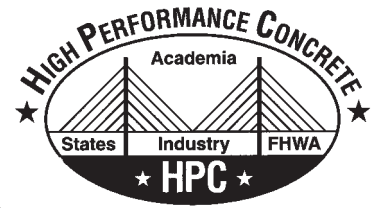




Bridge Views



<http://knowledge.fhwa.dot.gov/cops/hpcx.nsf/home>

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HPC IN MONTANA

Craig Abernathy, Montana Department of Transportation

In the summer of 2002, the Montana Department of Transportation (MDT) initiated a research project on Secondary Road No. 243 near the town of Saco in northeast Montana. This research opportunity was afforded by the construction of three bridges with the same geometry on the same route within 1/4 mile (400 m) of each other. The variability in conditions between test sites typically encountered in large-scale field investigations was minimized in this situation. Notably, the bridges would have a common quality of construction and would experience the same vehicular and environmental conditions. This situation offered the opportunity to evaluate the relative performance of three different bridge decks.

Each bridge consists of three spans with a total length of 146 ft (44.5 m) and a width of 27.6 ft (8.4 m). The superstructure consists of four lines of AASHTO Type I precast, prestressed concrete beams spaced at 7.9 ft (2.4 m) centers with a cast-in-place reinforced concrete deck approximately 8 in. (200 mm) thick. Epoxy-coated reinforcement is used in the deck. The bridge decks were cast in the second quarter of 2003.

The objective of the project was to investigate the performance of the following three types of concrete bridge decks:

- Conventionally reinforced deck made with standard concrete, designed and constructed following MDT's standard practices.
- Deck with reinforcement designed according to the empirical design approach of the AASHTO LRFD Bridge Design Specifications, made with standard concrete, and constructed following MDT's standard practices.
- Conventionally reinforced deck made with high performance concrete (HPC).

The specifications for the HPC deck required a minimum cementitious materials content of 615 lb/cu yd (365 kg/cu m), a silica fume content of 5 to 7 percent by weight of the cementitious materials, a maximum water content of 270 lb/cu

yd (160 kg/cu m), a slump of 1.6 to 3.1 in. (40 to 80 mm), an air content of 5 to 7 percent, and a minimum compressive strength of 4500 psi (31 MPa) at 28 days. Subsequently, the use of fly ash up to a maximum of 20 percent by weight of cementitious materials was permitted. Each deck was required to be water cured for 14 days using a burlap cover and fogging nozzles.

Each bridge deck was instrumented to monitor strains during live load tests, long-term deflections, and long-term strains. In addition, crack and corrosion monitoring will be performed on a regular basis.

Measured compressive strengths at 28 days for the HPC ranged from 7270 to 8340 psi (50.1 to 57.5 MPa) and for the standard concrete ranged from 3920 to 4840 psi (27.0 to 33.4 MPa).

Crack mapping of the decks approximately 5 weeks after their construction showed that hairline cracks had formed over the bents of all bridges except one bent with the HPC deck. An inspection of the decks approximately 9 months after casting indicated only one additional crack—a full depth diagonal crack near a corner at the abutment of one bridge. After 12 months, no additional cracking was observed and all cracks are still considered hairline.

In addition to monitoring the bridge instrumentation, MDT has a program underway to develop a cost effective HPC for use in bridge deck applications. The program includes testing for compressive strength, modulus of elasticity, rapid chloride permeability, chloride penetration resistance, freeze-thaw durability, scaling resistance, and shrinkage.

Further Information

For further information, contact the author at cabernathy@state.mt.us or 406-444-6269. For project reports, go to www.mdt.state.mt.us/research/projects/mat/high_concrete.shtml.

EVOLUTION OF HPC IN WASHINGTON STATE

Jerry Weigel, Washington State Department of Transportation

The Washington State Department of Transportation (WSDOT) has been very active in the development of high performance concrete (HPC). WSDOT, as a member of the AASHTO/SHRP Lead States Team, conducted a demonstration project in 1996 through 1998 on the use of HPC to design and construct the three-span bridge carrying State Route 18 over State Route 516.* A showcase on this project was conducted in 1997 to illustrate the use of HPC and to create a mechanism to share the experience with interested parties.

Cost Savings

The project presented an opportunity to compare the standard bridge designs with those made using HPC. The design comparison proved the economic and long-term benefits of using this new technology. HPC allowed the number of girder lines to be reduced from seven to five, realizing a net cost savings of at least \$50,000. As a result, WSDOT began using HPC in all its precast, prestressed concrete bridge girders and has used this technology for an average of 20 bridges per year since 1998. When the cost savings is extrapolated to all HPC bridges, significant savings can result. Approximately 41 percent of the current WSDOT bridge inventory, and seven out of ten bridges designed in the past ten years, have precast, prestressed concrete superstructure elements.

Super Girder

HPC technology has also been instrumental in the development of 83- and 95-in. (2.10- and 2.41-m) deep precast, prestressed concrete "super girders" for longer span lengths. This is particularly important with the increasing demand for "rapid construction" (get in, get out, and stay out) and satisfying environmental requirements to keep bridge supports out of wetlands and waterways. High economic value results from the inherent cost efficiency of precast, prestressed concrete girder construction compared to other long span alternatives. Using HPC and the 95-in. (2.41-m) deep section, we are able to build a precast, prestressed concrete girder bridge with a span length of 225 ft (68.6 m).

Design and Specification Changes

Prior to the AASHTO/SHRP Lead States activity, WSDOT required the use of 0.5-in. (12.7-mm) diameter 270 ksi (1.86 GPa) strands and minimum concrete compressive strengths of 4000 to 5000 psi (28 to 34 MPa) at transfer and minimum design concrete compressive strengths of 5000 to 5500 psi (34 to 38 MPa). Since the casting bed turnover rate was of utmost importance to the fabricators, they routinely provided a final strength much higher than the minimum specified value. This was the direct result of their need to acquire high concrete compressive strengths at early ages. To accomplish the high early strength, the mix designs were such that the concrete compressive strengths achieved were far greater than the 5500 psi (38 MPa) required.

Working with industry representatives, WSDOT structural designers found that they could establish higher strengths at transfer and could also require much higher design strengths. During the demonstration project, the final compressive strength was required to be 10,000 psi (69 MPa) with a strength at transfer of 7500 psi (52 MPa). This combination turned out to be very difficult to achieve on a routine basis. As a result, the structural designers reevaluated the strength needs and determined that, for most applications, a design compressive strength of 8500 psi (59 MPa) is structurally adequate and easily attainable.

The following design and specification revisions have been implemented in the state of Washington as a direct result of the AASHTO/SHRP Lead States HPC program research and showcases:

- Accepted the use of 0.6-in. (15.2-mm) diameter prestressing strands, which can provide a much higher compressive force in the limited girder space.
- Use of a compressive strength at transfer of 7000 to 7500 psi (48 to 52 MPa) to allow an improved casting bed turnover rate and an ideal design compressive strength. The strength at transfer can be as high as 8500 psi (59 MPa) for special circumstances, but comes with a higher cost and introduces additional risk.

- Use of a minimum design compressive strength of 8500 psi (59 MPa) at 28 days.

Depending upon section type, the precast, prestressed concrete girder can be shipped after a minimum maturity time of 7 or 10 days, provided that the concrete has attained the required minimum design compressive strength. Thereafter, the specifications allow the girders to be shipped when 95 percent of the specified minimum design compressive strength is achieved. This reflects WSDOT's recognition that contractors want to ship girders as soon as possible.

Computer Software

WSDOT Bridge and Structures Office has created computer aided design software and has made it available through a mechanism labeled "open source." One of the more successful programs, PGSuper™, is a precast girder superstructure design tool. The program features the use of LRFD Bridge Design Specifications and designs and analyzes precast, prestressed concrete girders for flexure and shear; provides camber and deflection analysis as well as long girder stability analysis for lifting and shipping; provides detailed reports to support every calculation; has a fully customizable library for any I- or U-shaped beams; and allows customization of design criteria. Free download of this software is available at <http://www.wsdot.wa.gov/eesc/bridge/software/>. Additional information on "open source" and help is available by contacting Rick Brice of the Bridge and Structures Office at 360-705-7174 or BriceR@wsdot.wa.gov.

Editor's Note

This article is the second in a series that describes how the use of HPC has progressed since it was first introduced into a state's program. The first article about Texas appeared in Issue No. 30.

*See HPC Bridge Views, Issue No. 2, March/April 1999.

HPC AND FRP FOR COLORADO BRIDGE DECK

Tarif Jaber, Jaber Engineering Consulting, Inc. and Ahmad Ardani, Colorado Department of Transportation

In 2000, the Colorado Department of Transportation (CDOT) received a \$700,000 award under the Innovative Bridge Research and Construction (IBRC) program to investigate new, innovative materials in the reconstruction of the I-225 and Parker Road interchange south-east of Denver. The design of the bridge deck included the development of high performance concrete (HPC) mixes, plus the use of partial depth, precast, prestressed concrete deck panels with fiber reinforced polymer (FRP) reinforcement.



Parker Road Interchange.

Parker Road Bridge

The bridge at the I-225 interchange consists of post-tensioned, cast-in-place, reinforced concrete box girders with 5-in. (12.7-mm) thick, precast, prestressed concrete deck panels and a cast-in-place slab for a total deck thickness of 8 in. (203 mm). Under the IBRC program, part of the bridge deck was constructed using the HPC mix and deck panels with FRP reinforcement.

To validate the design, several studies were undertaken at the University of Colorado at Boulder. The studies included the development of HPC mixes; evaluation of the mechanical properties of FRP reinforcement under static and cyclic fatigue loads, after environmental preconditioning; evaluation of the load carrying capacities of full scale, precast, prestressed concrete deck panels with FRP reinforcement; and evaluation of long-term fatigue endurance of a model bridge deck simulating the Parker Road bridge.

HPC Mixes

CDOT experimented with several HPC mixes. The objective was to develop

a mix that improved durability by reducing cracks from shrinkage and reducing permeability to deicing chemicals. At the same time, the mix had to meet criteria for strength and workability. This was achieved by reducing the cementitious materials content in an effort to produce a concrete with a lower modulus of elasticity and higher creep at early ages.

Seven bridge deck mixes with lower cement content, silica fume, and Class C or F fly ash were evaluated and tested for compressive strength, rapid chloride permeability, crack resistance, and drying shrinkage. As a result of the study, two mixes were adopted by CDOT — Class H for full depth concrete decks and Class HT for overlays. These are now being used in many CDOT projects. Class H was used on the Parker Road bridge.

The two selected HPC mixes have a low early strength and low heat of hydration. These characteristics allow the concrete to better accommodate volume changes and temperature variations and make it more resistant to shrinkage cracking. They also have low chloride permeability values at 56 days. Details of the study are presented in CDOT Report No. CDOT-DTD-R-2003-13 available from the National Technical Information Service.

FRP Reinforcement

In addition to the development of new and improved HPC mixes, the project investigated the use of carbon FRP (CFRP) and glass FRP (GFRP) bars as reinforcement in the precast concrete deck panels. Pretensioned CFRP bars were used in place of the conventional steel strands and GFRP bars were used instead of non-prestressed steel reinforcement. The objective was to reduce both construction and life cycle costs by reducing corrosion problems experienced with steel reinforcement. Extensive tests were performed to validate how exposure to severe environments affected the durability of the FRP reinforcement. Both CFRP and GFRP bars were subjected to freeze-thaw cycles. Loading tests were then performed to predict the effect on the tensile strength of the reinforcing bars and to establish a basis for cyclic fatigue testing procedures.

Both the tests and actual performance to date on the I-225 bridge deck indicate that the corrosion resistance, light weight, and superior tensile strength of the FRP reinforcement will prove beneficial in extending service life and lowering life cycle costs.

The Future

The project and related studies have demonstrated that new construction materials can make a major difference in the cost and effort of maintaining bridge decks and roads in severe climates. CDOT will continue to measure the benefits it receives from the combination of creative thinking and solid engineering that results from projects like this.

Concrete Mix Proportions

Material	Quantities
Portland Cement, ⁽¹⁾ lb/yd ³	465 to 485
Fly Ash, ⁽²⁾ % of cement	20 to 25
Silica Fume, % of cement	4.0
Fine Aggregate, lb/yd ³	1231 to 1398
Coarse Aggregate, ⁽³⁾ lb/yd ³	1595 to 1780
Set Retarder, fl oz/lb cement	2 to 3
HRWR, fl oz/lb cement	5 to 12
Air Entrainment, fl oz/lb cement	0.5 to 1.5
w/cm ratio	0.37 to 0.41

⁽¹⁾Type I/II

⁽²⁾Class F

⁽³⁾For Class HT, maximum size = 3/8 in.

Concrete Properties

Property	Value
Slump, in.	4 to 6 in.
Air Content, %	5.5 to 8.5
Permeability at 28 days, C	2700 to 2900
Permeability at 56 days, C	1400 to 1600
First Cracking Age, days	14 to 18
Comp. Strength at 3 days, psi	2500 to 3500
Comp. Strength at 7 days, psi	3500 to 4300

Question

Can I use the LRFD Bridge Design Specifications for concrete strengths above 10 ksi (69 MPa)?

Answer

The recently published Third Edition of the AASHTO LRFD Bridge Design Specifications states that the provisions of Section 5: Concrete Structures are based on concrete strengths ranging from 2.4 to 10.0 ksi (17 to 69 MPa), except where higher strengths are allowed. Article 5.4.2.1 – Compressive Strength states that design concrete strengths above 10.0 ksi (69 MPa) shall be used only when allowed by specific articles or when physical tests are made to establish the relationships between the concrete strength and other properties. The wording to allow the use of higher strength concretes in specific articles was introduced so that the results of ongoing research on high strength concrete can be introduced as the research projects are completed and revisions to the Specifications are approved. There are currently three National Cooperative Highway Research Program projects underway to address design for shear; transfer, development, and splice lengths; and flexure and compression. It is anticipated that results from these projects will allow the respective provisions to be extended for design concrete compressive strengths of at least 15.0 ksi (103 MPa) and possibly 18.0 ksi (124 MPa).

In the meantime, the only article in the Third Edition that specifically references a concrete compressive strength above 10.0 ksi (69 MPa) is 3.5.1 – Dead Loads for the unit weight of concrete. This new revision requires that the unit weight of normal weight concrete be increased when the specified concrete strength used in design exceeds 5.0 ksi (35 MPa). The revision is applicable to concrete compressive strengths up to 15.0 ksi (103 MPa).

At the 2004 Annual Meeting of the AASHTO Subcommittee on Bridges and Structures, several revisions were approved to existing articles to allow their use for concrete compressive strengths up to 15.0 ksi (103 MPa). The articles are 5.4.2.3 – Shrinkage and Creep, 5.4.2.4 – Modulus of Elasticity, 5.4.2.6 – Modulus of Rupture, 5.7.1 – Modular Ratio, and 5.9.5.1 through 5.9.5.4 – Prestress Losses. In addition to allowing these articles to be used for higher compressive strengths, other revisions to the articles were made to make them more applicable to the higher strength concretes. These revisions, however, do not become the official specification articles until they are published by AASHTO.

HPC BRIDGE CALENDAR

October 17-20, 2004

PCI National Bridge Conference — Bridges for Life,™ Atlanta, GA. See www.pci.org for more information.

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.

July 17-20, 2005

Sixth International Bridge Engineering Conference: Reliability, Security, and Sustainability in Bridge Engineering, Boston, MA. Organized by the Transportation Research Board. See www.trb.org/conferences/IBEC/ for more information.

HPC SURVEY

In 2003-2004, FHWA conducted a survey of State DOT's implementation of HPC as reported in *HPC Bridge Views*, Issue No. 32, March/April 2004. Results are now available at <http://knowledge.fhwa.dot.gov/cops/hpc.x.nsf/home>, scroll down and click on "2003-2004 Survey Results of State DOT HPC Implementation."

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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; e-mail: hgr-inc@att.net.

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