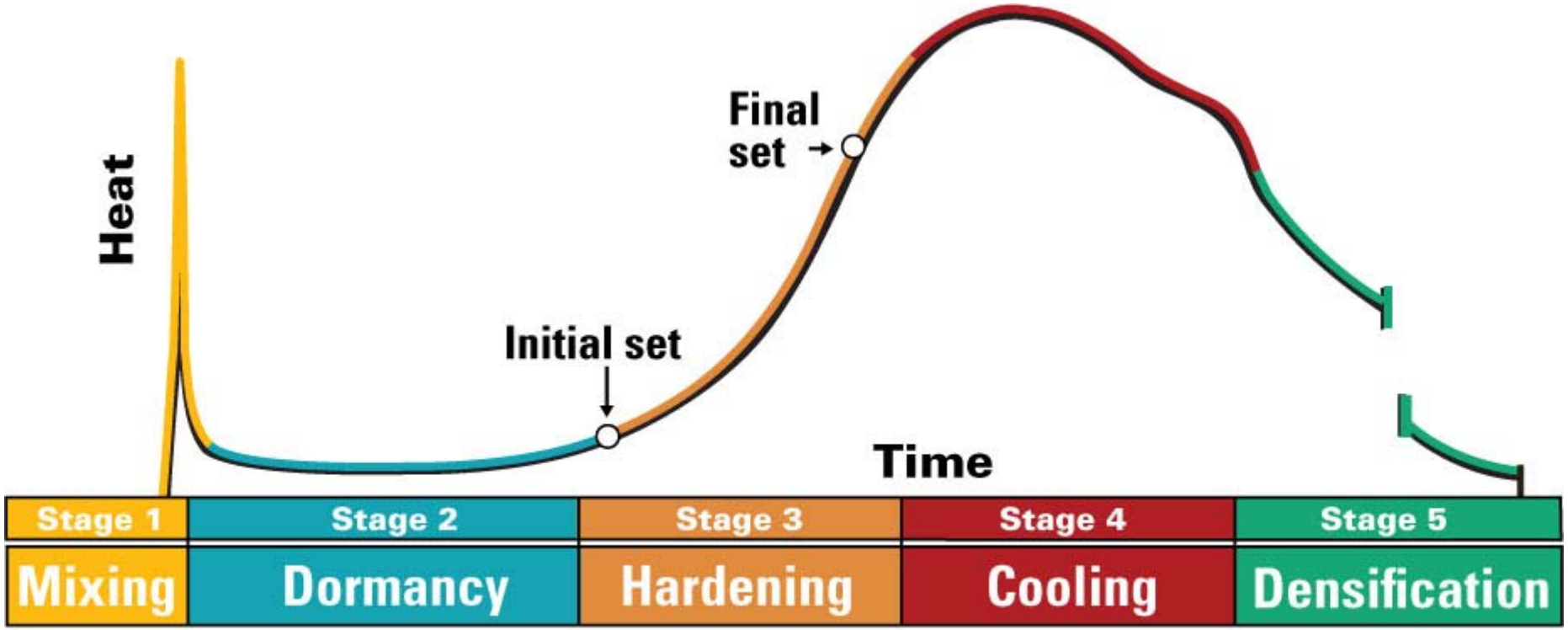
Gypsum precipitate (False set)



High Temperature

Accelerates reactions

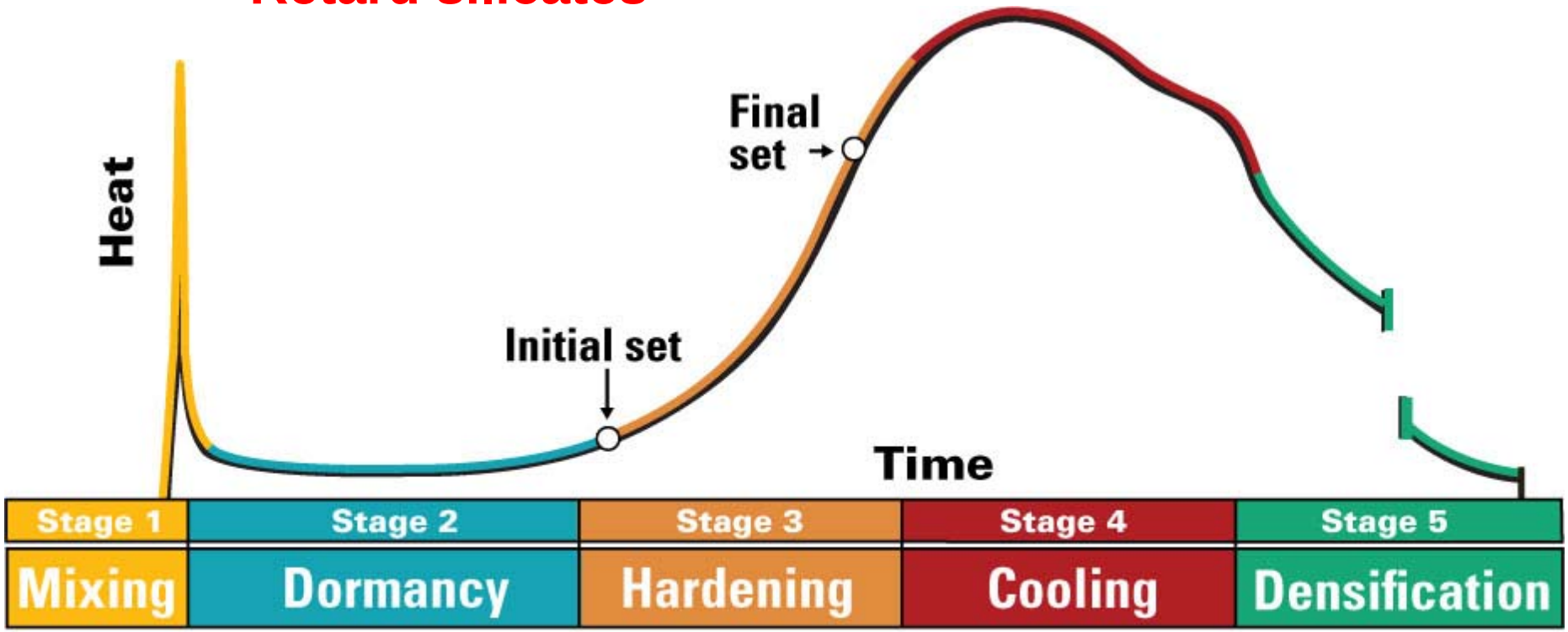
Reduces rate that calcium dissolves



Water Reducers

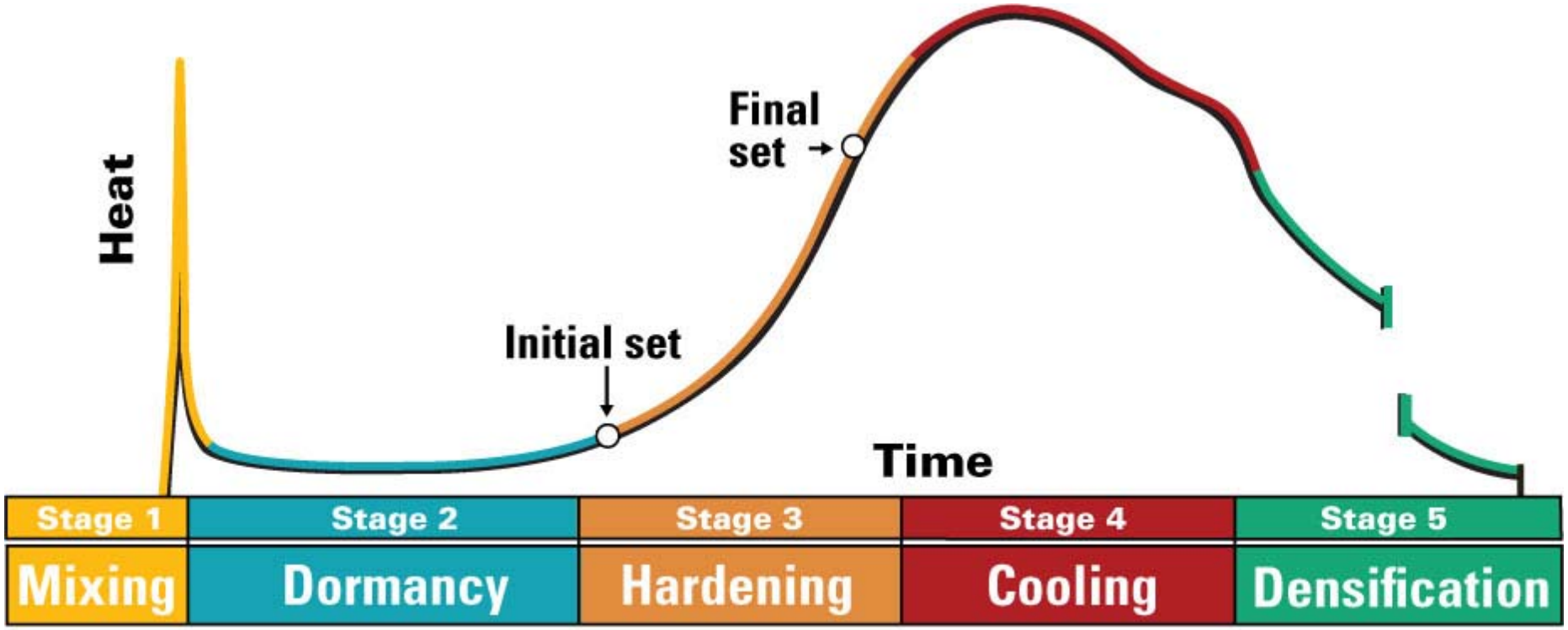
Accelerate aluminates

Retard silicates



Fly ash

High calcium fly ash may contain extra C_3A



Case History 1

New observation: The color has changed

Case History 1

Now what?

- Panic
  (Doesn't help)
- Visit the batch plant
  - Concrete looks great in the truck
  - Calibrations are OK
  - Aggregates are the same
  - Fly ash is different!!!

Case History 1

Actions:

- Leave out fly ash
  (Inspector refuses; it has to be there for ASR mitigation)
- Revert to original fly ash supply
  (No longer available)
- Delay WRA addition by 30 seconds
  (It works)

Case History 1

Why?

- Classic incompatibility
- Fly ash with high C_3A content
- WRA at high temperature

Case History 2

The problem:

- It's October and warm
- Everything is going well, until…
- One 200-yard section is cracked transversely every 6 feet

Early Age Transverse Crack

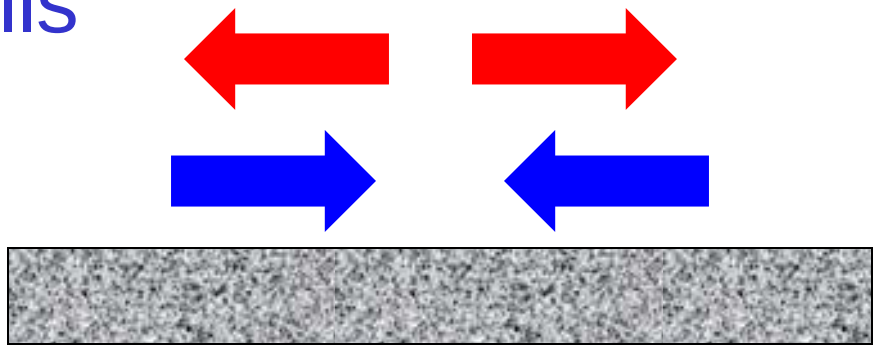
Case History 2

Review:

- No change in materials
- No change in saw timing
- No change in base and subgrade
- Concrete placed between 9 and 11 am

Primary Factors of Early-Age Cracking

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

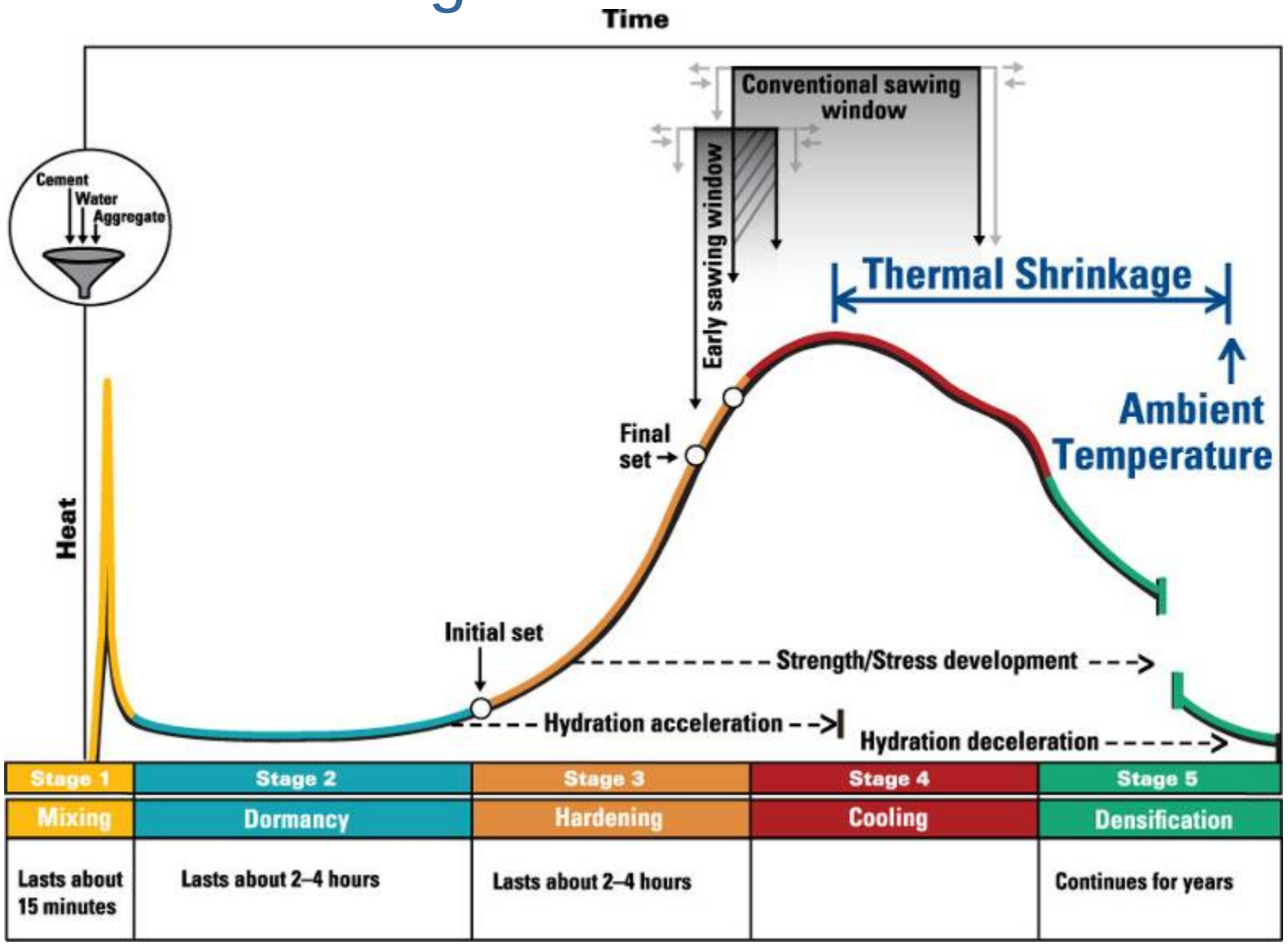


- Concrete expands as **moisture** increases and contracts as **moisture** decreases

Drying and Thermal Shrinkage

- Drying and thermal contraction shrinkage
  - ✓Most frequent causes of early-age cracks
  - ✓Thermal-related cracks
    - Normally observed in the first day
  - ✓Drying-related cracks
    - May appear over a longer period

Thermal Shrinkage



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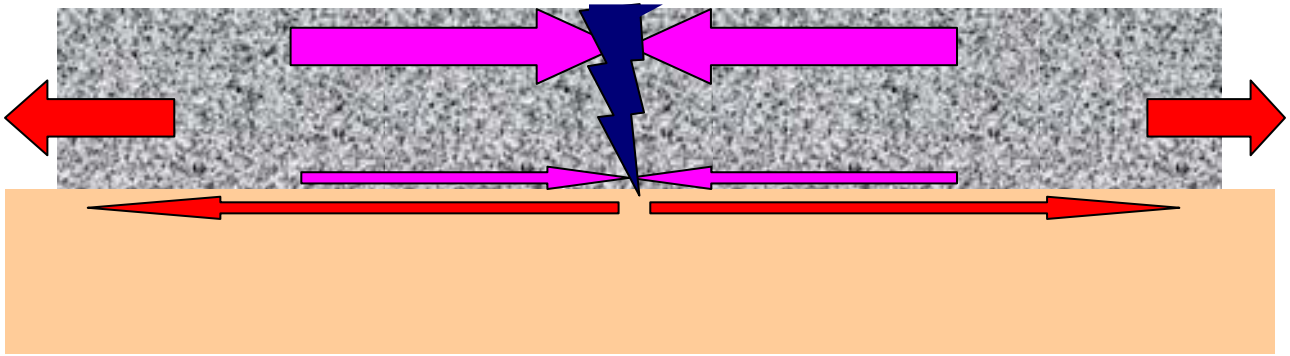
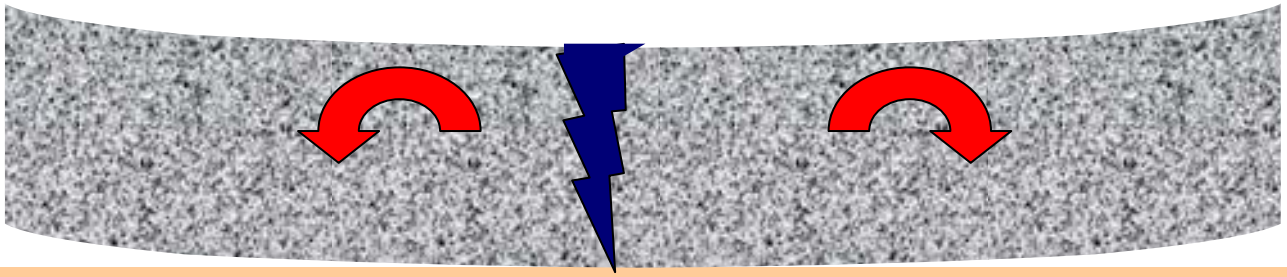
Thermal Shrinkage

- Air temperature can cause significant changes in shrinkage and expansion rates
- Hydration peaks within the first 12± hours after the concrete is placed
  - ✓ Volume starts to contract as hydration slows and concrete temperature drops
  - ✓ Movement of slab is constrained by subgrade
  - ✓ Contraction produces tension
  - ✓ Accelerated contraction (such as cold front) can cause thermal shrinkage cracking

Thermal Stresses





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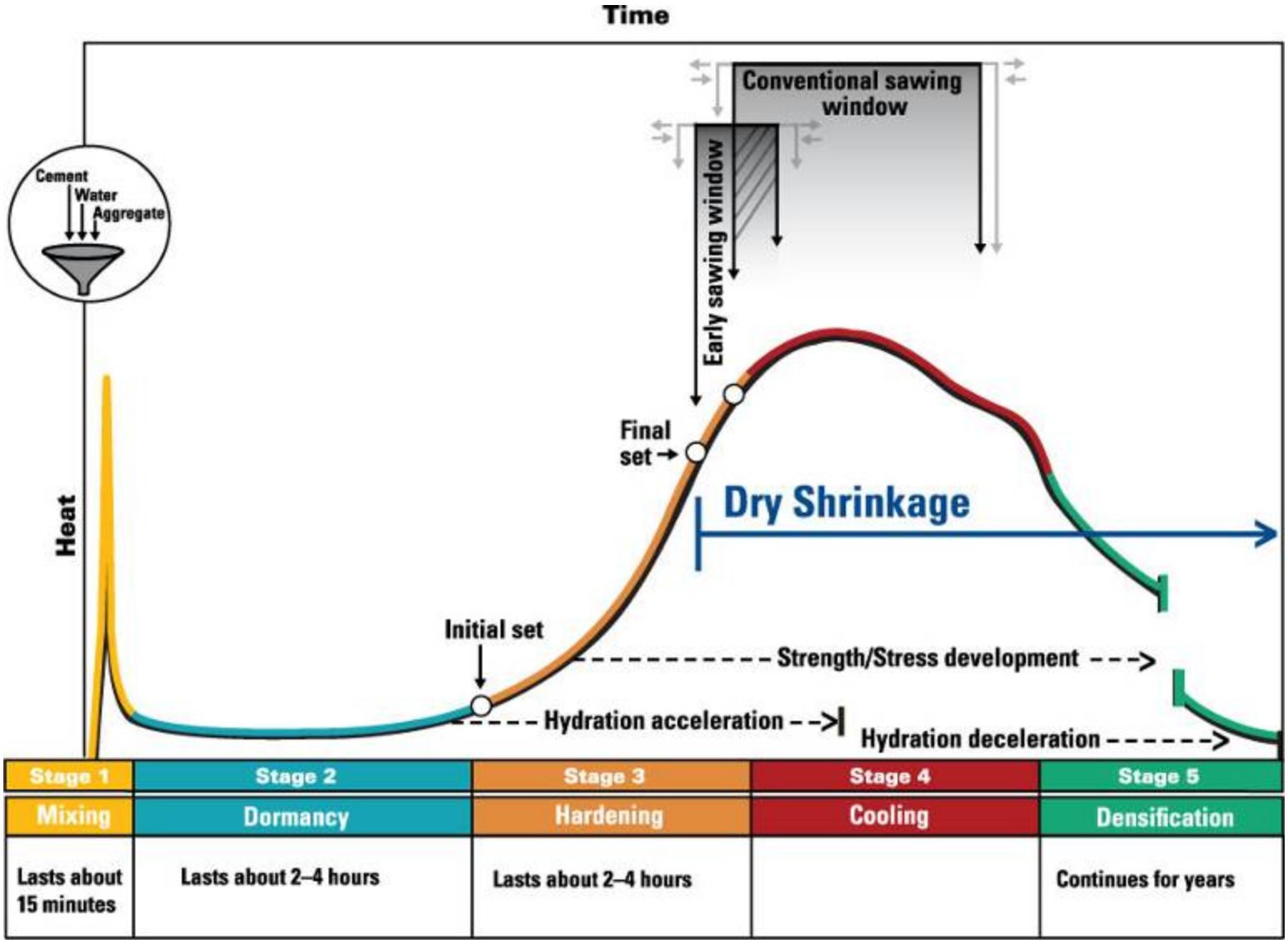
(IMCP—pages 161–162)

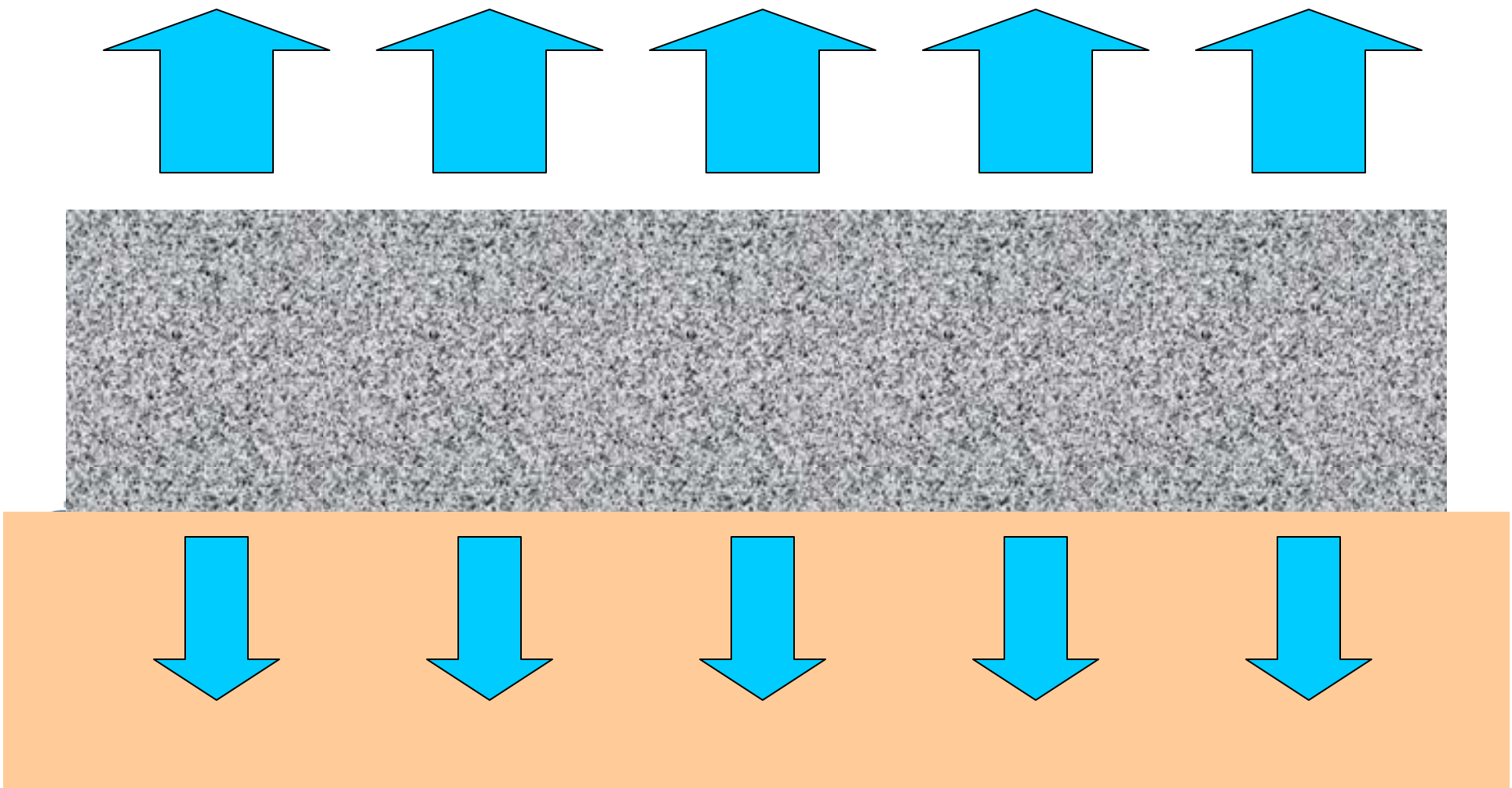
Drying Shrinkage

- Loss of mixing water through hydration and evaporation
  - ✓Overall volume contracts
  - ✓Greater paste content results in greater drying shrinkage and higher tensile stress
  - ✓Low relative humidity of air can affect shrinkage diffusion

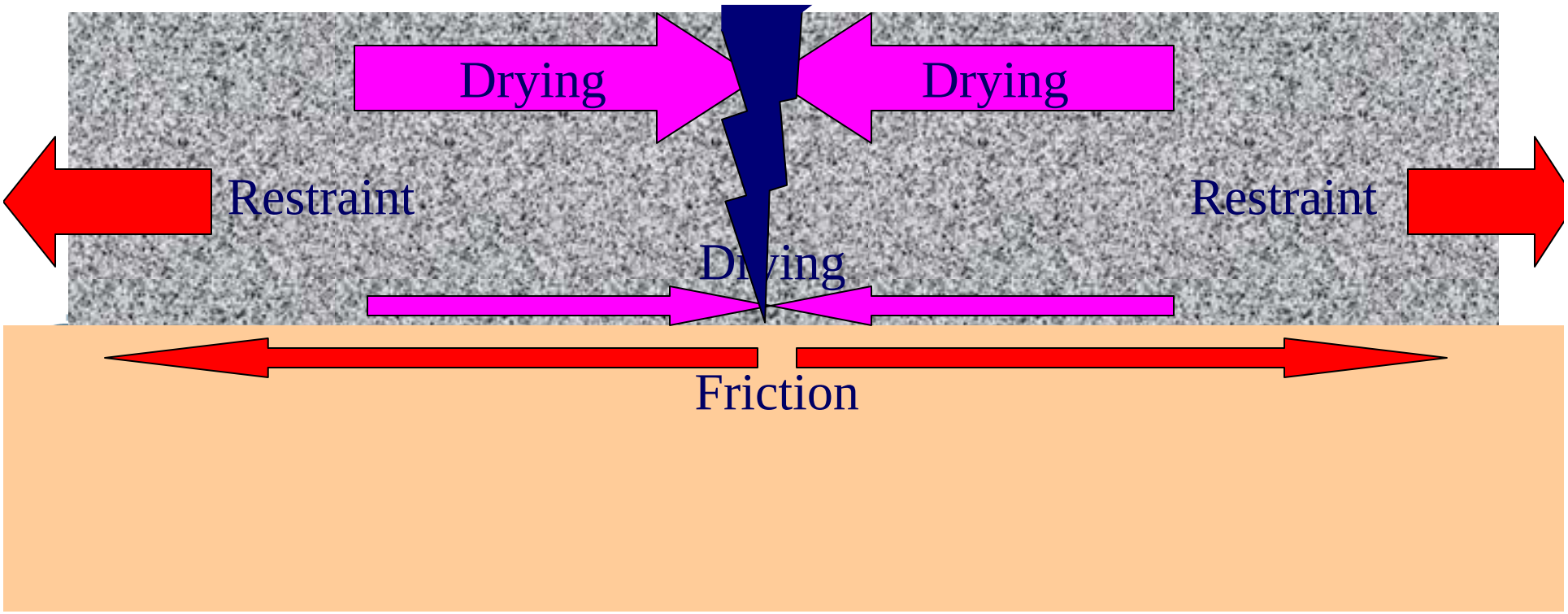
Drying Shrinkage



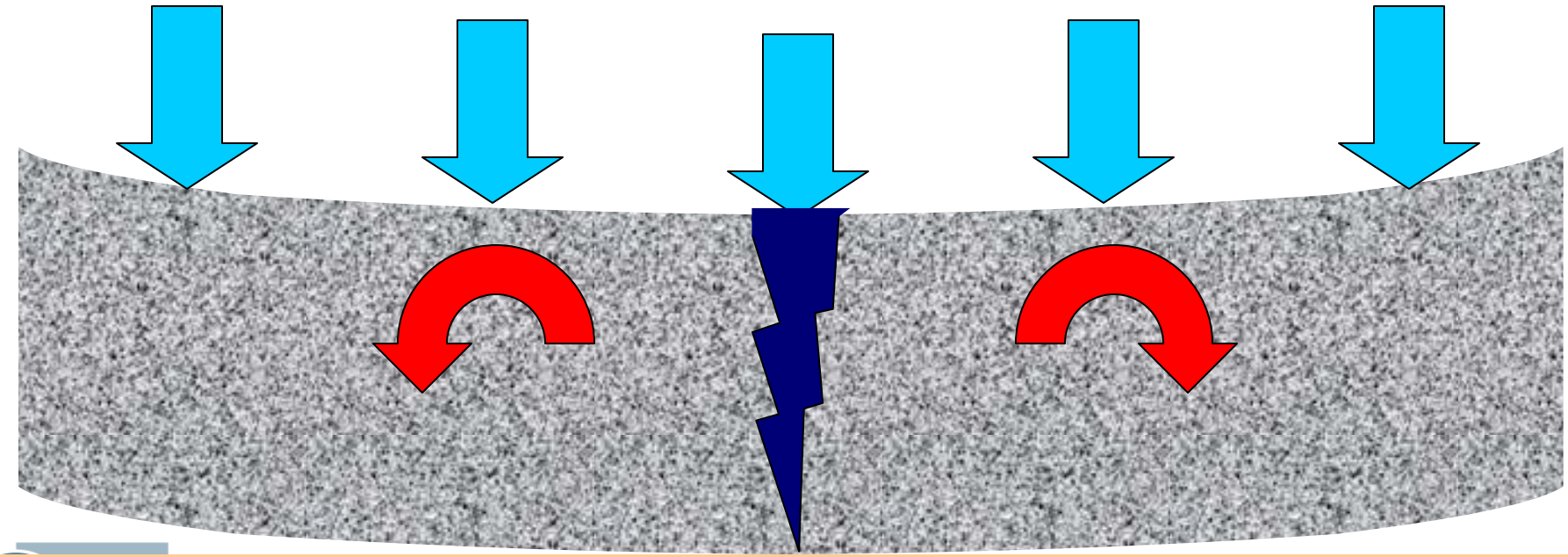
Drying



Drying Strains and Stresses



Warping



Curling and Warping

- Differential temperature and moisture levels throughout slab depth typically occur during the first 72 hours
- As a result, concrete contracts or expands differently throughout the depth

(IMCP—pages 150–151)

Curling and Warping

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

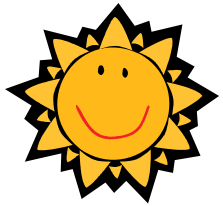
Curling => Change in **Temperature**

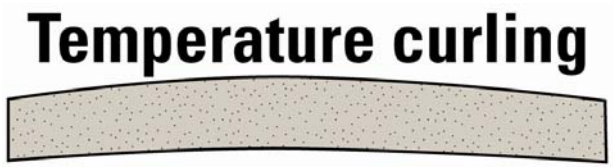
Warping => Change in **Moisture**

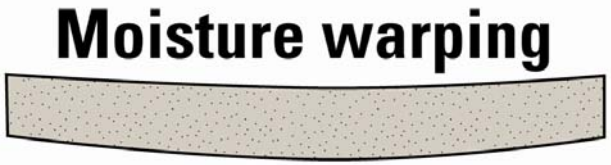
- These movements, especially when restrained, can cause cracking

(IMCP—pages 150–151)

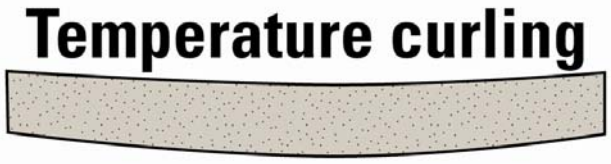
Curling and Warping of Slabs

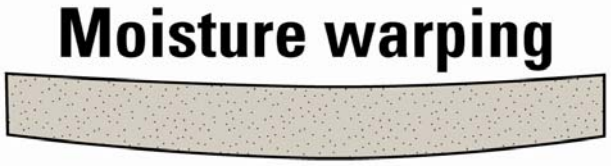






Hot days (curling counteracts warping)





Cool nights (curling compounds warping)

Case History 2

Review:

- No change in materials
- No change in saw timing
- No change in base and subgrade
- Concrete placed between 9 and 11 am
- It rained at 6 pm

Case History 2

Cause:

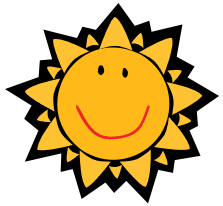
- Sharp drop in temperature when concrete is at its hottest
- Added surface moisture which goes into expansion

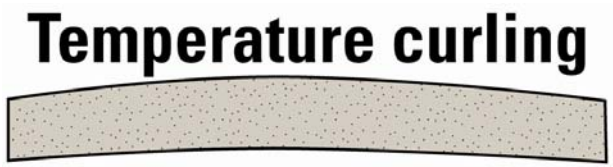
Solution:

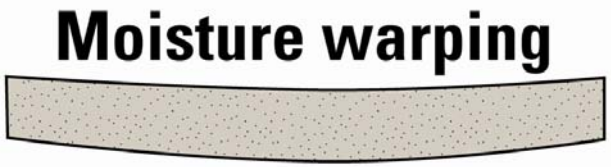
- Keep it covered
- Early entry sawing

(IMCP—pages 150–151)

Curling and Warping of Slabs







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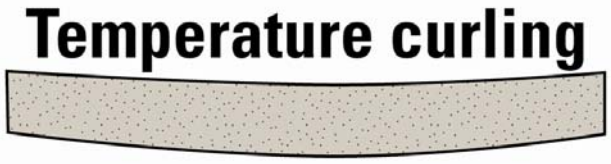

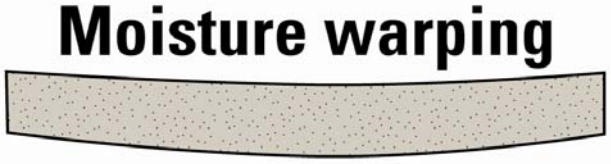

Cool nights (curling compounds warping)

Case History 3

The problem:

- It's late October with beautiful warm days and frost at night
- You have placed 2 lanes and now are adding the third
- You see transverse cracks, about a foot or so long, taking off from the joint in the new lanes lanes, and heading for the cold joint next to the previously placed lanes
- They only occur about every 3rd or 4th joint
- They only occur in the first half of the day's pour

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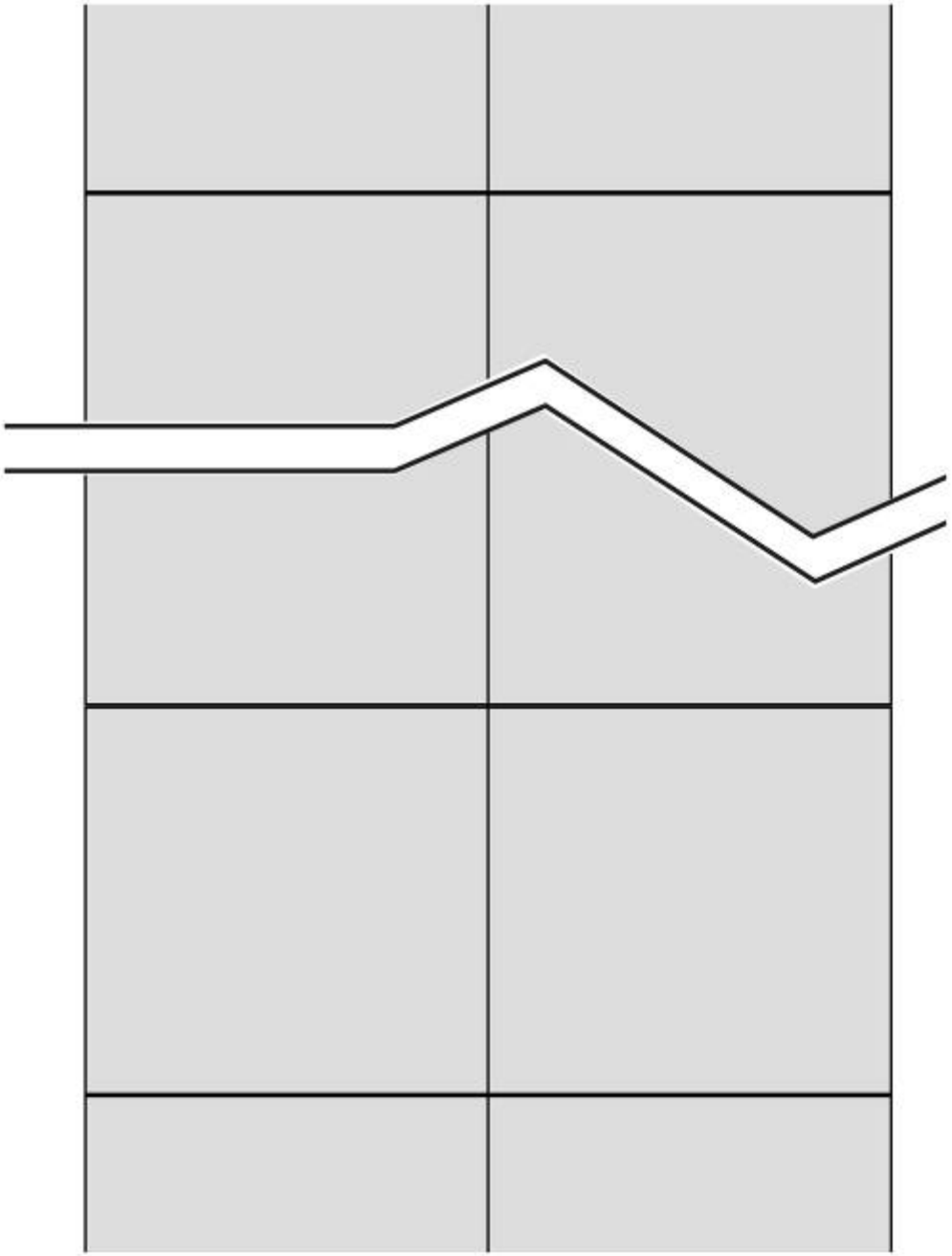

2 lane existing roadway

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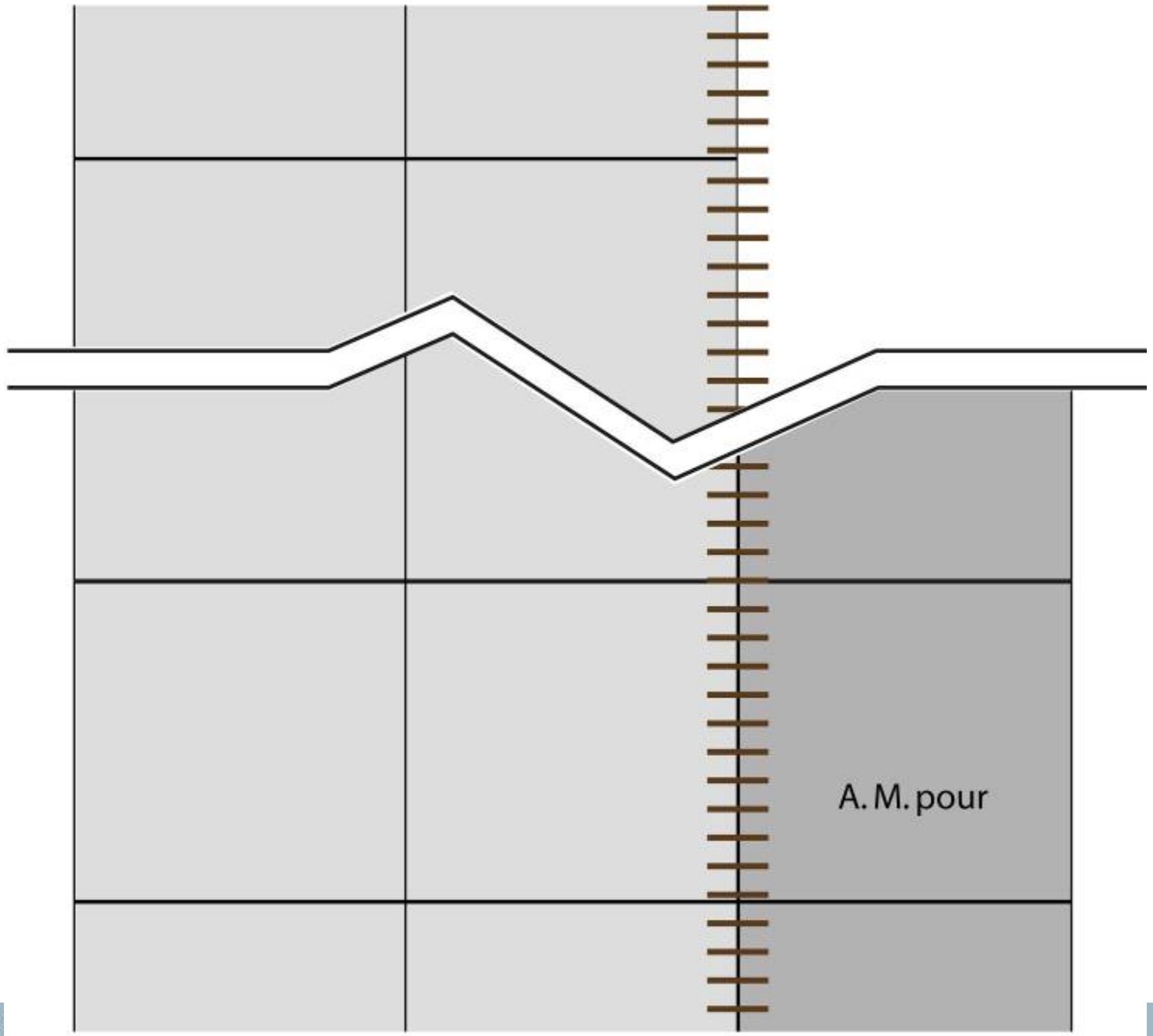

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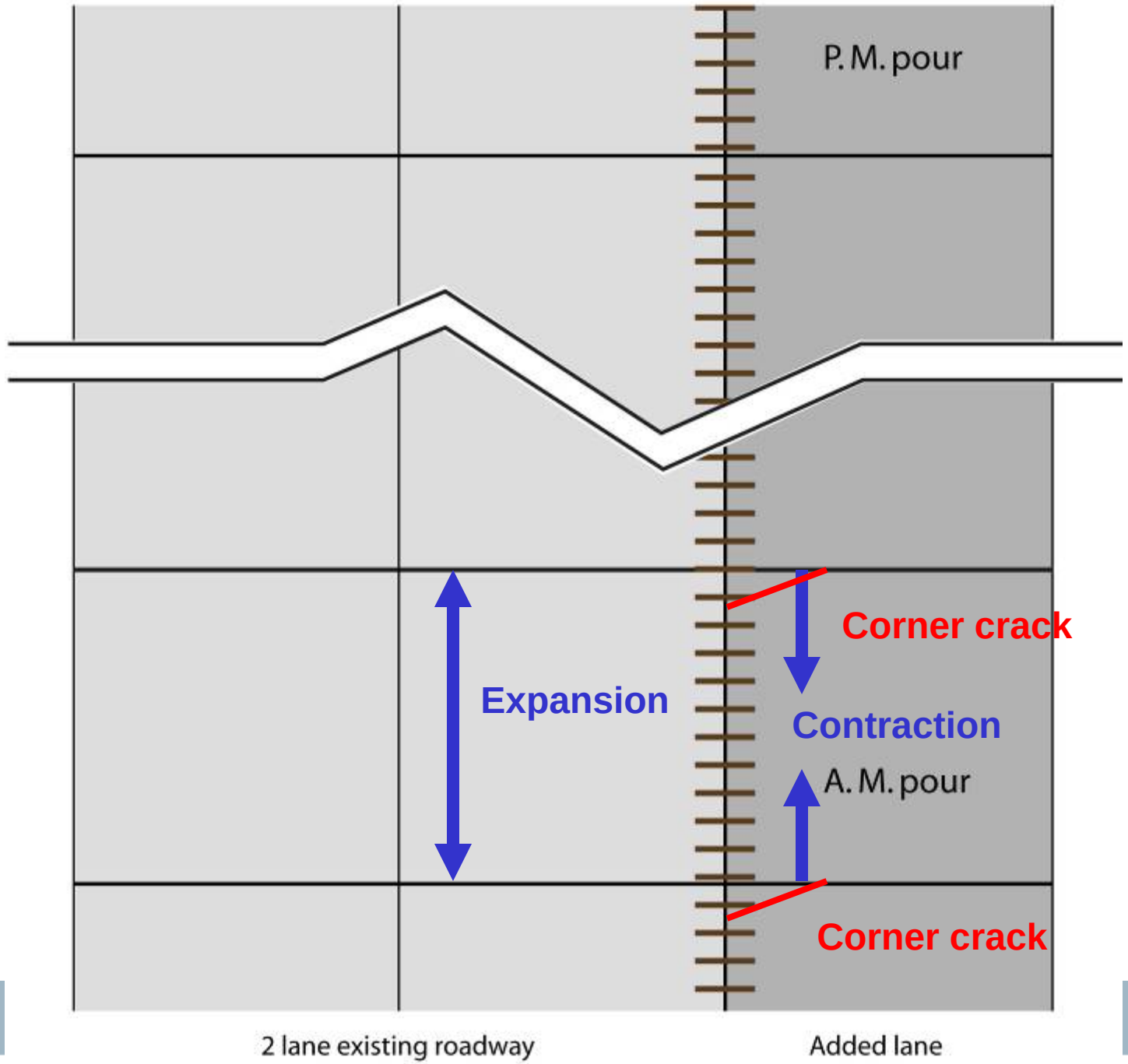

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Case History 3

Cause:

- Thermal expansion or later contraction in the existing lanes puts stress on the new concrete. At the same time, shrinkage in the fresh concrete or later thermal expansion put an additive stress on the slab at the tie bars

Solution:

- Saw as soon as possible, with an early entry saw
- Start paving later in the day

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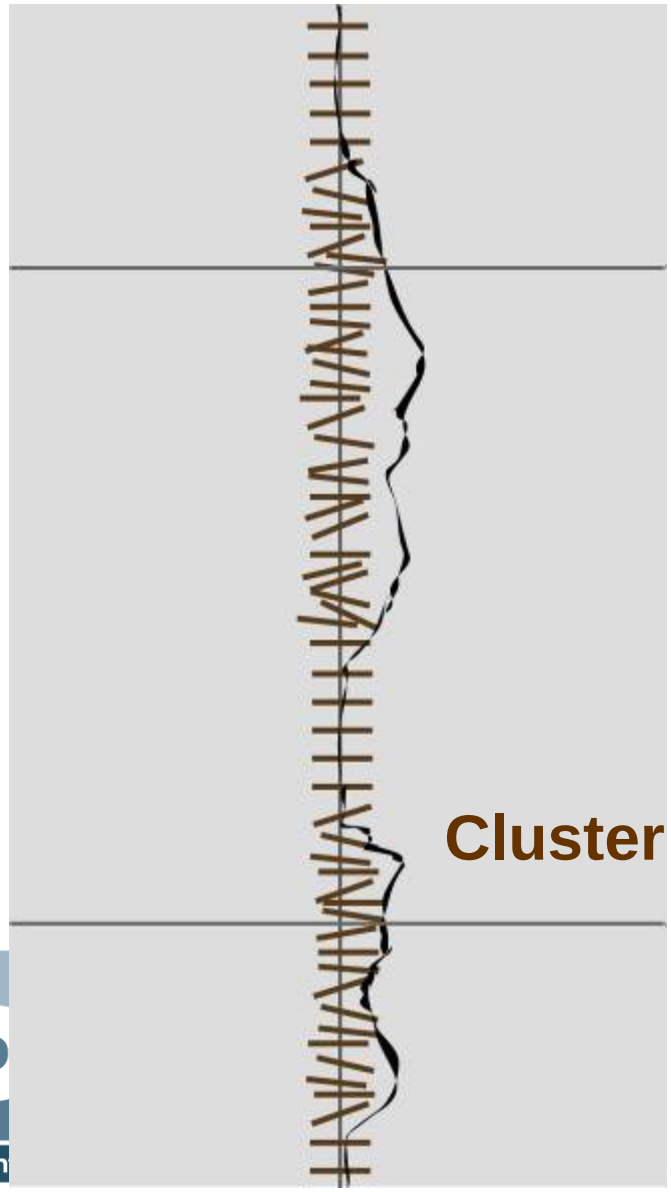
Case History 4

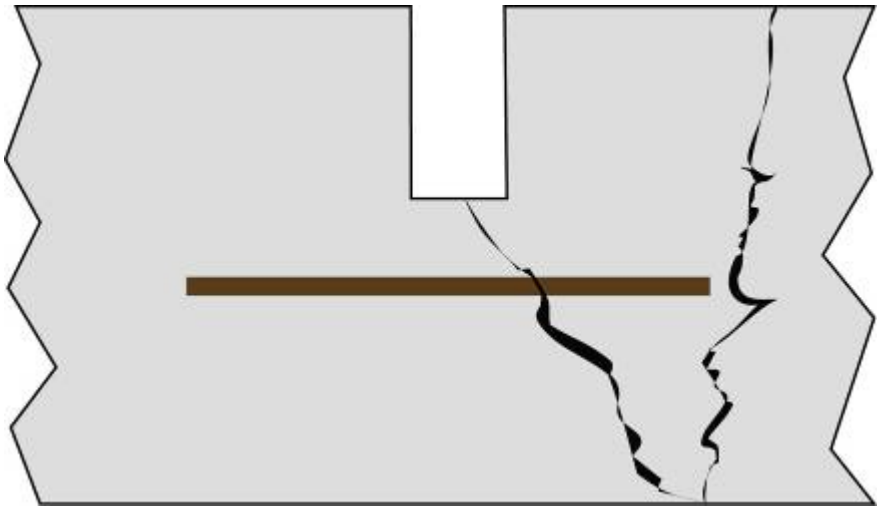
The problem:

- It's early summer with temperatures in the 90's during the day and high 70's at night.
- You have placed 2 -12 lanes and completed transverse and longitudinal sawing in an timely manner. There are dowel bars in the transverse joints.
- After about three days you see very light longitudinal crack, running parallel too and about 1.5 ft± from the longitudinal joint.
- The cracks periodically goes into the longitudinal joint and this in and out pattern continues down the highway in a random manner.

Longitudinal crack



What happened?



Cluster of tie bars

Case History 4

Cause:

- The longitudinal tied steel were spaced in very tight groupings (by hand) in some locations and properly spaced in others. In all cases the tied steel bars were not properly aligned horizontally or vertically.

Solution:

- Make sure the tie-bar inserter is properly inspected
- Tied bars are periodically checked in place.

THANK YOU!

Dale Harrington, Peter Taylor
Representing the National Concrete Pavement Technology Center