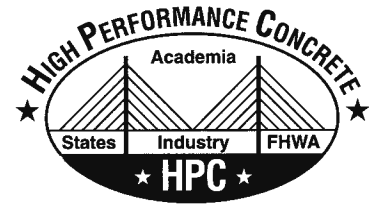




Bridge Views



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Issue No. 39

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INSIDE THIS ISSUE...

HPC for Woodrow Wilson Memorial Bridge

Improved Compressive Strength Testing

HPC Web Site

Urgent Notice

HPC Bridge Calendar

HPC FOR WOODROW WILSON MEMORIAL BRIDGE

Alan Kite, Parsons

The Woodrow Wilson Memorial Bridge project, located approximately 8 miles (13 km) south and within sight of downtown Washington, DC, involves the structural replacement and capacity upgrades of the existing structure over the Potomac River. The new bridge is part of the I-95 and I-495 Capital Beltway. It is comprised of two adjacent and independent bridges known as the Inner and Outer Loops, which are 124 ft (37.8 m) and 110 ft (33.5 m) wide, respectively. Each bridge carries six traffic lanes with full-width shoulders. A sidewalk is provided on the north side of the Inner Loop bridge to connect the parks at each end of the bridge. The new bridge has 35 spans, including a double-leaf bascule span, and is approximately 6075 ft (1,852 m) long.

In order to limit the ingress of chlorides to the concrete over the first layer of reinforcing steel, the project Special Provisions require the chloride permeability of the concrete to be less than 2,000 coulombs at 56 days. To meet these permeability requirements, the contractor is permitted to use ground granulated blast-furnace slag for as much as 75 percent of the cementitious materials content. The slag also provides improved flexural strength, compressive strength, durability, workability (especially in warm weather), and consolidation of the concrete. Epoxy-coated reinforcing steel is used in the 10-in. (254-mm) thick fixed span decks. Calcium nitrite, a corrosion inhibitor, is also used at a dosage rate of 2 gal/cu yd (9.9 L/cu m) to protect the reinforcing steel and effectively increase the bridge service life.

Deck Concrete

For the cast-in-place concrete bridge deck, the objectives were to obtain an economical concrete mix that will result in a durable deck with minimal cracking and a low permeability to minimize chloride intrusion. The bridge is located in a moderate to aggressive environment where deicing salts are used extensively in the winter. In order to meet these objectives and a required 75-year projected service life of the bridge, various deck concrete mixes and corrosion protection systems were evaluated.

Curing of the deck concrete requires that the contractor begin fog spraying within 15 minutes of concrete placement and place two layers of wet burlap over the slab within 30 minutes of placement. The burlap must remain continuously saturated for the 7-day curing period. This curing method is expected to minimize the drying and plastic shrinkage cracks at the deck surface. After the deck has cured, two coats of linseed oil or a silane based sealer are applied to the finished deck.

Based on the above requirements and using Fick's Second Law of Diffusion applied to the uncracked concrete, it will require an estimated 60 years for chloride ingress to initiate corrosion activity at the level of the reinforcing steel assuming that corrosion begins at a chloride concentration of 2.0 lb/cu yd (1.2 kg/cu m). An additional 20 years from the start of corrosion of the top reinforcing steel until corrosion damage occurs will provide a service life in excess of the required 75 years.*



The V-piers and tie beams used HPC.

*Grace Construction Products, 2000 "Durability Report: Corrosion Protection," 20 pp.

(continued on pg. 2)

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(continued from pg. 1)

For the bascule pier deck, the same requirements as those for the fixed decks are used with several modifications. To minimize the size of machinery and the wear-and-tear on the machinery parts, a lightweight concrete with a density of 120 lb/cu ft (1.92 Mg/cu m) is used for the 7.5-in. (190-mm) thick deck. In addition, solid stainless steel reinforcing bars (ASTM A955, Type 2205 Duplex or Type 316LN) are specified for the bascule deck. Although more expensive than uncoated or epoxy-coated reinforcing steel, the design team and sponsoring agencies decided that the advantages of better corrosion resistance, extended service life, and reduced maintenance cost offset the additional initial cost. The use of calcium nitrite is not specified for the bascule deck.

Substructure Concrete

For the precast and cast-in-place concrete V-piers, the main objective for the concrete mix design was to provide an economical design mix with a low permeability. The water in the Potomac River at the project site is brackish, providing a moderate to aggressive exposure. Particular attention was given to the underwater pile caps and areas of the pedestal within the splash zone. Concrete placements for the pier foundations range in size from 700 cu yd (535 cu m) to 6000 cu yd (4587 cu m). For the large bascule pier, the contractor cast 130 cu yd/hr (99.4 cu m/hr) continuously for 45 hours. All reinforcing steel in the pile caps and pedestals is epoxy coated.

Due to the large size of the foundation, strict mass concrete requirements were imposed to minimize thermal cracking. The differential temperature between the center and surface of the pour was limited to 35°F (19°C), and a maximum concrete temperature of 160°F (71°C) was specified. The contractor was required by specification to demonstrate his ability to meet this criterion by performing a thermal analysis. The use of slag for 75 percent of the cementitious materials resulted in lower heat of hydration and helped reduce the concrete temperatures. The contractor also chose to use chilled water and ice in the mix during the summer months when the maximum concrete temperature was a concern. In the winter months, the contractor used sur-

face insulation to control the temperature gradient. At several locations, cooling pipes were installed to minimize internal concrete temperatures.

The precast segmental V-pier legs utilize two standard hollow box girder sections. The segments were match cast in long-line beds constructed within the project right-of-way. Up to 75 percent of the cementitious materials could be slag per the specification. However, since slag slows the strength gain, the contractor chose a final mix using 50 percent slag to allow earlier stripping of the forms. Also, since the pier legs are outside the splash zone and protected overhead by the bridge deck, uncoated reinforcing steel was specified since the economics outweighed the limited benefits of using epoxy-coated bars at this location.

The two precast pier legs at each foundation are tied together at the top with two parallel concrete tie beams as shown in the photograph. These tie beams are a solid precast member, which is cast off-site. These critical elements are post-tensioned to provide compression in the tie beams under all loading conditions. The tie beams have a specified compressive strength of 8000 psi (55 MPa), with all other mix design criteria being the same as for the pier legs. High strength concrete was required in order to minimize the number of stages of post-tensioning for the tie beams.

For the cast-in-place bascule piers, the criteria for chloride permeability, compressive strength, percent pozzolans or slag, water-cementitious materials ratio,

and mass concrete temperature limits are the same as for the fixed precast pier legs. Since the bascule pier design is sensitive to creep and shrinkage, additional tests were required to determine concrete modulus of elasticity, creep, and shrinkage for the final concrete mix. The results of these tests were considered when computing final camber values for the post-tensioned elements of the bascule pier. Epoxy-coated reinforcing steel is required throughout the bascule pier to provide a higher level of durability, especially since road salts can reach the pier from the bascule tail joint.

Schedule

The anticipated completion of the Outer Loop bridge is approximately mid-2006. All traffic will be diverted from the existing bridge to the Outer Loop bridge to allow demolition of the existing bridge and construction of the Inner Loop bridge. Completion is anticipated by mid-2008.

Further Information

For further information about this project, go to www.wilsonbridge.com or contact the author at t.alan.kite@parsons.com or 410-223-2740.

Specified Concrete Properties

Location ⁽¹⁾	28-day Specified Compressive Strength, psi	Max. Water-Cementitious Materials Ratio	Clear Cover to Reinforcing Steel, in.
CIP Fixed Deck	5000	0.45	2.5
CIP Bascule Deck	4500	0.40	2.5
P/C Pier Legs	6500	0.40	2
P/C Tie Beam	8000	0.40	2
CIP Bascule Pier Legs and Tie Beams	6500	0.40	3
CIP Pile Cap	4000	0.40	4

⁽¹⁾CIP = cast-in-place. P/C = precast.

IMPROVED COMPRESSIVE STRENGTH TESTING

Nicholas J. Carino, Engineering Consultant

The relevant standards related to compressive strength testing are AASHTO T 23 (ASTM C 31) for making and curing specimens, AASHTO T 231 (ASTM C 617) for capping, and AASHTO T 22 (ASTM C 39) for compressive strength testing. This article discusses some recent changes to these standards to reduce inter-laboratory discrepancies, especially with high strength concrete.

Background

In the 1980s and early 1990s, field problems were reported where inconsistent results were being obtained between different laboratories testing the same samples of high strength concrete. In response to these problems, ASTM Subcommittee 09.61 on Strength Testing established an ad-hoc task group on high strength concrete to study whether the existing standards could be improved to reduce the likelihood of these inconsistencies. The task group studied recent research and the standards related to specimen fabrication, curing, capping, and compressive strength testing. As a result, some significant changes to ASTM C 31, C 617, and C 39 were adopted by ASTM. Some of these changes are being incorporated into the corresponding AASHTO standards.

Specimen Size and Fabrication

AASHTO T 23-04 and ASTM C 31-03a define the standard cylinder size as 6x12 in. (150x300 mm). However, AASHTO T 23 states that specimens “may be” 4x8 in. (100x200 mm), whereas ASTM C 31 states that 4x8-in. (100x200-mm) cylinders are permitted “when specified.”

The benefits of using 4x8-in. (100x200-mm) cylinders include ease of handling, simpler field curing facilities, and less wear and tear on testing machines. On the other hand, there has been concern over the slightly higher strengths obtained with the smaller size cylinders. A joint NIST/NRMCA study⁽¹⁾ showed that the differences in strength between the two specimen sizes could be reduced by fabricating the smaller cylinders using two layers of concrete instead of three. The task group recommended changing ASTM

C 31 to require two layers for fabricating the smaller cylinders. The task group also recommended removing the restriction on using vibration to consolidate concrete with a slump greater than 3 in. (75 mm). There was no evidence that excessive segregation occurs by vibrating high-slump concretes provided limits are placed on the duration of vibration. These recommendations were adopted.

Initial Curing

Another significant modification to ASTM C 31 was to reduce the permitted range of the initial storage temperature of specimens from 60 to 80°F (16 to 27°C) to 68 to 78°F (20 to 26°C) for concrete with specified strengths of 6000 psi (40 MPa) or greater.

Loading Rate

Loading in compression tests is done at a constant rate of movement of the platen relative to the crosshead. The deformation rate should result in a loading rate within specified limits. Before 2004, the loading rate range in ASTM C 39 was 20 to 50 psi/s (0.14 to 0.34 MPa/s). A joint NIST/NRMCA/FHWA study⁽²⁾ showed that the upper limit of the range resulted in 2.2 percent higher strength than testing at the lower limit. Thus, the task group recommended reducing the acceptable tolerance to one-half of the previous value. The 2004 version of ASTM C 39 requires a loading rate of 35 ±7 psi/s (0.25 ±0.05 MPa/s). In addition, the language related to screw-type machines was deleted and a new note was added, which states that for screw-driven or displacement-controlled testing machines, the operator needs to establish the appropriate rate of movement to achieve the required loading rate. The appropriate rate of movement depends on the size of the test specimen, elastic modulus of the concrete, stiffness of the testing machine, and whether unbonded caps are used.

ASTM C 39-04 also addresses machines with break detectors that stop loading when a prescribed drop in load occurs. To ensure that small momentary drops in load do not stop a test, a drop in the load of at least 5 percent has to occur before the break detector stops the test.

Bonded Caps

An NRMCA study⁽³⁾ showed that sulfur caps can be used to test high strength concrete without an adverse effect if cap thickness is limited and sufficient aging of the sulfur is allowed before testing. A follow-up study⁽⁴⁾ showed that the unconfined cube compressive strength of the capping compound may not be as important as its elastic modulus. The best capping compound is one that has a high elastic modulus.

As a result of these findings, changes were made to ASTM C 617 on the use of bonded caps (see *HPC Bridge Views* Issue No. 16, p. 3). The cap thickness for cylinders made with concrete stronger than 7000 psi (50 MPa) is now limited to a maximum of 3/16 in. (5 mm) and an average of 1/8 in. (3 mm). To ensure that greater attention is paid to controlling cap thickness, the laboratory is required to check cap thickness on at least three specimens during the day's testing operations.

The traditional requirement of specifying capping material with a strength at least that of the concrete to be tested was dropped for concrete strengths greater than 7000 psi (50 MPa) and replaced by a performance requirement. A capping material is acceptable if it results in an average cylinder strength that is at least 98 percent of the average strength of cylinders capped with neat cement paste or ground flat. Also, the standard deviation of the capped cylinders has to be less than 1.57 times the standard deviation of the reference cylinders.

Troubleshooting Low Strength Results

High strength concrete is inherently more sensitive to details of specimen fabrication, curing, end preparation, and testing procedure. According to ACI 363.2R,⁽⁵⁾ experience has shown that special care is needed for concretes stronger than 8000 psi (55 MPa). Standards-writing committees have attempted to improve testing requirements to reduce discrepancies between laboratories testing the same concrete. When unexpected low strength test results occur, the following details should be investigated:

(continued on pg. 4)

(continued from pg. 3)

- Was the cylinder properly fabricated and cured? Weighing each cylinder provides a check of gross errors in specimen fabrication. Check field records of initial curing conditions.
- If bonded caps were used, was the material qualified for the concrete strength? Were the ends of the cylinders sufficiently flat and perpendicular to preclude excessive cap thickness?
- For unbonded pad caps, were the ends of the cylinders sufficiently flat and perpendicular to the cylinder axis? Are the pads of the correct hardness and in acceptable condition?
- Are the loading surfaces of the testing machine plane? Do the dimensions of the spherically seated head satisfy requirements?
- Is the spherically seated head properly lubricated so that it rotates freely upon contact with the cylinder but behaves as a fixed head during loading? Do not use grease as a lubricant for the spherical head.
- Is the loading rate within the requirements? A slower loading rate may produce a lower strength.
- Was the cylinder loaded to its ultimate capacity?

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5. "Guide to Quality Control and Testing of High-Strength Concrete," ACI 363.2R-98, American Concrete Institute, Farmington Hills, MI, 1998, 18 pp.

Editor's Note

This article is the third in a series that describes tests for use with HPC. Previous articles appeared in Issue Nos. 36 and 37. For additional articles on testing high strength concrete, the reader is referred to Issue Nos. 6, 14, 15, and 16.

HPC WEB SITE

This address of the FHWA HPC web site has been shortened to:
<http://knowledge.fhwa.dot.gov/hpc>.

URGENT NOTICE

Because of delays in passing the Transportation Reauthorization Bill, distribution of the next few issues of *HPC Bridge Views* may need to be made electronically. If you enjoy reading *HPC Bridge Views* and do not want to miss any issues, please send us your email address by going to www.cement.org/bridges. Your email address will be used for distribution of *HPC Bridge Views* and other concrete bridge industry news.

HPC BRIDGE CALENDAR

June 20-24, 2005

Seventh International Symposium on Utilization of High Strength/High Performance Concrete, Washington, DC. Organized by ACI. See www.concrete.org and click on Events and International Conferences for more information.

October 16-19, 2005

PCI National Bridge Conference — Bridges for Life,™ Innovative Solutions: Imagineering with Concrete Bridge, Palm Springs, CA. See www.pci.org for more information.

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