Illinois Department of Transportation

# IDOT Bridge Decks:

## Ongoing IDOT Research & An FHWA Process Review


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# Bridge Deck Cracking in Illinois

- Transverse cracks at regular intervals at both positive and negative moment regions commonly observed
- Longitudinal cracking occurs after extensive transverse cracking

Concrete Girder

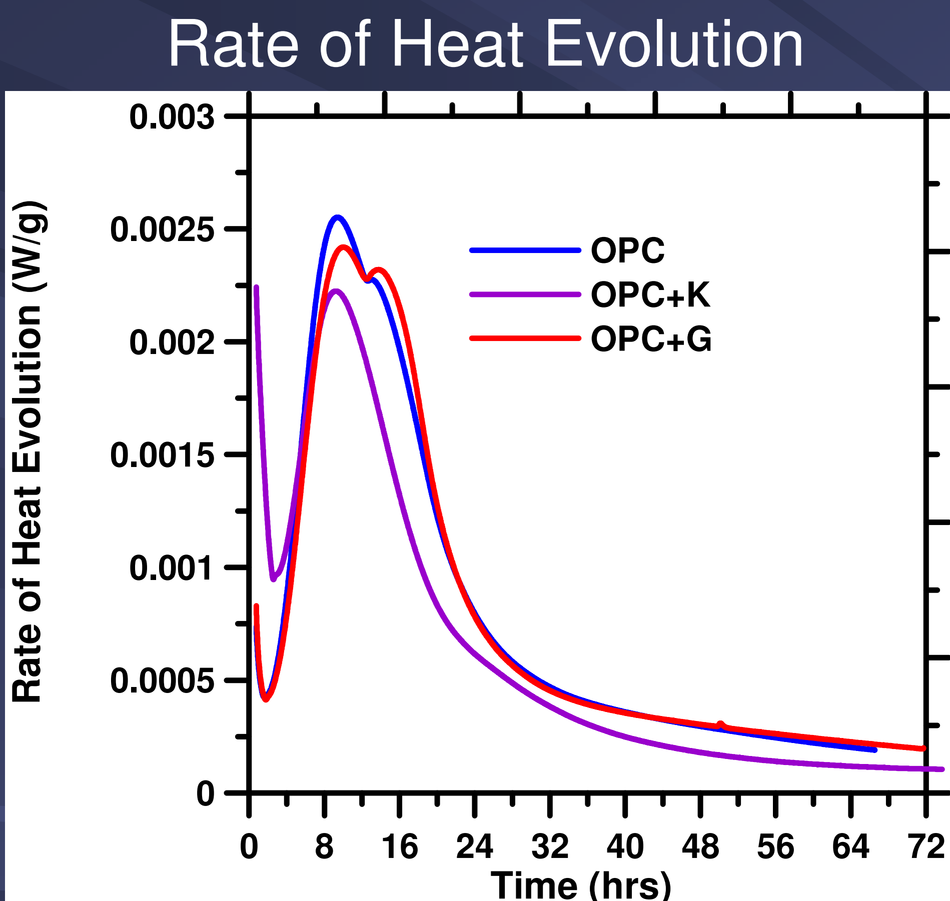
Steel Girder

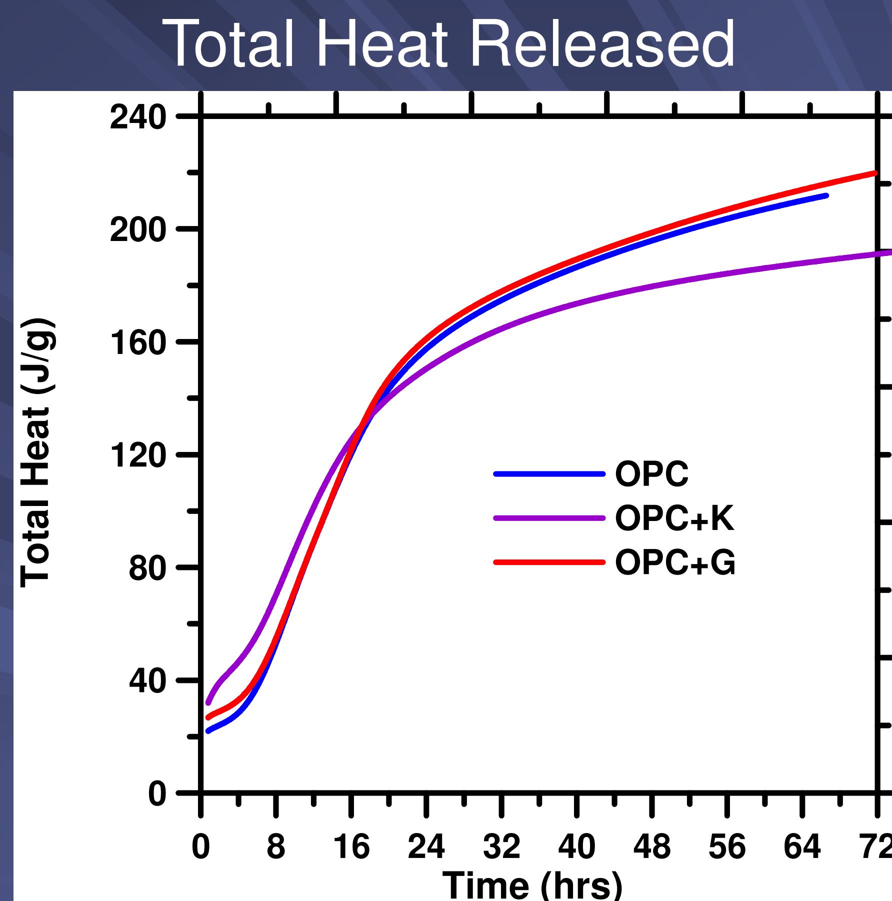
Crack

# Types K & G Expansive Cementitious Material

- Shrinkage compensating (expansive) supplement
- Expands in volume at early age
- If restrained: develops compressive stress that may compensate tensile stresses from shrinkage

# Characterizing Materials

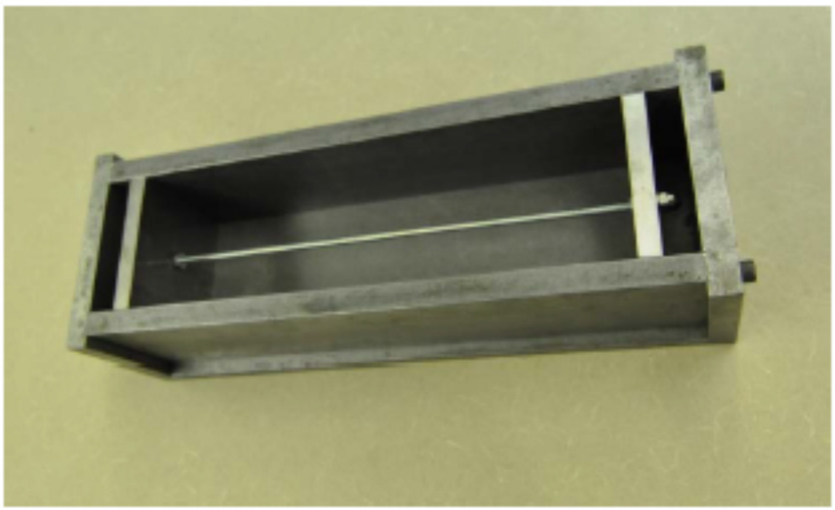



**Total heat released during hydration similar to ordinary portland cement paste.**

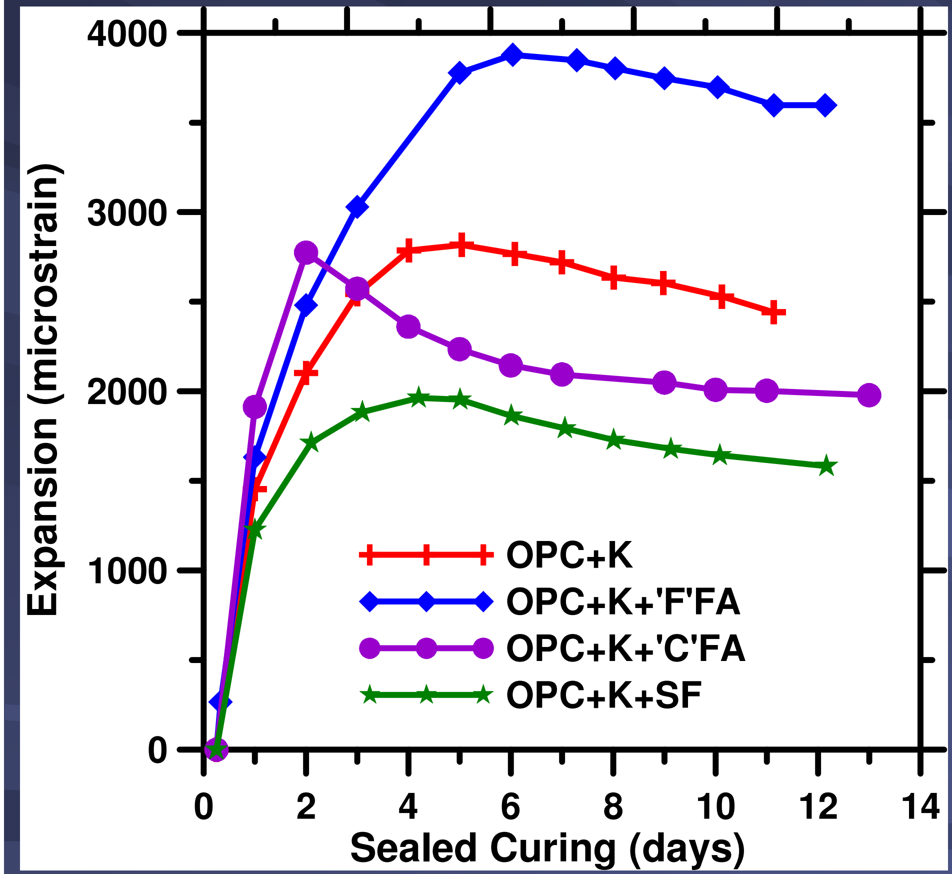
# Characterizing Materials

Restrained Expansion
(ASTM C 878)

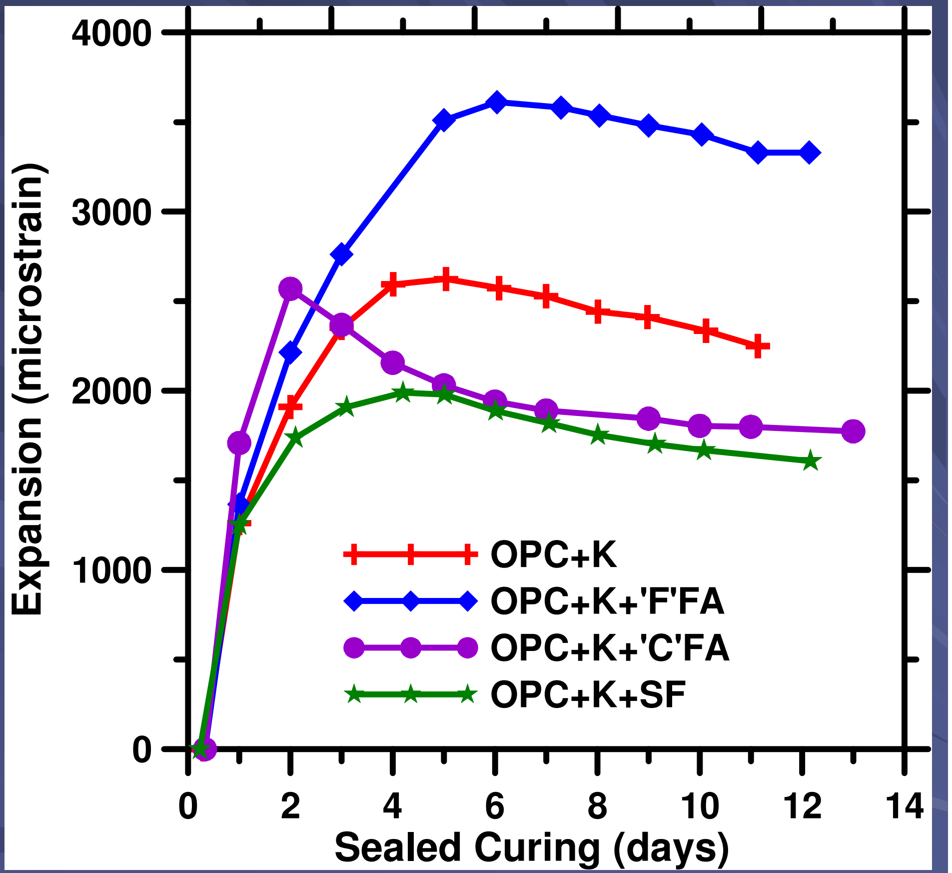


Unrestrained Deformation
(ASTM C 1698)

# Unrestrained Expansion of Paste

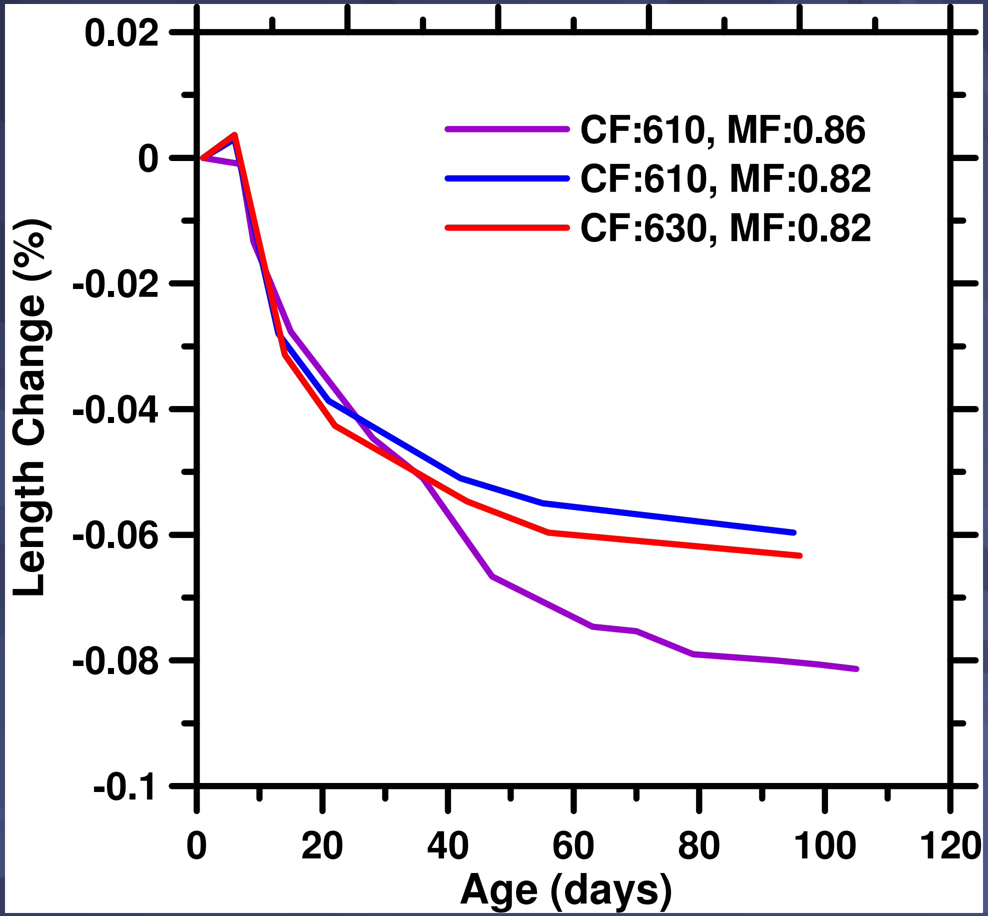



Measurements starting at 6 hrs




Measurements starting at Final Set

# Optimizing Mixes




MF: Mortar Factor
CF: Cement Factor

**~25% reduction in drying shrinkage by optimizing mix**

# Large-Scale Study

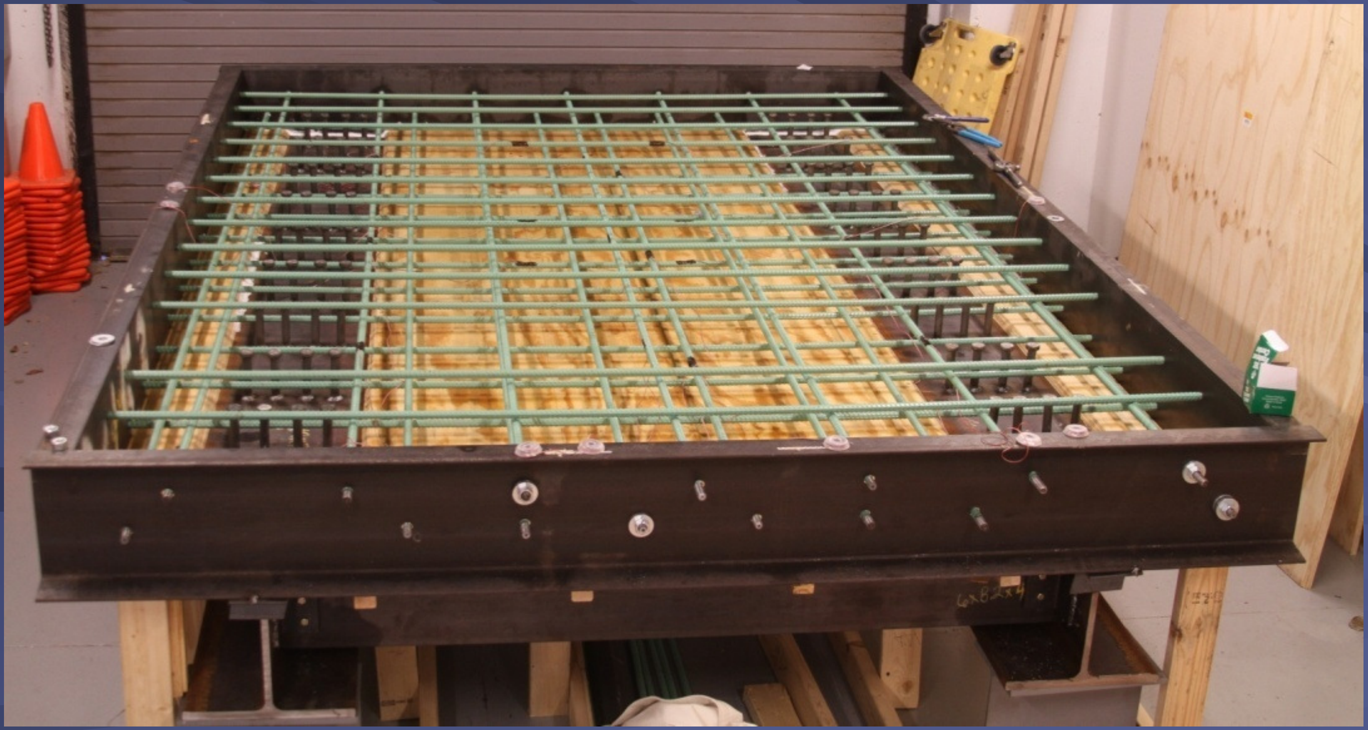
- **Focus:** Cracks due to temperature and shrinkage
- Cracking due to restraint provided by superstructure
- Cracking (tensile) stress depends on many other factors such as
  - **Girder Stiffness**
  - **Deck Thickness**
  - **Slab Reinforcement (including shear studs)**
  - **Support Conditions**
  - Skew Angle
  - Type of Bearings
  - Form Types
  - Others

# Large-Scale Simulation

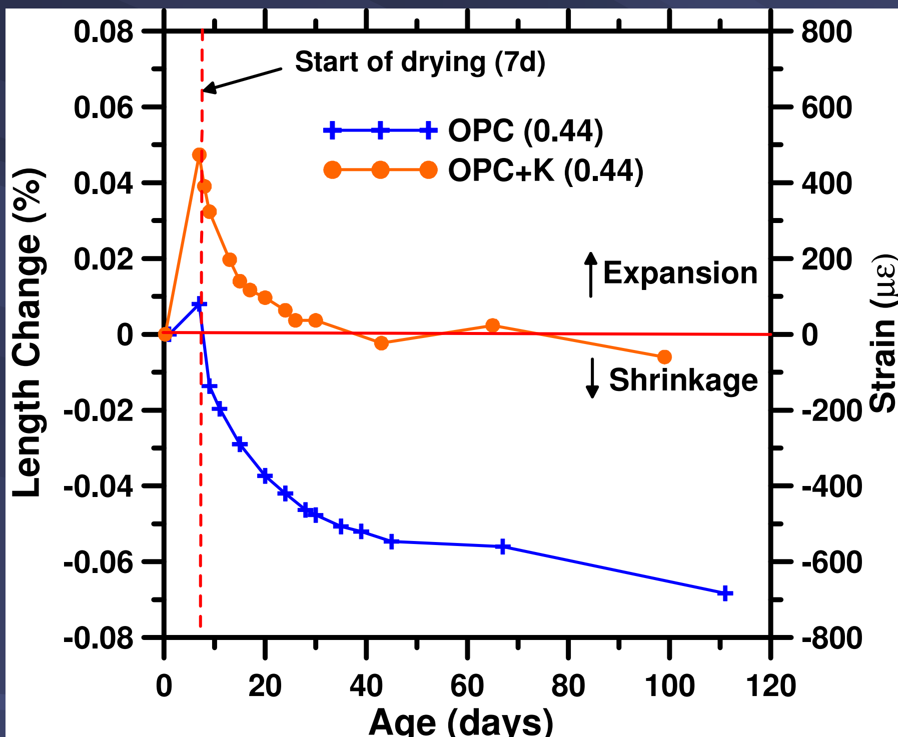
- Simulate bridge superstructure
- Concrete surface, rebar, and girders instrumented to measure strains, temperatures and deformations
- Data obtained will be used to calibrate FEM model for a full scale 3-span bridge

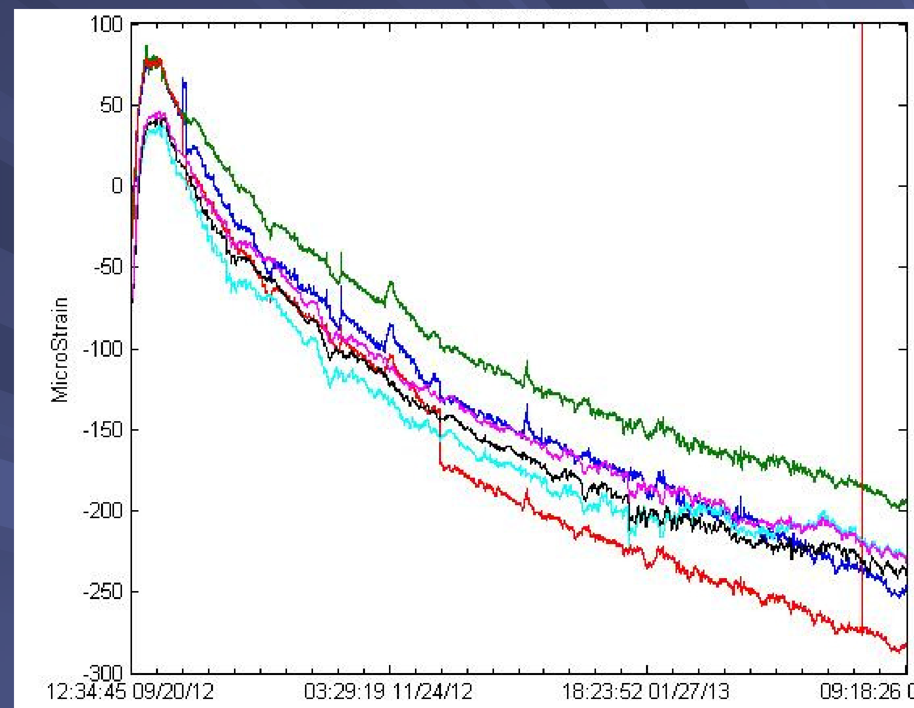
# Large-Scale Simulation

- Dimensions: 7’ x 10’, 8” deck thickness, 6’ girder spacing
- Longitudinal reinforcement fixed to rigid steel C-channels to simulate continuity of longitudinal reinforcement
- Shear studs included



# Small-Scale & Large-Scale Study



# Linking Small-Scale Testing with Large-Scale Simulation

- Correlating shrinkage reduction from small-scale testing with…
- tensile strain reduction in reinforcing bar from large-scale simulation:

i.e., maximum strain registered by longitudinal bar was 75 $\mu\varepsilon$ compared to 500 $\mu\varepsilon$ expansion in small-scale testing

The **external restraint** (C-channels) and **higher percentage of reinforcement** in large-scale deck simulation created a much stiffer system which resulted in lower strain values in reinforcing bar compared to that in small-scale concrete prisms.

# Linking Small-Scale Testing with Large-Scale Simulation

- How does compressive stress developed by expansion mitigate tensile stress due to shrinkage?
- How much does external restraint impact such mitigation?
- Does it matter if creep reduces the developed compressive stress?
  - Elastic modulus plays important role in governing deformation under load (or creep).

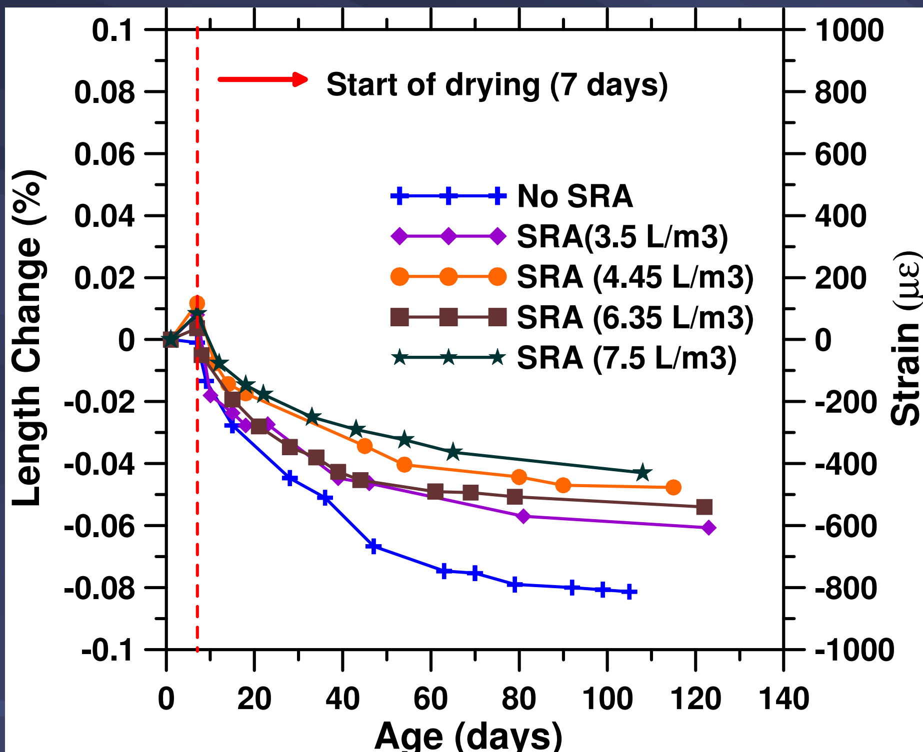
# Type K Bridge Deck Poured 2012

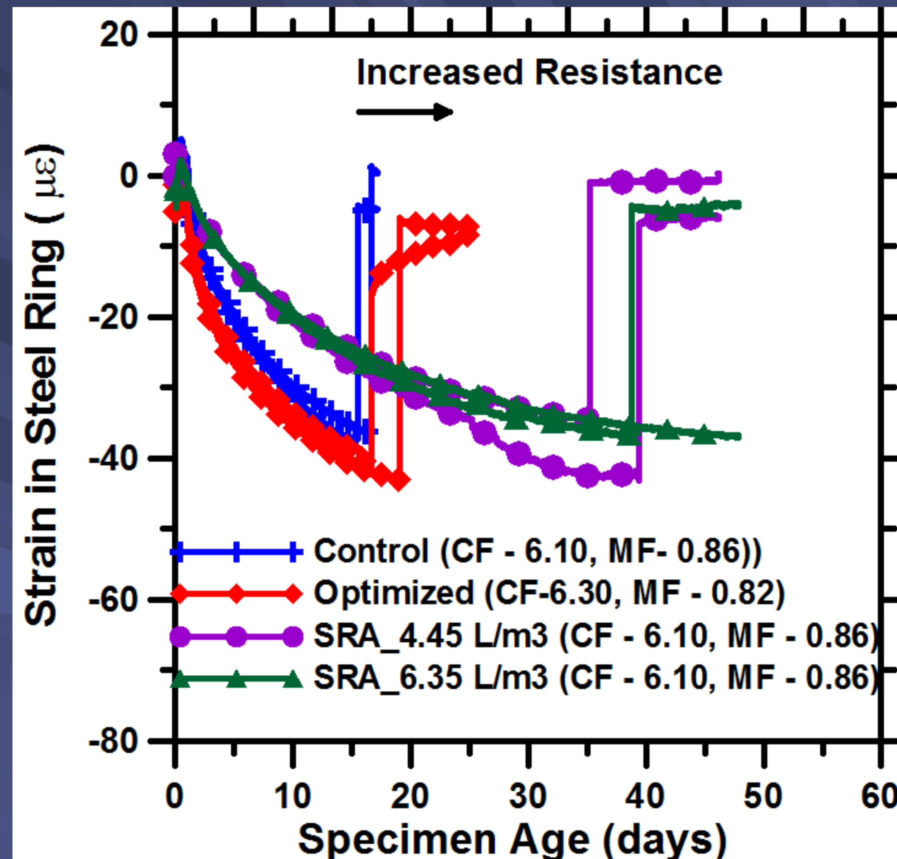
# Balling in Mix

# Balling in Mix → Blisters

4
RED END
5
ENGINEERS
6
OIL
8
JOINTS
9
P.R. APP'D.
10

# Also Evaluating SRAs




SRA has been found to be effective reducing shrinkage; effectiveness depending on dosage.

# IDOT Bridge Deck Construction:

An FHWA Process Review

# FHWA Process Review

- Conducted in 2012
- Observed 27 bridge decks pours
- Consisted of BMPR, BBS, Construction, Districts, FHWA, and Industry
- Resulted in 14 Findings, Recommendations

# Findings, Recommendations

1. Fogging
2. Curing
3. Exterior beam rotation
4. Too much hand finishing
5. Use of vibratory screeds
6. Ambient temperature restrictions
7. Concrete testing methods
8. Alternative curing materials
9. Bridge deck grinding
10. Cleaning leaking mortar off the beams
11. Concrete delivery rates
12. Plastic chair supports for deck reinforcement
13. Location of finishing machine rails
14. Training course for bridge deck construction

# Item 1: Fogging

- Foggers now banned from finishing machine
  - Their use was ineffectual or counter-productive
- Handheld foggers to be used until curing mats are placed
  - Minimum pressure 2,500 psi - like a backyard power washer

# Evaporation Rate

- Not a result of the process review
- Instead of referring to the evaporation chart to determine if fogging is needed, the following equation was added:

$$E = (T_c^{2.5} - rT_a^{2.5})(1 + 0.4V)x10^{-6}(English)$$

$$E = 5[(T_c + 18)^{2.5} - r(T_a + 18)^{2.5}](V + 4)x10^{-6}(Metric)$$

Where:

$E$ = Evaporation Rate, lb/ft$^2$/h (kg/sq m/h)

$T_c$ = Concrete Temperature, °F (°C)

$T_a$ = Air Temperature, °F (°C)

$r$ = Relative Humidity in percent/100

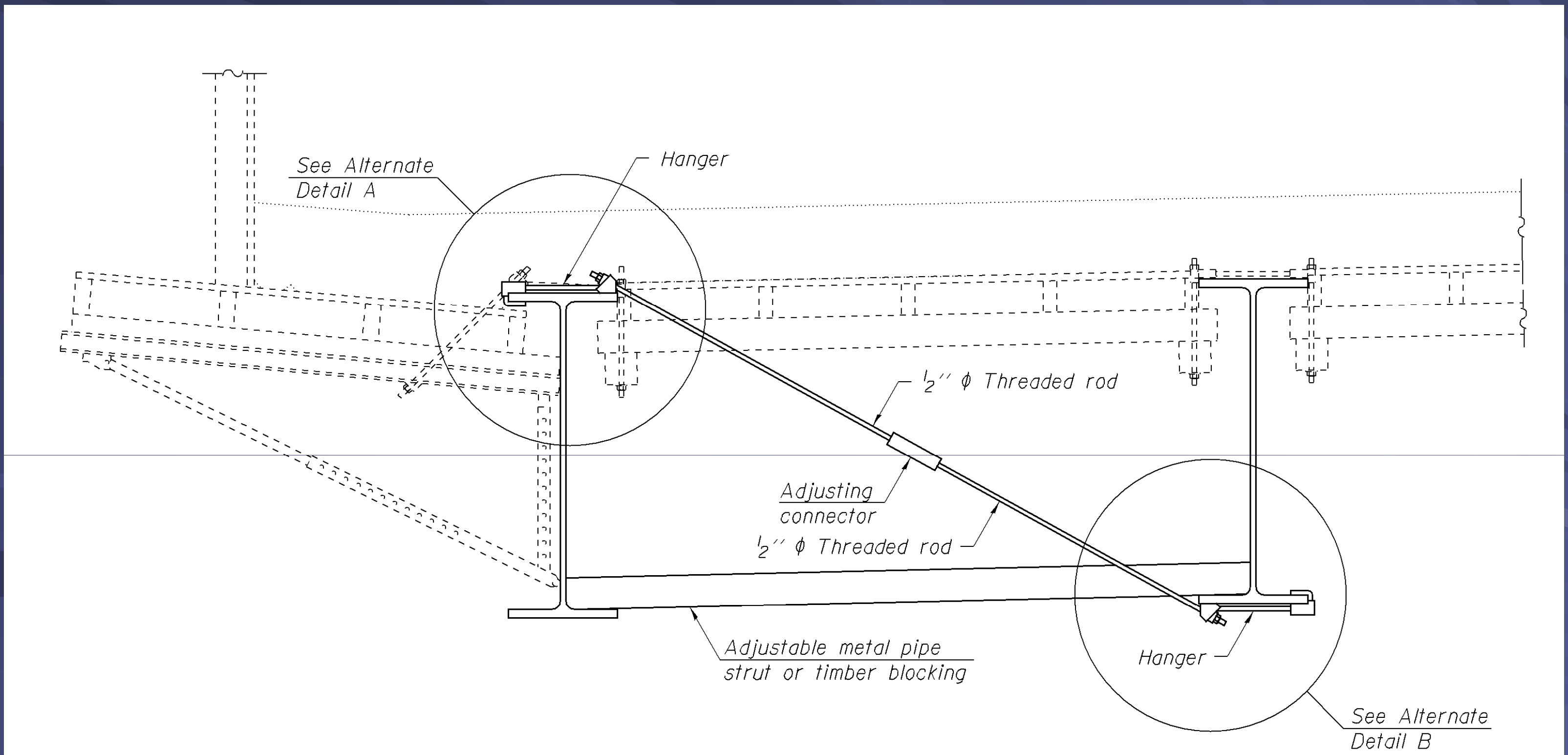
$V$ = Wind Velocity, mph (km/h)

# Item 2: Curing

- Long delays in placing cotton mats
- Common excuse: trying to avoid marring the deck
- Revise language to de-emphasize marring

# Item 3: Exterior Beam Rotation

- Illinois Center for Transportation study



# Item 4: Hand Finishing

- 21 of 27 decks had hand finishing over all or the majority of the deck – undesirable practice
- **Goal:** Let the finishing machine do the work
- Limit to problems found during straightedge testing and for those surfaces not reached by the finishing machine

# Item 5: Vibratory Screeds

- Now allow vibratory screed in lieu of finishing machine
- Allowed on deck pours up to 24’ wide
- Vibratory screeding followed by finishing with hand-operated longitudinal floats having blades not less than 10 ft long and 6 in. wide

# Item 6: Ambient Temperature

- Currently no ambient temperature restrictions for deck pours
- Concrete temperature of 90F at discharge
  - Ice or water chillers
  - Nighttime pours
  - Water/shade stockpiles

# Ambient Temperature Debate

- 85F air temperature requirement may or may not force nighttime deck pours
  - Contractors may have trouble bidding
    - Low bidders maybe assumed daytime pours
  - District may not want nighttime pours
  - Several day wait for cooler weather

# Questions

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