HPC Bridge Views

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Charenton Canal Bridge – Louisiana's First HPC Bridge

Paul Fossier, Louisiana Department of Transportation and Development

When the Charenton Canal Bridge on LA 87 in St. Mary Parish opened on November 4, 1999, the occasion marked the completion of Louisiana's first high performance concrete (HPC) bridge. HPC was used in all components of the bridge. Completion of the project marked the implementation of HPC that began with research work in Louisiana in the early 1980's.

The project consisted of the replacement of a 55-year old reinforced concrete bridge with a 365-ft (111-m) long continuous prestressed concrete structure using Type III AASHTO girders. Each 73-ft (22.3-m) span consists of five girders that are spaced at 10-ft (3.1-m) centers and support an 8-in. (203-mm) thick cast-in-place concrete deck. The substructure for the bridge consists of cast-in-place concrete bent caps supported on 24- and 30-in. (610- and 762-mm) square precast, prestressed concrete piles. Specified compressive strength of the girders and piles was 10,000 psi (69 MPa) no later than 56 days. The bridge deck and bent caps had a specified concrete compressive strength of 4200 psi (29 MPa) at 28 days. A rapid chloride permeability of 2000 coulombs or less at 56 days was specified for concrete used in all members.

The use of HPC enabled the bridge to be designed with one less line of girders than would be required when using 6000 psi (41 MPa) compressive strength concrete. The additional strength in the precast piles increased their resistance to compressive and tensile driving stresses and allowed the casting and shipping of longer lengths. We anticipate a 75- to 100-year service life for the bridge instead of the normal 50-year service life for concrete structures.

The use of match-cure cylinder molds was a requirement for the precast fabricator. The internal concrete temperature of all precast members was limited to 160°F (71°C). The contractor elected to use fly ash in the precast members and slag in the cast-in-place members. As part of the project, material testing, bridge instrumentation, and bridge monitoring are being performed by Tulane University in cooperation with the Louisiana Transportation Research Center. The instrumentation was used to measure girder curing temperatures and prestressing forces during fabrication and is being used to determine prestress losses, strains in the bridge deck, and girder deflections.

Completion of the Charenton Canal Bridge proves that it is feasible to construct an HPC bridge in Louisiana with local materials and local contractors. The success of the project has now enabled the Department to plan for three more HPC bridge projects in the next two years.

HPC was used in substructure and superstructure for strength and durability.

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HPC provided an opportunity to extend production capabilities.

A FABRICATOR'S OPPORTUNITY

Don Theobald, Gulf Coast Pre-Stress, Inc.

To most fabricators, the thought of producing high strength, high performance concrete (HPC) can be very intimidating. When the term HPC became the buzzword several years ago, I couldn't imagine Gulf Coast Pre-Stress, Inc. producing concrete with strengths greater than 7000 psi (48 MPa) with our materials.

In January 1997, the Louisiana Department of Transportation and Development announced plans for their first HPC project. The Charenton Canal Bridge replacement, located in St. Mary Parish, was well within our market area. The products would be AASHTO Type III girders and 14-, 24- and 30-in. (355-, 610-, and 762-mm) square piles, each designed with 10,000 psi (69 MPa) concrete. The release strength for the girders was initially 6000 psi (41 MPa) but was later increased to 7000 psi (48 MPa) to demonstrate that higher strengths could be achieved. The project was scheduled for bidding in the first quarter of 1998.

Management immediately made a commitment to begin necessary research to successfully produce HPC with as many of our present raw materials as possible. The strategy was to decide on materials and proportions, and then batch laboratory trial mixtures. Next, we scheduled two separate 3 cu yd (2.3 cu m) batches to cast full-size specimens of AASHTO Type III girders. With the help of our cement supplier, several thermocouples were placed in the members to determine time-temperature relationships for steam- and naturally-cured specimens.

The Louisiana Transportation and Research Center (LTRC) announced that they would be making several laboratory trial mixtures in preparation for the Charenton Canal project. I made every effort to be at LTRC each time a new trial mixture was batched. I wanted to get first-hand experience with the plastic concrete. I learned that HPC, with high percentages of Class C fly ash, had good workability. The concrete was very cohesive, even with large doses of high-range water-reducing admixtures. Concrete slumps as high as 9 in. (230 mm) demonstrated uniformity.

Larry Niceley, our quality control manager, and I began analyzing our materials. Our cement is a Type III so we had to be concerned about heat of hydration due to the increased cement content of the mix. We were of the opinion that the use of Class C fly ash at 30 percent of the total cementitious material content would help reduce internal temperatures. Maximum internal concrete temperature for the project was specified as 160°F (71°C). Our sand, consisting of natural quartz with a fineness modulus averaging 2.6, appeared adequate. Another concern was coarse aggregate. Previous experience indicated that our washed river gravel was too smooth to provide the bond needed for strengths over 10,000 psi (69 MPa). We considered using crushed washed gravel, but realized there would still be a percentage of smooth edges. We eventually found a source of good quality washed crushed limestone that was stockpiled in the neighboring state of Alabama. We chose to use a 1/2-in. (13-mm) nominal maximum size aggregate because of the necessity for high mortar-aggregate bond. The final pieces to the material puzzle were chemical admixtures. We experimented with three types but eventually chose our present water-reducing and high-range water-reducing admixtures for economical reasons.

After several weeks of laboratory trial batches, the 28-day strength test for our reference mix was in excess of 14,000 psi (97 MPa). By June, we were ready to cast full-scale girder specimens. We cast two specimens on separate days in the middle of June and a third in July. With successive tests, the 28-day strengths showed noticeable increases. The first cast had an average compressive strength of 10,820 psi (74.6 MPa) with the second and third casts averaging 11,760 and 12,210 psi (81.1 and 84.1 MPa), respectively.

Lessons Learned

Several lessons were learned from our year-long research in preparation for the Charenton Canal project. Scanning thermometers to monitor internal concrete temperatures and a reliable cylinder match-cure system are a must. Converting to neoprene caps and 4x8-in. (102x203-mm) cylinder specimens from traditional sulphur caps and 6x12-in. (152x305-mm) cylinders was a necessity. Providing additional moisture control devices at the batch plant proved extremely valuable. And of course, executing a very thorough quality control plan was essential for our successful completion of the Charenton Canal project. In production, our release strengths ranged from 7620 to 9850 psi (52.5 to 67.9 MPa) and our 56-day strengths from 10,500 to 12,020 psi (72.4 to 82.9 MPa).

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CAMBER OF HIGH STRENGTH CONCRETE BRIDGE GIRDERS

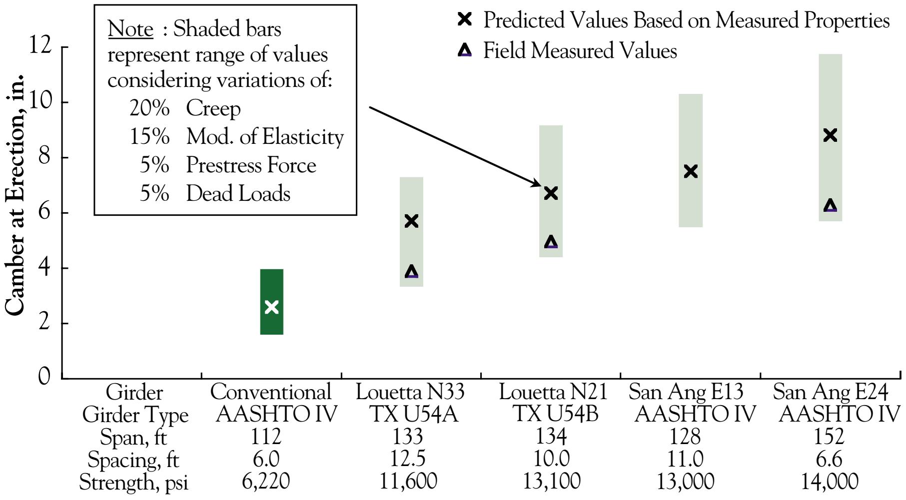
Shawn P. Gross, Villanova University

Camber is an important serviceability consideration for the design of precast, prestressed concrete bridge girders. In simple terms, net camber is the difference between an upward component due to prestress and several downward components caused by loads. Both material properties and structural parameters influence girder camber. Consequently, camber behavior of high strength concrete (HSC) girders can be significantly different than for conventional strength concrete girders.

The higher modulus of elasticity and lower specific creep of HSC tend to reduce the elastic and time-dependent components of upward camber or downward deflection. Prestress losses are also affected by differences in these material properties. In general, losses are lower per unit prestress, which results in slightly greater camber for HSC girders.

The use of HSC in bridge girders is usually associated with very efficient structural designs. Longer span lengths lead to a significant increase in the magnitude of individual components of camber. The use of higher prestressing forces, which are required to accommodate these efficient designs, usually leads to a significant increase in the upward component of camber associated with prestressing. Larger girder spacing can significantly increase the superimposed loads, thereby increasing the downward components of deflection.

An analytical comparison of the predicted camber at the time of girder erection for HSC and conventional concrete designs is shown in Fig. 1. The HSC girders in this example are actual designs selected from the Louetta* and San Angelo Texas HPC Showcase Projects. The analyses for these girders utilized a computerized time-step procedure and material properties measured as part of the research projects for these bridges. The HSC designs exhibit large camber values at erection, with predicted values of 5.0 to 8.3 in. (130 to 210 mm). This can be attributed directly to the use of higher prestressing forces in these girders and longer span lengths.



1000 psi = 6.895 MPa   1 ft = 0.305 m

Fig. 1. Girder camber at erection

Although camber can be difficult to predict accurately even for conventional concrete girders, the variation in key material properties and structural parameters will generally have a more substantial impact for HSC. In Fig. 1, the range of potential camber values at erection were calculated using an upper- and lower-bound approach that considered variations in creep, modulus of elasticity, prestressing force, and dead load. The range of values can be seen to be as large as 6.0 in. (150 mm) for the HSC designs. The sensitivity of these HSC designs is more than twice that of the conventional strength concrete design.

As part of the Texas HPC Showcase projects, camber measurements were recorded from release through service on 22 HSC girders. Typical results from this research program are shown in Fig. 2. In general, measured values were somewhat lower than predicted values (based on measured properties), but showed an acceptable level of accuracy. Probable reasons for this lower-than-predicted camber include variations in material properties between test specimens and the actual girders, and the effect of thermal gradients and differential shrinkage.

When designing with HSC, the increased camber sensitivity of HSC designs must be considered. Simplified methods of camber prediction are not applicable for HSC because of the many possible combinations of material properties and structural configurations. Even with a detailed procedure such as a time-step or computer analysis, accuracy can only be achieved when important material properties and structural parameters are known.

Material properties may be determined by trial batching or by past experience with a given mix design in similar conditions.

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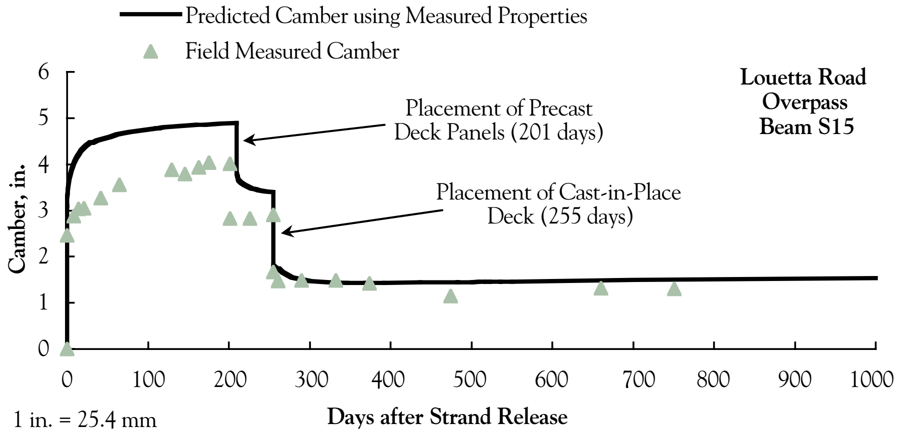

1 in. = 25.4 mm

Fig. 2. Measured and predicted camber vs. time for a Texas HSC girder

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* *The Louetta Road project was described in HPC Bridge Views No. 1.*

(continued from pg. 3)

An upper- and lower-bound approach is suggested so that a reasonable range of expected values may be defined.

Further Information

For more detailed information on camber in HSC girders, see:

Gross, S. P. and Burns, N. H., "Field Performance of Prestressed High Performance Concrete Highway Bridges in Texas," Center for Transportation Research, The University of Texas at Austin, Research Report 580/589-2, to be published.

FHWA HPC PROJECT

The Federal Highway Administration has announced the award of a three-year study entitled "Compilation and Evaluation of Results from High Performance Concrete Bridge Projects."

The objectives of the study are as follows:

1. Collect and compile information about concrete mixtures, concrete properties, research projects, girder fabrication, bridge construction, live load tests, and specifications from each of the joint State-FHWA High Performance Concrete bridge projects and other HPC bridge projects completed or underway. This includes all information related to material and structural properties and behavior.
2. Analyze and evaluate the compiled information in comparison with existing AASHTO specifications and guidelines for materials, testing, and structural design. For topics where the AASHTO specifications and guidelines need to be revised or do not exist, the compiled information will be evaluated in comparison with specifications and guidelines from other organizations such as ASTM and ACI.
3. Where sufficient research results exist on a given topic, recommendations for revised equations, specifications, or guidelines will be developed for use by the AASHTO Highway Subcommittee on Materials and the AASHTO Highway Subcommittee on Bridges and Structures.
4. Where sufficient research results do not exist on a given topic, specific recommendations for needed research will be developed.

The study will result in a single source for information about HPC bridge projects. The compiled information from the HPC projects will be placed on a compact disc for use on a variety of computer systems.

The work is being conducted under Contract No. DTFH61-00-C-00009 by Henry G. Russell, Inc. The Principal Investigator is Henry G. Russell working in cooperation with Dr. Richard A. Miller of the University of Cincinnati, Dr. H. Celik Ozyildirim, and Dr. Maher K. Tadros of Tadros Associates, LLC. Readers of HPC Bridge Views who wish to contribute information to the project may contact the Principal Investigator at 847-998-9137; (fax) 847-998-0292; or hgr-inc@worldnet.att.net.

HPC BRIDGE CALENDAR

April 3-5, 2000
5th International Bridge Engineering Conference, Tampa, FL
(Session 18, High Performance/High Strength Concrete)
Contact Bill Dearasaugh, Transportation Research Board at Phone: 202-334-2955 or at the web site at www4.nationalacademies.org/trb/TRBBridge.nsf

September 24-27, 2000
Second International Symposium on High Performance Concrete, Orlando, FL.
Jointly sponsored by PCI, FHWA, and *fib.*
Contact Paul Johal, Precast/Prestressed Concrete Institute at 312-786-0300 or info@pci.org.

HPC PUBLICATIONS

"High Performance Concrete-Research to Practice," Publication No. SP-189, American Concrete Institute, 2000, 466 pp.

Detwiler, R. J., Whiting, D. A., and Lagergren, E. S., "Statistical Approach to Ingress of Chloride Ions in Silica Fume for Concrete Bridge Decks," ACI Materials Journal,, Vol. 96, No. 6, November-December, 1999, pp. 670-675.

Utilization of High Strength/High Performance Concrete, Proceedings of the Fifth International Symposium, Sandefjord, Norway, 1999, 1460 pp. Available from Norwegian Concrete Association. Fax: 47 22 92 75 02, email: siri.engen@nif.no.

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Reproduction and distribution of this newsletter is encouraged provided that FHWA and NCBC are acknowledged. Your opinions and contributions are welcome. Please contact the Editor, Henry G. Russell, at 847-998-9137; (fax) 847-998-0292; email: hgr-inc@worldnet.att.net.

For further information on High Performance Concrete, contact:

FHWA Headquarters: Terry D. Halkyard, 202-366-6765; (fax) 202-366-3077; e-mail: terry.halkyard@fhwa.dot.gov

AASHTO Lead States Team: Mary Lou Ralls, TXDOT, 512-416-2576; (fax) 512-416-2599; e-mail: mralls@dot.state.tx.us

NCBC: Basile G. Rabbat, PCA, 847-966-6200; (fax) 847-966-9781; e-mail: basile_rabbat@portcement.org