Program Background and Introduction to Specifications

9th Annual Meeting - Construction of Crack-Free Concrete Bridge Decks
July 19, 2011
Kansas City, MO

Outline
• Overview of LC-HPC
• Specifications and their application
• Where we stand

Scope of Work
Low-Cracking High Performance Concrete (LC-HPC) Bridge Decks

23 LC-HPC decks (28 placements) completed through 2010
1 LC-HPC deck to be constructed this year
More to be let in MN

Bridges
Primarily composite steel girder bridges
Full-depth slabs
Removable forms
Matching bridges to serve as a control where possible (Phase I)

Why LC-HPC?

Negative impact of cracks on concrete in the decks.

Negative impact of cracks on corrosion performance of both conventional and epoxy-coated reinforcement.
Our goal
- Eliminate cracking in bridge decks
- To do this, we need to minimize cracking due to
  - Plastic shrinkage
  - Settlement over reinforcing bars
  - Thermal contraction
  - Drying shrinkage

Factors that affect cracking
- Age
- Deck type
- Cement paste content
- Compressive strength
- Air content
- Slump
- Temperature
- Construction date
- Curing
- Construction techniques

Age

<table>
<thead>
<tr>
<th>Bridge Age, months</th>
<th>Crack Density, mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>25</td>
<td>0.20</td>
</tr>
<tr>
<td>50</td>
<td>0.40</td>
</tr>
<tr>
<td>75</td>
<td>0.60</td>
</tr>
<tr>
<td>100</td>
<td>0.80</td>
</tr>
<tr>
<td>125</td>
<td>1.00</td>
</tr>
<tr>
<td>150</td>
<td>1.20</td>
</tr>
<tr>
<td>175</td>
<td>1.40</td>
</tr>
<tr>
<td>200</td>
<td>1.60</td>
</tr>
<tr>
<td>225</td>
<td>1.80</td>
</tr>
<tr>
<td>250</td>
<td>2.00</td>
</tr>
<tr>
<td>275</td>
<td>2.20</td>
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</tbody>
</table>

Bridge Deck Type

<table>
<thead>
<tr>
<th>Bridge Deck Type</th>
<th>Crack Density, mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>7% SFO</td>
<td>0.51</td>
</tr>
<tr>
<td>5% SFO</td>
<td>0.49</td>
</tr>
<tr>
<td>CO</td>
<td>0.44</td>
</tr>
<tr>
<td>MONO</td>
<td>0.33</td>
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</tbody>
</table>

Number of Bridges: 9 (7%), 18 (5%), 30 (CO), 16 (MONO)
Number of Surveys: 9 (7%), 36 (5%), 52 (CO), 32 (MONO)

Paste Content

<table>
<thead>
<tr>
<th>Percent Volume of Water and Cement, %</th>
<th>Crack Density, mm²</th>
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<tbody>
<tr>
<td>26</td>
<td>0.19</td>
</tr>
<tr>
<td>27</td>
<td>0.15</td>
</tr>
<tr>
<td>28</td>
<td>0.68</td>
</tr>
<tr>
<td>29</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Number of Placements: 8 (26), 16 (27), 4 (28), 1 (29)
Number of Surveys: 16 (26), 31 (27), 9 (28), 11 (29)

Slump

<table>
<thead>
<tr>
<th>Slump, mm (in.)</th>
<th>Crack Density, mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>38 (1.5)</td>
<td>0.18</td>
</tr>
<tr>
<td>51 (2.0)</td>
<td>0.31</td>
</tr>
<tr>
<td>64 (2.5)</td>
<td>0.51</td>
</tr>
<tr>
<td>76 (3.0)</td>
<td>0.87</td>
</tr>
</tbody>
</table>

Number of Placements: 5 (38), 23 (51), 5 (64), 1 (76)
Number of Surveys: 10 (38), 40 (51), 11 (64), 3 (76)
Control of early evaporation and improved curing - Silica Fume Overlays

Control of early evaporation and improved curing - Silica Fume Overlays

Date of Construction - Silica Fume Overlays

Overall Approach
Work to reduce plastic, settlement, thermal and drying shrinkage cracking

Low cement & water contents
Low slump
High strength is not good
Low evaporation rate
Construction methods and materials matter
More early cracking means more total cracking
LC-HPC Specifications

- Optimized Aggregate Gradation
- Low-absorption Aggregate
- 1 inch Max Size Aggregate
- Cement Content $\leq 540$ lb/yd$^3$
- w/c ratio = 0.43 – 0.45
- Air Content of 8 ±1½%
- Designated slump 1½ – 3 in. (3½ in. max)
- Controlled temperature
- Improved curing

Concrete temperature control

55 – 70°F
50 – 75°F if approved by Engineer

Cold-weather concreting

Maintain temperature of both girders and deck.

Alternatives to Pumping

Concrete Buckets
Conveyor Belts
Placing

- Air cuff/bladder valve on pump or limit drop with conveyor
- Filling end walls and diaphragms ahead of slab

Consolidation Requirements

Vertically mounted internal gang vibrators

Concrete Finishing

- General Rule: Less is More
  - Pan or burlap drag
  - Bullfloating only if needed
  - Water is not a finishing aid!

Curing

- Presoaked burlap
- Timely placement
- Constantly wet
  - Spray hoses
  - Soaker hoses
  - 14 days

Cost effectiveness

- Cost of equipment: approximately $5000
- Cuts work crew to handle burlap on day of placement from 11 to 5
- Contractor added power to move the work bridges between first and second deck

Three work bridges. Four rolls of pre-cut, pre-soaked burlap, two on each side
Curing
Followed by curing compound to slow the rate of evaporation

Concrete Testing & Acceptance
- Clearly define testing schedule ahead of time
- Communicate how out-of-spec concrete will be handled

Construction Schedule
- Qualification Batch & Slab
- Bridge Construction

Specifications
- 07-PS0167 Construction
- 07-PS0166 Concrete
- 07-PS0165 Aggregates
Where we stand

- LC-HPC decks are working
- Current provisions, however, don’t encompass all of the technologies that can be brought to bare
- We chose not to propose those technologies until we were assured that they posed no durability problems

- We’ve now evaluated those technologies for durability and are prepared to recommend their adoption
- Ready for some more decks!

This year’s crack surveys

- Adherence to the rules...

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