# Bridge Views

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## IBRC PROGRAM ADVANCES HPC

*John M. Hooks, Federal Highway Administration*

The Innovative Bridge Research and Construction (IBRC) program was established under the Transportation Equity Act for the 21st Century. The intent of the IBRC program is to develop and promote applications of innovative (high performance) materials for bridges. The IBRC program is funded for six years through fiscal year 2003 at a total authorized level of $102 million. As of fiscal year 2001, 157 projects have been selected for funding. By the time the program expires, IBRC funds will have supported the construction or rehabilitation of an estimated 250 bridges with innovative materials. Eighteen states have used IBRC funds to design, build, and monitor the performance of high performance concrete (HPC) in bridges. Twenty-nine HPC projects have been approved and include applications in deck slabs, substructure elements, concrete I-girders, concrete box beams, and bridge railings. Nineteen of the 29 projects include HPC in the bridge deck slab; this reflects the concern with durability and service life of concrete bridge decks, especially those subjected to deicing chemicals in ice and snow areas. It also reflects the expectation that low permeability HPC will produce decks with significantly longer service lives.

The true value of the IBRC program is in advancing technologies that will enable all bridges to last longer at a lower total cost. IBRC funds are being used for special engineering studies, materials testing and evaluation, mix designs, and instrumentation and post-construction monitoring of performance of the HPC components of the bridges. Under normal circumstances, agencies might not be able to afford these extra efforts because of the shortage of staff, pressure of project schedules, or lack of funds. IBRC funds can fill this gap and are often used to enlist the services of local universities to conduct the necessary studies.

The Virginia Department of Transportation (VDOT), with funding from the IBRC program, initiated a project to evaluate the use of structural lightweight, high performance concrete in prestressed concrete bridge girders. The project includes the fabrication of three AASHTO Type II girders with deck slabs for measurement of transfer length, development length, and flexural strength and two AASHTO Type IV girders for monitoring long-term prestress losses and camber. Three girders in the actual bridge will be instrumented for long-term monitoring of concrete strains. As a result of this study, VDOT hopes to benefit from a reduction in dead load as well as the other strength and durability advantages of HPC.

IBRC funding allowed the New Hampshire Department of Transportation (NHDOT) to collaborate with the University of New Hampshire (UNH) on the use of innovative materials in bridges. The project involved the development of HPC mixtures and design details for fiber-reinforced plastic reinforcement. The funding supported experimental research at UNH. The results were immediately implemented by NHDOT in a bridge.

Both innovative materials will enable the NHDOT to design more durable bridges. The actual performance of the HPC and FRP materials in the bridge is being monitored. Test results will be used to refine the predictive models. This program is allowing practitioners to gain confidence with advanced materials and, by doing so, is incrementally advancing the state-of-the-art in both HPC and FRP.

### Summary

The IBRC program provides funds to offset additional engineering and monitoring costs and increases confidence in new materials. IBRC funds also help offset the risks and premium costs of experimenting with innovative materials. The next project solicitation will be announced on March 15, 2001, with project applications due by July 15, 2001. For further information on the IBRC program, visit the IBRC website at http://ibrc.fhwa.dot.gov.

# MISSOURI'S HPC BRIDGE EXPERIENCE

*Tim Chojnacki, Missouri Department of Transportation*

In the fall of 1998, two companion bridges on Missouri Route 21 over Route M in Jefferson County were opened to traffic. The northbound bridge was constructed using prestressed concrete I-girders made of high performance concrete (HPC) with a design strength of 10,000 psi (69 MPa) and a release strength of 5500 psi (38 MPa). The southbound bridge was constructed using prestressed concrete I-girders made of conventional concrete with a design strength of 5000 psi (34 MPa) and a release strength of 4000 psi (28 MPa). The conventional bridge required six lines of Missouri Department of Transportation (MoDOT) Type 6 girders for a total of 24 girders, while the HPC required only five lines of the MoDOT Type 6 girders for a total of 20 girders.

The costs of fabrication and placement of the HPC girders per foot of bridge was 16 percent higher than for the conventional girders. Reduced maintenance and longer life are expected to offset this initial cost.

## Concrete Properties

The HPC mix was designed by the fabricator to meet the requirements of the special provisions. The required compressive strength was 10,000 psi (69 MPa) at 56 days and the required chloride permeability measured in accordance with AASHTO T 277 was 1000 coulombs or less at 56 days. For improved quality control, the HPC specifications were written with tighter tolerances to minimize variations during construction. The coarse aggregate had to meet the Missouri Standard Specifications for pavement quality. The fabricator chose Plattin Limestone. The measured air content of the fresh concrete could be no less than the design air content, nor could it exceed that value by more than 3.5 percentage points. The slump could not exceed 8 in. (203 mm) and had to be within 2 in. (51 mm) of that stated in the approved mix design. The water/cement (w/c) ratio had to be within 0.02 of that specified in the approved mix design. To achieve the strength and permeability characteristics required on the project, the concrete contained 50 lb/cu yd (30 kg/cu m) of silica fume and 850 lb/cu yd (504 kg/cu m) of Type I cement.

The average compressive strengths of the HPC were 11,480 psi (79.2 MPa) at 7 days and 12,360 psi (85.2 MPa) at 28 days. The average compressive strengths of the conventional concrete were 6380 psi (44.0 MPa) at 7 days and 6850 psi (47.2 MPa) at 28 days. In both cases, release strengths were reached in 1 day and design strengths were reached in 3 days. The average chloride permeability of the HPC was very low at 110 coulombs while the conventional concrete had an average value of 3050 coulombs.

Both the HPC and the conventional concrete were subjected to freezing and thawing tests in accordance with ASTM C 666 Procedure B. The freeze-thaw resistance of the conventional concrete was excellent. However, the freeze-thaw resistance of the HPC was poor. This warranted additional investigation and a follow-up research study is currently underway.

All of the test specimens for MoDOT's research were cured in a "match-cure" environment in an effort to better simulate the actual member curing temperatures. The temperature of test specimens was maintained within 3°F (1.7°C) of the internal girder temperature. A comparison was made of the compressive strength of the "match-cured" cylinders and member-cured cylinders used by the fabricator. The compressive strengths at early ages were higher for "match-cured" cylinders than for member-cured cylinders and should be more representative of the actual girder strengths. At 56 days, the member-cured and match-cured cylinders had similar strengths.

The high compressive strength and low permeability achieved on this project have shown that HPC is a viable concept in Missouri, although further study into the freeze-thaw durability is needed. Locally available materials exist that can be used in the production of HPC.

## What's Next?

Missouri is pursuing additional HPC bridge projects. Currently, there is an Inverset™ steel/concrete composite bridge being built over I-70 in St. Louis. This bridge incorporates HPC with a 7000 psi (48 MPa) design strength and low permeability concrete in the deck portion of the bridge units. A similar HPC mix will be used in a cast-in-place bridge deck on Route 291 near Kansas City in 2001. A bridge incorporating HPC in both the prestressed concrete I-girders and the deck will be built on U.S. Route 412 in Missouri's Boot Heel in the near future.

## Further Information

Chojnacki, T. M., "Determination of High Performance Concrete (HPC) Characteristics," MoDOT RDT Report No. RDT99-008, September, 1999. For a copy of the report or for further information, contact the author at 573-526-4337 or chojnt@mail.modot.state.mo.us

*The use of high strength concrete allowed wider girder spacing.*

# CAPPING CYLINDERS FOR TESTING HIGH STRENGTH CONCRETE

*Jon I. Mullarky and Leif Wathne, Federal Highway Administration*

The use of unbonded caps on test cylinders is becoming an increasingly popular part of the procedure to determine the compressive strength of concrete. The ASTM Standard Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders (ASTM C 1231) previously in effect, cautioned that unbonded caps are not to be used for acceptance testing of concrete with compressive strengths above 7000 psi (48 MPa). The current version of the Standard Practice has a limit of 12,000 psi (85 MPa). The limitation of 7000 psi (48 MPa) had created a difficulty for many testing laboratories, including the Federal Highway Administration's (FHWA) Mobile Concrete Laboratory (MCL), that routinely use unbonded pads in the testing of lower strength concretes and would like to use the same procedure for high strength concretes. The difficulty is further complicated by the lack of commercially available capping compounds that are suitable for use with high strength concretes.

## Previous Research

According to published literature, there is little agreement about the best method for the end treatment of high strength concrete cylinders. Some research suggests that pad caps are the most suitable, since strength results are typically slightly higher and significantly less variable than results using sulfur caps.[1] Pistilli and Willems concluded that, for high strength concretes, use of pad caps resulted in slightly higher and less variable strengths than with sulfur caps.[2] However, their preferred end treatment was grinding, since sulfur caps were unsuitable at strength levels above 13,000 psi (90 MPa). Others believe that surface grinding is the most suitable method for high strength concretes with compressive strengths above 10,000 psi (69 MPa).[3] ASTM C 1231 implies that, for concretes with compressive strengths up to 12,000 psi (83 MPa), strengths measured on specimens with sulfur caps and ground ends are the same, since the qualification requirements allow for comparisons of pad cap strengths to either of the two methods.

One common thread in all of this literature, however, is that the most appropriate method for providing plane cylinder surfaces for high strength concrete is grinding.

## FHWA Evaluation Program

The FHWA's MCL is often called upon to support the implementation of high performance concrete programs by state highway agencies. Routinely the MCL tests high strength concrete. The staff of the MCL, with assistance from the Turner-Fairbank Highway Research Center, recently conducted a small-scale investigation to determine if grinding or the use of pad caps was appropriate for compressive testing of high strength concrete.

Twenty-eight 4x8-in. (102x203-mm) cylinders were cast from a single batch of high strength concrete. Mixture proportions for a silica fume concrete used in a previous, unrelated investigation were used for the test program. The concrete was known to reach a compressive strength of 12,000 psi (83 MPa) in 36 days. Test specimens were molded and cured in accordance with ASTM C 192.

All specimens were tested in accordance with ASTM C 39. Prior to testing, the cylinders were randomly divided into three groups of nine cylinders. One group was capped with a high strength sulfur capping material. Ends of the second group were ground to meet the requirements of ASTM C 39. The third group of cylinders was tested using 70 durometer neoprene pads.

Unbonded and ground specimens were paired with sulfur capped specimens and evaluated using the statistical method outlined in Section 9 of ASTM C 1231. There was no significant difference in compressive test results between the group receiving sulfur end treatments and the group tested with neoprene pad caps. There was, however, a significant difference between the average values for cylinders tested with pad and sulfur caps and the average values for cylinders prepared with ground ends. Grinding led to a strength reduction of approximately 15 percent compared to the reference specimens with sulfur caps and unbonded caps. Variability, as measured by the standard deviation, was approximately twice the variability of the reference specimens.

| End Condition | Strength, psi | Standard Deviation, psi |
|---|---|---|
| Ground | 10,210 | 449 |
| Sulfur | 12,030 | 301 |
| Neoprene | 12,270 | 236 |

## Conclusions

For the high strength mixture studied, the specimens tested with neoprene pads and sulfur caps had higher strengths and lower variability than companion specimens with ground ends. Consequently, the neoprene pads met the qualification guidelines of ASTM C 1231, and are appropriate for use in testing concrete with compressive strengths up to 12,000 psi (83 MPa). However, the difference between the results of the specimens with ground ends and the specimens with sulfur caps led to doubts about the assumption in ASTM 1231 that both methods provide a basis for comparison. The test results clearly indicate the importance of considering different end preparation methods and selecting the most appropriate one for use in testing throughout the project.

## References

1. Carrasquillo, P. M. and Carrasquillo, R. L., "Evaluation of the Use of Current Concrete Practice in the Production of High-Strength Concrete," ACI Materials Journal, Vol. 85, No. 1, January-February, 1988, pp. 49-54.
2. Pistilli, M. F. and Willems, T., "Evaluation of Cylinder Size and Capping Method in Compression Strength Testing of Concrete," Cement, Concrete, and Aggregates, CCAGDP, Vol. 15, No. 1, Summer, 1993, pp. 59-69.
3. Burg, R. G., "Compression Testing of High Strength Concrete," HPC Bridge Views, Issue No. 6, November/December 1999, pp. 3.

# TIA OFFERS HPC WORKSHOPS

*Charles H. Goodspeed, University of New Hampshire*

As part of the national program to continue the implementation of high performance concrete (HPC) in bridges, a series of seven training modules will soon be available from the Transportation Industrial Alliance (TIA). The TIA is managed by the Department of Civil Engineering at the University of Florida, Gainesville, as part of their Local Technical Assistance Program (LTAP) to encourage partnerships between the private sector, academics, and local highway departments. The HPC modules are based on experiences and lessons learned during the design and construction of several HPC bridges that were built as part of the joint state-FHWA SHRP HPC implementation program.

Each module consists of slides and accompanying text. The modules will be available on a compact disc in PowerPoint format. A workbook for the determination of strength and durability parameters is also included on the disc.

The seven modules consist of the following:

1. Executive Introduction by James A. Moore, *New Hampshire Department of Transportation*
2. Mixture Design, Quality Control, and Implementation by H. Celik Ozyildirim, *Virginia Transportation Research Council*
3. Structural Design by Maher K. Tadros, *University of Nebraska*
4. Fabrication and Erection by Mary Lou Ralls, *Texas Department of Transportation*
5. Cost Analysis by M. Myint Lwin, *FHWA*
6. Research and Monitoring by Henry G. Russell, *Henry G. Russell, Inc.*
7. Case Studies by T. Michael Baseheart and Richard A. Miller, *University of Cincinnati*

A prototype workshop, using the modules, was co-hosted by TIA and the Virginia Transportation Technology Transfer Center in Richmond, VA, on November 15-17, 2000. Based on feedback from the participants, the modules will be revised for the first release, which should soon be available.

The modules and support for future workshops are being offered by TIA. Professional organizations, highway agencies, and other institutions interested in acquiring the modules or hosting an HPC workshop using the modules should contact Gib Peaslee at Civil Engineering Department, Transportation Research Center, P.O. Box 116585, 512 Weil Hall, Gainesville, FL 32611-6585; phone 352-392-2371 ext. 245; email: gib@ce.ufl.edu. The TIA is prepared to offer a full menu of training support options that a prospective workshop host can select from when organizing a workshop. Workshop information will be mailed in early spring to those agencies participating in FHWA's HPC bridge programs, all LTAP Centers, FHWA Division Offices, FHWA Resource Centers, and State Highway Agencies. Anyone else who would like to be on the mailing list should contact Gib Peaslee.

The availability of the modules has resulted from the efforts of many people throughout the U. S. highway community. Preparation of the modules would not have been possible without their input and support. The FHWA and TIA extend their thanks to those who have contributed to the successful implementation to date. However, the process of technology transfer is only beginning. Consequently, we would like feedback from those using the modules for workshops, classrooms, or general reference to ensure that the modules contain the most current material about HPC. Please send comments to Charles H. Goodspeed at the Department of Civil Engineering, University of New Hampshire, Durham, NH 03824; phone: 603-862-1443; email: chgi@christa.unh.edu.

### NCBC WEB SITE

*The National Concrete Bridge Council (NCBC) has announced its new web site at www.nationalconcretebridge.org.*

HPC Bridge Views is published jointly by the Federal Highway Administration and the National Concrete Bridge Council. Previous issues can be viewed and downloaded at http://www.portcement.org/br/newsletters.asp.

For a free subscription to this newsletter, change of address, or copies of previous issues, contact NCBC at 5420 Old Orchard Road, Skokie, IL 60077-1083; 847-966-6200; (fax) 847-966-9781; email: ncbc@portcement.org.



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