The causeway is in a tailwater carry-
ing the railroad tracks and an access-
road. The previous timber bridge was con-
structed in 1935. Estimated life span of timber bridges is 30 to 50 years. For the roadway bridge, the expected life span is 75 years, with average costs for 20 to 45 million tons per year. The conclusion was obvious—a
railway bridge on the causeway, daily traffic
road. The previous timber bridge was con-
mested. The railroad track and an access
gate size. For all aggregate passing a 2-in.
beams and diaphragms, variable environ-
mental conditions that affect the concrete and would affect the results of this study on
HPC Test Results Unrestrained Drying Shrinkage

HPC Bridge Views

Specifications to Reduce Bridge Deck Cracking

Great Salt Lake Causeway

specimen is immersed in water, any
other information on High Performance Concrete, contact:
For further information on High Performance Concrete, contact:

HPC Bridge Views is published jointly by the Federal Highway Administration and the National Conference on Concrete Bridge. Permission must be obtained from the Editor before republication or translation of any part of the content. The Editor reserves the right to accept or reject contributions without giving reasons. This article describes the test method for measuring concrete drying shrinkage. This test was designed to determine the distribution of strength and density, with an equal number of con-
mits to 50 percent more from one test to another. The test specimens were made using 15-in.

The railroad bridge was removed first and
Wolfgang R. Pehrson,

HPC Tests Unrestrained Drying Shrinkage
Henry G. Russell, Editor

John S. Dick, PCI

www.nationalconcretebridge.org

Editor’s Note

Previous articles appeared in Issue Nos.

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For further information on High Performance Concrete, contact:

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HPC Bridge Views No. 46, Page 2: The
Table 1. Concrete Requirements

<table>
<thead>
<tr>
<th>ASTM No.</th>
<th>Material Property</th>
<th>Requirement</th>
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</thead>
<tbody>
<tr>
<td>C 150</td>
<td>Compressive Strength</td>
<td></td>
</tr>
<tr>
<td>C 150</td>
<td>Split Tensile Strength</td>
<td></td>
</tr>
<tr>
<td>C 150</td>
<td>Ultrasonic Pulse Velocity</td>
<td></td>
</tr>
<tr>
<td>C 150</td>
<td>Chloride Permeability</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Concretes for Cl H and HT Concretes

<table>
<thead>
<tr>
<th>Cl H 400</th>
<th>Cl H 500</th>
<th>Cl H 600</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>500</td>
<td>600</td>
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</tbody>
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Table 3. Field Curing Techniques

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Film Curing</td>
<td>Low-moisture, low-temperature curing</td>
</tr>
<tr>
<td>Wet Curing</td>
<td>High-moisture, high-temperature curing</td>
</tr>
</tbody>
</table>

Table 4. Bridge Decks without Membranes

<table>
<thead>
<tr>
<th>Class</th>
<th>Number of Cracks</th>
<th>Average Crack Width</th>
<th>Average Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl A</td>
<td>250</td>
<td>0.05 mm</td>
<td>3 mm</td>
</tr>
<tr>
<td>Cl B</td>
<td>150</td>
<td>0.10 mm</td>
<td>5 mm</td>
</tr>
<tr>
<td>Cl C</td>
<td>100</td>
<td>0.15 mm</td>
<td>7 mm</td>
</tr>
</tbody>
</table>

Table 5. Bridge Decks with Membranes

<table>
<thead>
<tr>
<th>Class</th>
<th>Number of Cracks</th>
<th>Average Crack Width</th>
<th>Average Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl A</td>
<td>50</td>
<td>0.02 mm</td>
<td>2 mm</td>
</tr>
<tr>
<td>Cl B</td>
<td>25</td>
<td>0.04 mm</td>
<td>3 mm</td>
</tr>
<tr>
<td>Cl C</td>
<td>15</td>
<td>0.06 mm</td>
<td>4 mm</td>
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</tbody>
</table>

Table 6. Bridge Decks with Membranes and Membrane Systems

<table>
<thead>
<tr>
<th>Class</th>
<th>Number of Cracks</th>
<th>Average Crack Width</th>
<th>Average Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl A</td>
<td>10</td>
<td>0.01 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td>Cl B</td>
<td>5</td>
<td>0.02 mm</td>
<td>2 mm</td>
</tr>
<tr>
<td>Cl C</td>
<td>2</td>
<td>0.03 mm</td>
<td>3 mm</td>
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</table>

Table 7. Bridge Decks with Membranes and Membrane Systems

<table>
<thead>
<tr>
<th>Class</th>
<th>Number of Cracks</th>
<th>Average Crack Width</th>
<th>Average Depth</th>
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</thead>
<tbody>
<tr>
<td>Cl A</td>
<td>2</td>
<td>0.005 mm</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Cl B</td>
<td>1</td>
<td>0.01 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td>Cl C</td>
<td>0</td>
<td>0.02 mm</td>
<td>2 mm</td>
</tr>
</tbody>
</table>

Table 8. Bridge Decks with Membranes and Membrane Systems

<table>
<thead>
<tr>
<th>Class</th>
<th>Number of Cracks</th>
<th>Average Crack Width</th>
<th>Average Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl A</td>
<td>0</td>
<td>0.005 mm</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Cl B</td>
<td>0</td>
<td>0.01 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td>Cl C</td>
<td>0</td>
<td>0.02 mm</td>
<td>2 mm</td>
</tr>
</tbody>
</table>

Table 9. Bridge Decks with Membranes and Membrane Systems

<table>
<thead>
<tr>
<th>Class</th>
<th>Number of Cracks</th>
<th>Average Crack Width</th>
<th>Average Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl A</td>
<td>0</td>
<td>0.005 mm</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Cl B</td>
<td>0</td>
<td>0.01 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td>Cl C</td>
<td>0</td>
<td>0.02 mm</td>
<td>2 mm</td>
</tr>
</tbody>
</table>

Table 10. Bridge Decks with Membranes and Membrane Systems

<table>
<thead>
<tr>
<th>Class</th>
<th>Number of Cracks</th>
<th>Average Crack Width</th>
<th>Average Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl A</td>
<td>0</td>
<td>0.005 mm</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Cl B</td>
<td>0</td>
<td>0.01 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td>Cl C</td>
<td>0</td>
<td>0.02 mm</td>
<td>2 mm</td>
</tr>
</tbody>
</table>

Table 11. Bridge Decks with Membranes and Membrane Systems

<table>
<thead>
<tr>
<th>Class</th>
<th>Number of Cracks</th>
<th>Average Crack Width</th>
<th>Average Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl A</td>
<td>0</td>
<td>0.005 mm</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Cl B</td>
<td>0</td>
<td>0.01 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td>Cl C</td>
<td>0</td>
<td>0.02 mm</td>
<td>2 mm</td>
</tr>
</tbody>
</table>

Table 12. Bridge Decks with Membranes and Membrane Systems

<table>
<thead>
<tr>
<th>Class</th>
<th>Number of Cracks</th>
<th>Average Crack Width</th>
<th>Average Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl A</td>
<td>0</td>
<td>0.005 mm</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Cl B</td>
<td>0</td>
<td>0.01 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td>Cl C</td>
<td>0</td>
<td>0.02 mm</td>
<td>2 mm</td>
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</tbody>
</table>

Table 13. Bridge Decks with Membranes and Membrane Systems

<table>
<thead>
<tr>
<th>Class</th>
<th>Number of Cracks</th>
<th>Average Crack Width</th>
<th>Average Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl A</td>
<td>0</td>
<td>0.005 mm</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Cl B</td>
<td>0</td>
<td>0.01 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td>Cl C</td>
<td>0</td>
<td>0.02 mm</td>
<td>2 mm</td>
</tr>
</tbody>
</table>

Table 14. Bridge Decks with Membranes and Membrane Systems

<table>
<thead>
<tr>
<th>Class</th>
<th>Number of Cracks</th>
<th>Average Crack Width</th>
<th>Average Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl A</td>
<td>0</td>
<td>0.005 mm</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Cl B</td>
<td>0</td>
<td>0.01 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td>Cl C</td>
<td>0</td>
<td>0.02 mm</td>
<td>2 mm</td>
</tr>
</tbody>
</table>

Table 15. Bridge Decks with Membranes and Membrane Systems

<table>
<thead>
<tr>
<th>Class</th>
<th>Number of Cracks</th>
<th>Average Crack Width</th>
<th>Average Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl A</td>
<td>0</td>
<td>0.005 mm</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Cl B</td>
<td>0</td>
<td>0.01 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td>Cl C</td>
<td>0</td>
<td>0.02 mm</td>
<td>2 mm</td>
</tr>
</tbody>
</table>

Table 16. Bridge Decks with Membranes and Membrane Systems

<table>
<thead>
<tr>
<th>Class</th>
<th>Number of Cracks</th>
<th>Average Crack Width</th>
<th>Average Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl A</td>
<td>0</td>
<td>0.005 mm</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Cl B</td>
<td>0</td>
<td>0.01 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td>Cl C</td>
<td>0</td>
<td>0.02 mm</td>
<td>2 mm</td>
</tr>
</tbody>
</table>

Table 17. Bridge Decks with Membranes and Membrane Systems

<table>
<thead>
<tr>
<th>Class</th>
<th>Number of Cracks</th>
<th>Average Crack Width</th>
<th>Average Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl A</td>
<td>0</td>
<td>0.005 mm</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Cl B</td>
<td>0</td>
<td>0.01 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td>Cl C</td>
<td>0</td>
<td>0.02 mm</td>
<td>2 mm</td>
</tr>
</tbody>
</table>
Table 1. Concrete Requirements

<table>
<thead>
<tr>
<th>Class</th>
<th>Strength</th>
<th>Water/Cement Ratio</th>
<th>Slump (in.)</th>
<th>Temperature (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HT</td>
<td>3,000</td>
<td>0.36</td>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>H</td>
<td>2,800</td>
<td>0.36</td>
<td>2</td>
<td>30</td>
</tr>
</tbody>
</table>

Note: HT = High-Performance Concrete; H = High-Strength Concrete.

Table 2. Cementitious Contents for Class H and HT Concretes

<table>
<thead>
<tr>
<th>Material</th>
<th>Compressive Strength (psi)</th>
<th>Water/Cement Ratio</th>
<th>Slump (in.)</th>
<th>Temperature (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly Ash</td>
<td>4,500-5,500</td>
<td>0.36</td>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>Slag</td>
<td>3,000-3,800</td>
<td>0.36</td>
<td>2</td>
<td>30</td>
</tr>
</tbody>
</table>

Note: Class H = Medium-Strength Concrete; Class HT = High-Strength Concrete.


table continued...
Table 1. Concrete Requirements

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
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<tbody>
<tr>
<td>Concrete strength</td>
<td>4000 psi</td>
</tr>
<tr>
<td>Water-cement ratio</td>
<td>0.45</td>
</tr>
<tr>
<td>Maximum aggregate size</td>
<td>3/4&quot;</td>
</tr>
<tr>
<td>Maximum moisture content</td>
<td>4%</td>
</tr>
<tr>
<td>Minimum steel bar size</td>
<td>1/2&quot;</td>
</tr>
<tr>
<td>Maximum temperature</td>
<td>75°F</td>
</tr>
</tbody>
</table>

**References**

1. Frosch, R. J., and Aldridge, T. S., "High-Performance Bridge Decks." Journal of Bridge Engineering, ASCE, 1998, 195 pp.
The project called for the removal of the first timber bridge and construction of a new concrete HPC bridge. The timber bridge had been in place since 1862 and was replaced due to the need for a 100-year service life in the salty environment.

**HPC Bridge Views**

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- **For a free subscription to this newsletter, change of address, or copies of previous issues, contact NCBC at 5420 Old Orchard Road, Skokie, Illinois 60077.**
- **For further information on High Performance Concrete, contact:**
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    - Linda White, (301) 420-8167, linda.white@fhwa.dot.gov
  - *NCBC*
    - Brian Gardner, (312) 553-1527, bgardner@ncbc.org

**HPC Bridge Views Issue No. 46**

**Editor’s Note**

Rigoberto G. Wortham, 208-334-8426; (fax) 208-334-4440; e-mail: gwortham@itd.state.id.us

HPC Bridge Views

HPC Bridge Views Issue No. 46, September/October 2007

- **NATIONAL CONCRETE BRIDGE COUNCIL**
- **Federal Highway Administration**

**Readers who have contributed to this newsletter are welcome. Please contact the Editor, Henry G. Russell, at 847-998-9137; (fax) 847-998-0292; e-mail: henry@hgrconcrete.org.**

**Errata**

This article is the seventh in a series on deck cracking in Indiana. To receive notification of future issues, please go to www.cement.org/bridges.

**EDITOR’S NOTE**

The necessary statistics for this article are shown in Table 1. To receive notification of future issues, please go to www.cement.org/bridges.

**HPC Bridge Views Issue No. 46, September/October 2007**

**Specifications to Reduce Bridge Deck Cracking**

Lyle Brown and David Danner, University of Kansas and Kenneth R. Franks, Kansas Department of Transportation

HPC tests unrestrained drying shrinkage

**Environmental Conditions for High Performance Concrete**

**Project Description**

The causeway in a mile inland carrying traffic on an island and an access road. The previous timber bridge was constructed in 1951. Estimated life span of timber bridges is 30 to 50 years. For the ready mix plants located within 23 miles of 49 million tons per year of production. The project had to be made to the bridge site using a job ready mix plant located at the crossing.

**Rigoberto G. Wortham, 208-334-8426; (fax) 208-334-4440; e-mail: gwortham@itd.state.id.us**

HPC Bridge Views

**HPC Bridge Tests Unrestrained Drying Shrinkage**

Jenny G. Greggs

**Specifications to Reduce Bridge Deck Cracking**

Lyle Brown and David Danner, University of Kansas and Kenneth R. Franks, Kansas Department of Transportation

T he project called for the removal of the existing timber bridge and construction of a new concrete HPC bridge. The timber bridge had been in place since 1862 and was replaced due to the need for a 100-year service life in the salty environment. A concrete HPC bridge with a uniform salinity in the lake. This site is the only bridge on the causeway, daily traffic included the need for the bridge and causeway to be replaced. The track was then moved to the original alignment. The project requirements for the box beams was 4700 psi (32 MPa) of 50 ± 4%. Other storage conditions may occur on the concrete and casting at night. The lower temperature causes water, however, cannot accumulate on the concrete. Cracking is reduced by decreasing the volume of water and aggregate. The finishing equipment supplemented with hand controlling the rate of evaporation from the concrete. Very elongated particles. Decks completed in Kansas have been placed using buckets or conveyors, unless the finishing equipment supplemented with hand controlling the rate of evaporation from the concrete. Very elongated particles. Decks completed in Kansas have been placed using buckets or conveyors, unless i...
The performance of the Trans-Continental good was crucial to the success of the project. The basic structural elements of the concrete were cast in a single operation at the construction site. The final 140-ft (42.7 m) bridge was concreted in 140 cumulative hours from 3:30 PM on June 23, 1997 to 2:30 PM on June 24, 1997 at a rate of 810 cu ft (22.9 cu m) per hour. The concrete was placed in sections 3.6 ft (1.1 m) thick and 6.5 ft (2.0 m) wide and was vibrated in place. The total volume of concrete placed was 26,000 cu ft (739 cu m) with a 5.0% air content. The hardened concrete had a crushing strength of 4,500 psi (31 MPa). The bridge was a significant accomplishment and set a precedent for the use of self-consolidating concrete in large-scale projects.

Water storage requires the specimens to be sealed in molds at 23.5 ± 0.5 hours after casting and then watered continuously for 28 days. The method is used for comparing different concrete mixes.

HPC Bridge Views

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Challenging Site

Because the initial reading is taken before the specimens are stored in lime-saturated water, the readings at that time are referred to as “immediate readings.” The test method requires an average of five readings at each age. The unrestrained drying shrinkage of the specimens is measured using the modified method for concrete and its implications. The major factor contributing to the concrete’s cracking is its creep behavior. A construction site in the middle of the lake is a challenging site due to the low-relaxation seven wire strands. The length change measured on the specimens was 26 ± 3%, which is acceptable. The beam design allowed for track placement and is shown in the table. The test method requires an average of five readings at each age.

HPC Bridge Views

Future Issues

Rigorlets Pass Bridge redesign used BT-78 specifications to reduce the amount of cracking in reinforced concrete bridge decks. This guide provides concrete mixtures that have been developed to meet the performance requirements of the American Association of State Highway and Transportation Officials (AASHTO) A23.1, 1.4, 5.3.5, 5.3.6, 5.3.7, and 5.3.8. Other conditions such as results are: 1. The length change measured on the specimens was 26 ± 3%, which is acceptable. The beam design allowed for track placement and is shown in the table. The test method requires an average of five readings at each age.

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