Concrete Bridge Deck Cracking

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March 2007

Problem

- Cracking of newly constructed decks
- Risk of concrete deterioration
- Shortened bridge deck service life

Types of Cracking

- Random
- Transverse
- Longitudinal
- Diagonal
- Pattern
Full Depth Transverse Cracking

Bridge Deck Deterioration

How to Avoid the Problem?
- Seal Cracks
- Prevent Cracking
Plastic Settlement Cracking

- **Time of Cracking:**
  - During Bleeding
- **Type of Cracking:**
  - Over Topmost Bar
- **Cause of Cracking:**
  - Concrete Settles between Bars

Cracking due to Plastic Settlement

Causes of Plastic Settlement Cracking

- Shallow Cover Depth
- High Slump
- Large Bar Size
Transverse Crack over Transverse Bar

Thermal Shrinkage Cracking

- Time of Cracking:
  - During Curing
- Type of Cracking:
  - Transverse, Full Depth
- Cause of Cracking:
  - Deck Cools Down & Shrinks, Beams Restrains

<table>
<thead>
<tr>
<th>Slump (in)</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/8</td>
<td>80.4</td>
<td>87.8</td>
<td>92.2</td>
</tr>
<tr>
<td>1</td>
<td>60.0</td>
<td>71.0</td>
<td>78.1</td>
</tr>
<tr>
<td>1 1/2</td>
<td>18.6</td>
<td>24.5</td>
<td>45.6</td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
<td>1.0</td>
<td>14.1</td>
</tr>
</tbody>
</table>
Curing Concrete Deck

Deck During Cure

Deck Restrained by Longitudinal Girders
Control of Thermal Shrinkage Cracking

- Differential Deck/Beam Temperature During Cure:
  - $\Delta T_{\text{Max}} \approx 40 \, ^\circ F$
  - $\Delta T_{\text{Safe}} \approx 22 \, ^\circ F$
- Watch for Decks During Cold Weather Cure

Methods to Minimize Thermal Shrinkage Cracking

- Reduce heat of hydration:
  - Use less cement.
  - Replace cement with fly ash or slag.
  - Use Type II cement.
  - Use cement from a proven source.
  - Use retarders.
Methods to Minimize Thermal Shrinkage Cracking

- Cold Weather Precautions:
  - Do not overinsulate deck:
    - Temp. 55 to 75°F
  - Enclose & heat beams
    - Temp. 55 to 75°F

Cold Weather Cure; Deck under Insulation

Heating Deck from Abutment
Drying Shrinkage Cracking

- **Time of Cracking:**
  - After Curing
- **Type of Cracking:**
  - Transverse, Full Depth
- **Cause of Cracking:**
  - Deck Dries & Shrinks, Beams Restrained
Deck Shrinkage Restrained by Longitudinal Girders

Transverse Cracks

Control of Drying Shrinkage Cracking

- Allowable Specimen Shrinkage (ASTM C157):
  - Long-Term Shrinkage ≤ 700 microstrain, or
  - 28-Day Shrinkage ≤ 400 microstrain
- In Conjunction with 22°F Differential Deck/Beam Temperature
Control of Drying Shrinkage

Cracking

- Decrease in Allowable Shrinkage for every 5°F
  - Increase in Diff. Deck/Beam Temperature:
    - Long-Term Shrinkage: 80 microstrain, or
    - 28-Day Shrinkage: 45 microstrain
  - Max. Diff. Deck/Beam Temperature = 35°F

Shrinkage Specimen Mold
3"x3"x11" Prism

Preparing Shrinkage Specimens
Factors Affecting Drying Shrinkage

- Aggregate Mineralogy
- Cement Source & Type (chemistry)
- Admixtures (chemistry)
- Excessive Water in Mix
- Excessive Paste in Mix

Aggregate Mineralogy (Laboratory Experiments)

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>Dolomite</th>
<th>Sandstone</th>
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</thead>
<tbody>
<tr>
<td>Drying shrinkage (microstrain)</td>
<td>420</td>
<td>1012</td>
</tr>
<tr>
<td>Absorption</td>
<td>0.25%</td>
<td>1.60%</td>
</tr>
</tbody>
</table>
Recommendation on Aggregate

1. Use “Hard” aggregate:
   - Quartz, Dolomite, Limestone
2. Do Not use “Soft” aggregate
   - Sandstone, Slate
3. If aggregate performance Questionable
   - Limit course aggregate Abs. to 0.50%
   - Limit fine aggregate Abs. to 1.50%

Cement Source & Type (Laboratory Experiments)

Cement source and type:

<table>
<thead>
<tr>
<th>Source</th>
<th>“A”</th>
<th>“B”</th>
<th>“C”</th>
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</thead>
<tbody>
<tr>
<td>Type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td>Drying shrinkage (microstrain)</td>
<td>375</td>
<td>785</td>
<td>488</td>
</tr>
</tbody>
</table>

Recommendation on Cement

1. Use cement with a proven source
2. Use type II cement
3. Use cement content as low as possible
**Recommendation on Admixtures**

1. Always make trial mix
2. Observe mix properties
3. Measure shrinkage
4. Change source if not satisfied

**Recommendation to Reduce Water**

1. Use lower Slump
2. Use larger Aggregate
3. Use more aggregate & less Paste
4. Use water reducers
5. Concrete at lower Temperatures