Best Practices in Bridge Deck Construction

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Bridge Deck Cracking
Types of Cracking

- Transverse
- Longitudinal
- Map
Transverse Cracking

- Appear before or shortly after opening
  - Typically less than 28 days
- Full depth
- Through plane of reinforcement
- Spaced 3 to 10 ft apart
- Concrete and steel superstructures
Transverse Cracking
Stay-in-place Forms
Wood Forming
Impact

Delamination in Deck

Corrosion of Reinforcement

Full Depth Transverse Crack
Longitudinal Cracking
Construction Detail

7 7/8"

W36x150
Map Cracking

Typically observed in Overlays
General Experience

• Monolithic Concrete Structures
  – Least cracking

• Steel Superstructures
  – Most cracking
  – Restraint
    • Composite action
    • Stay-in-place steel forms
Field Instrumentation
I65 over SR25
Deck Instrumentation
Longitudinal Reinforcing Strain

Microstrains

Date (2000)

Traffic

8/15  8/20  8/25  8/30  9/4
Stress Transfer

#4 Top & #5 Bottom Long. Bars @ 11 13/16”

\[ f'_{c} = 5,600 \text{ psi} \]
\[ @ \text{19 days} \]
\[ f_{cr} = 6\sqrt{f'_{c}} \]

\[ T_{c} = T_{s} \]
\[ (450 \text{ psi})(12\text{ in.} \times 7\frac{7}{8}\text{ in.}) = (0.52\text{ in.}^{2}) f_{s} \]

\[ f_{s} = 81,800 \text{ psi} \]
Field Instrumentation Findings

- Transverse cracking at 19 days
- Longitudinal reinforcement yielded
- Cracking not influenced by live loads
Field Investigations

• 4 bridges
  – I-65 (Standard Design)
  – SR 18 (Empirical Designs)
  – Thayer Road Bridge (FRP)
  – SR 23 (HPC & Purdue Empirical)

• Instrumentation
  – Strain Gauges
  – Thermocouples

• Crack Mapping
Field Study Findings

• Field Investigation
  – Low shrinkage concrete decreases cracking
  – Reinforcement affects cracking
  – Thermal effects contribute to cracking
  – Crack Growth
    • Maximum cracks 5x initial
  – Reinforcement may yield
Restrained Shrinkage

• Eliminate Restraint
  – Composite action
  – Pan forms

• Eliminate Shrinkage
  – Concrete shrinks

• Eliminate Cracking
  – Minimize cracking
Laboratory Composite Models

As Built

Free Shrinkage
Shrinkage Investigation

Direction Of Shrinkage Measurement

4’-4”
7 7/8”
2’-9 1/2”
Specimen Variables

- Wood Forms
  - Unsealed
  - Sealed
- SIP Forms
  - Transverse
  - Longitudinal
- Reinforcement
- Thickness
Effect of Sealing

Top of Deck

Micro Strains

Sealed

Unsealed

7-7/8”
Deck Pan Stiffness

Longitudinal Orientation Top

Transverse Orientation

Deck Pan (Sealed)

No Pan (Sealed)

300 0 -300 300 0 -300
Micro Strains Micro Strains

9 7/8"
Concrete shrinkage & curing
Low Shrinkage Concrete

- Reduced cement and water content
- Increased sand, addition of fly ash

![Graph showing compressive strength over time for Low Shrinkage and Class C concrete.](image-url)
Shrinkage Behavior

![Graph showing shrinkage behavior with time. The graph has a y-axis labeled 'Strain (µε)' and an x-axis labeled 'Time (days). The graph shows the wet cure, drying shrinkage, and thermal expansion and shrinkage phases.](image)
Effect of Concrete Mix

- Long term effects
  - Low shrinkage mix: decreased total shrinkage
Reinforcement Stress at Time of Cracking

\[ f_t = 6\sqrt{f_c} \]

\[ F_c = 6\sqrt{f_c}A_c \]

\[ T = F_c \]

\[ A_c \left(6\sqrt{f_c}\right) = A_s f_s \]

\[ \rho_g = \frac{6\sqrt{f_c}}{f_y} \]
Maximum Crack Width

Crack Width (mils)

Steel Stress (ksi)

9” Spacing

18 mils

12 mils

6 mils

Black

1.3 Factor
Reinforcement Layout

18” Spacing, #4 bar
Minimum
0.27%

4” Spacing, #4 bar
Minimum
1.25%

ρ_g
Specimen Construction
Strain - # 4 Bars

- S1 (ρ=0.27%, s=18")
- S4 (ρ=0.42%, s=12")
- S6 (ρ=0.63%, s=8")
- S2 (ρ=1.25%, s=4")
- Concrete Shrinkage

Strain (με)

Time (Days)
Control Cracking

- Design
- Materials
- Construction
Recommendations

• Curing is Essential
  – Minimum 7 day wet cure

• Minimize drying shrinkage
  – Mix design
  – Minimize concrete strength

• Alternative forming system
  – Flat forms
  – Remove forms
Recommendations

- Additional reinforcement required
  - Above Shrinkage and Temperature

\[ A_s = \frac{6\sqrt{f'_c}}{f_y} A_g \]

- Max spacing 9 in. for Epoxy Coated Reinforcement