HPC Bridge Views

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A STRATEGIC PLAN FOR HPC BRIDGES

Basile G. Rabbat, National Concrete Bridge Council

During the last 15 years, research performed on high performance concrete (HPC) has led to the construction of a number of HPC bridges in the United States. In the late 1980s, the Strategic Highway Research Program identified HPC as one of seven key technologies to be considered for further development and implementation. In 1991, ISTEA provided funding through FHWA to assist states in building HPC bridges and to showcase the results. Under TEA-21, the Innovative Bridge Research and Construction Program (IBRC) was instituted to encourage innovation and improve the long-term performance of bridges through the use of HPC and other materials. Success stories and lessons learned from design and construction of many of the HPC bridges were reported in previous issues of this newsletter.*

In a memorandum dated May 12, 1997, FHWA Executive Director Anthony R. Kane stated: "A goal of the AASHTO Lead States and of the FHWA HPC Technology Delivery Team is the completion of at least one HPC bridge project in every state by the year 2002." As of this date, nearly 50 bridges in 30 states have been built under ISTEA's FHWA showcases or TEA-21's IBRC program.

Bridges are an integral part of our highway system. They are essential for the movement of people and goods and for our nation's economic growth and prosperity. The most promising materials and construction methods must be selected to extend the life of bridges. In the January 31, 2000, issue of *ENR*, FHWA Administrator Kenneth Wykle challenged industry and academia to design and build bridges to achieve 100-year useful lives. Wykle saw advances in HPC as a way to get there.

Realizing the need to coordinate the HPC experiences learned, and to respond to Wykle's challenge, industry initiated the development of a strategic plan for HPC bridges. Representatives from FHWA, state highway agencies, consulting engineering firms, academia, and industry met in a focus group in November 2000. They brainstormed over the advantages, weaknesses, opportunities, and threats to HPC for bridges. The group identified several critical issues that need to be addressed: lack of understanding on the use of HPC, lack of technology transfer mechanisms, inadequate education of engineers, and little training in life-cycle cost methods for bridges. The focus group concluded its meeting by agreeing that a detailed plan for cooperative research, implementation, and technology transfer for HPC bridges was needed to enable all bridge owners to benefit from this technology.

To address this need, the National Concrete Bridge Council (NCBC) is developing a white paper that will outline a strategy to tackle the focus group's critical issues. Development of a detailed action plan with participation of all stakeholders will follow the publication of the white paper. The action plan will identify the scope and estimated costs of individual research and development projects and technology transfer programs.

HPC holds great promise for improving the condition of our highway bridge inventory and for maintaining the momentum for economic growth and welfare of our nation. The speed of construction with precast HPC has helped overcome many congestion and work zone safety issues. New HPC decks have exhibited reduced cracking and will, undoubtedly, extend the service lives of bridges, with minimal maintenance. Valuable information, specifications, materials, and methods have been developed within the last decade. The white paper and action plan will provide a framework and cost estimate for gathering this information, synthesizing it, supplementing it with needed research, and for training designers, specification writers, constructors, inspectors, and quality control supervisors in implementing HPC technology.

Further Information

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** Previous issues of this newsletter are available at: http://www.portcement.org/br/newsletters.asp.*

The use of HPC allowed for a wider girder spacing and more durable structure.

HPC REPEAT SUCCESS IN NEW HAMPSHIRE

Mark D. Whittemore, New Hampshire Department of Transportation

The success of New Hampshire's first high performance concrete (HPC) bridge—Route 104 in Bristol[1]—made the decision to proceed with the next HPC bridge an easy choice. Actually, during New Hampshire's early involvement in HPC, it was planned to make the second project serve as an experimental control to the Route 104 HPC bridge. However, soon after completion of the Route 104 bridge, the New Hampshire Department of Transportation (NHDOT) determined it would be better to look forward, rather than revert back to the conventional deck and girder concrete construction. The goal, therefore, was to build on the results of the Route 104 bridge, making adjustments where problems had occurred, and solidifying where successes had been achieved.

The second HPC bridge, also located in Bristol, carries NH Route 3A over the Newfound River and is about one mile from the Route 104 bridge. The new bridge is a 60-ft (18.3-m) long simple-span structure that is 30 ft (9.1 m) from curb to curb with one 5-ft (1.52-m) wide sidewalk. The superstructure consists of 3-1/2-in. (90-mm) thick precast concrete deck panels with a 5-1/2-in. (140-mm) thick cast-in-place (CIP) concrete deck, and four precast, prestressed concrete New England bulb-tee (NEBT) 1000 HPC girders.

The advantages of combining HPC with the NEBT girders became apparent early in the design process. Girder spacings were increased to 11 ft-6 in. (3.51 m) on center. This reduced the number of girders from five to four. The NEBT was also 5-1/2 in. (140 mm) shallower than the AASHTO/PCI Type III girder, providing additional vertical clearance over the design flood elevation. The same girder concrete compressive strength of 8000 psi (55 MPa) used on the Route 104 bridge was specified for use on Route 3A bridge. Attaining this strength consistently was an issue on the Route 104 bridge and, consequently, several modifications were made to the specifications on the Route 3A bridge.

First, the air entrainment requirement for the girders was reduced from a range of 5 to 8 percent to a target value of 5 percent with a lower limit of 3.5 percent. Justification for this was that the girders would not be subjected to wetting from melting snow and deicing salts, and research supported the freeze-thaw durability of concrete with air entrainment values as low as 3 percent.[2] Second, a more proactive approach was taken in pursuing the necessary trial batching for developing an acceptable concrete mix design. The precaster aggressively supported a cooperative effort and trial batches consistently achieved strengths required by the specification.

A big asset to the contractor in pursuing a condensed construction schedule was the use of partial depth precast, prestressed concrete deck panels. On the Route 104 bridge, the contractor expressed a need for a less expensive method of forming the deck. The use of deck panels on the Route 3A bridge helped to reduce the costs associated with special deck forms needed for the wider girder spacings.

Average 28-day compressive strengths of 9000 psi (62.1 MPa) were obtained in the field for the CIP deck concrete along with chloride permeabilities well below the specification goal of 1000 coulombs at 56 days. The proper finishing and curing of the deck was crucial in order to achieve an excellent and durable concrete surface. Using a work bridge behind the screed machine, cotton mats were spread out on the deck and most were wetted within 10 minutes after the screeding operations. The cotton mats were kept wet for seven days. Inspections to date have revealed an excellent surface with only four visible hairline cracks. The completed bridge was opened to traffic in June 1999. This bridge received the 2000 PCI Design Award for the best bridge with spans less than 65 ft (19.8 m).[3]

The NHDOT has been extremely pleased and satisfied with its second bridge using HPC. Several concerns from the first HPC project were addressed to our complete satisfaction. The girders, deck panels, and CIP deck have performed superbly. With another success for HPC, the Department is well on its way to making HPC the standard concrete practice for New Hampshire's bridges.

Further Information

For further information about the Route 3A bridge, contact the author at 603-271-2731 or mwhittemore@dot.state.nh.us.

Information about the Route 104 and Route 3A bridges is available in the compilation described on Page 4 of this newsletter.

References

1. Waszczuk, C. M., "Crack Free HPC Bridge Deck–New Hampshire's Experience," HPC Bridge Views, Issue No. 4, July/August 1999, p. 2.
2. SHRP High Performance Concrete Showcase Notebook, Houston, TX, March 25-27, 1996, Ramon Carrasquillo's presentation on Mix Proportioning, p. 4-18.
3. Ascent Magazine, Precast/Prestressed Concrete Institute, Fall 2000, pp. 74-75.

BENEFITS OF LIGHTWEIGHT HPC

Thomas A. Holm and John P. Ries, Expanded Shale Clay and Slate Institute

There are many advantages to the use of lightweight aggregate in high performance concrete. This article highlights the primary design- and construction-related benefits.

Improved Structural Efficiency (Strength/Weight)

Structural lightweight concrete is typically 25 to 35 percent lighter than normal weight concrete. This translates into lighter superstructures and smaller loads for substructure design. The award winning Shelby Creek Bridge in Kentucky provides an excellent example of structural efficiency where a 7000 psi (48 MPa) concrete compressive strength was attained with a density of less than 130 pcf (2.08 Mg/cu m).

Reduced Seismic Forces

The new Benicia-Martinez Bridge in California is a cast-in-place concrete, post-tensioned box girder bridge situated in a high seismic zone. The bridge will be built using the balanced cantilever method. To reduce the seismic forces caused by the structure's self weight, the designers have specified a concrete density of 120 pcf (1.92 Mg/cu m) and a concrete compressive strength of 6500 psi (45 MPa).

Improved Constructibility

Constructibility and transportation issues need to be considered early in the design and planning process of any project. Since precast, prestressed concrete bridges cannot be built unless the beams can be transported, lightweight HPC is often used to comply with over-the-road state weight limitations, or to carry more members on each truck. Fewer truck deliveries (especially in restricted areas) are environmentally beneficial, safer, and generate fewer public complaints. The use of a longer crane reach or a smaller crane are added benefits.

Improved Hydration Due To Internal Curing

Lightweight aggregate containing high internal moisture contents may be substituted for conventional aggregates to provide "internal curing." High cementitious concretes with very low water-cementitious materials ratios are vulnerable to self-desiccation. These concretes benefit significantly from the added internal moisture of properly pre-wetted lightweight aggregates. Internal curing is particularly helpful for concretes containing high volumes of silica fume and other materials known to be sensitive to curing procedures. In these applications, density reduction is a positive by-product. Because of the improved cement hydration developed by the moisture released from the reservoir of water absorbed within the pores of the lightweight aggregate, the improvement in the quality of concrete over time is greater with lightweight HPC than with concrete containing normal weight aggregates.

Renovation and Repair

One of the most extensive applications of structural lightweight concrete is in bridge re-decking where lower dead load is achieved. This often means that bridge widths, traffic lanes, and the thickness of structural slabs can be increased while utilizing existing piers, footings, and other structural members. The use of lightweight concrete often allows the live load capacity of older structures to be increased.

Economic Considerations

The use of lightweight aggregates, while more expensive than conventional aggregates, does not increase the total project cost. Consider the use of lightweight HPC on an 8-in. (200-mm) thick concrete bridge slab with a cost premium of $30/cu yd ($39/cu m). One cubic yard (0.76 cu m) of concrete will yield approximately 40 sq ft (3.7 sq m) of deck causing an increase in slab cost of 30/40 = $0.75/sq ft ($8.07/sq m). For a bridge with a total cost of $75/sq ft ($807/sq m) this results in a cost increase of one percent. However, this one percent material cost is offset by the reductions in the cost of slab reinforcement and the reduced size and cost of girders, piers, and foundations all due to a lower superstructure self weight of approximately 20 percent.

Lightweight concrete was used on the Shelby Creek Bridge to reduce superstructure weight. (Photo courtesy of PCI.)

Durability

Lightweight concrete has been used in bridge decks for over 50 years. The excellent in-service performance in these structures as well as in marine structures and ships has demonstrated that lightweight concrete is a durable concrete. More detailed information about durability is provided in Reference 1.

Further Information

For more information on the advantages of lightweight concrete, contact your local supplier of rotary kiln expanded shale, clay, or slate lightweight aggregate. Your nearest supplier may be located by going to www.escsi.org.

Reference

1. Holm, T. A. and Bremner, T. W., "State-of-the-Art Report on High-Strength, High-Durability Structural Low-Density Concrete for Applications in Severe Marine Environments," U.S. Army Corps of Engineers, Report No ERDC/SL TR-00-3, August 2000, 116 pp. available at www.wes.army.mil/SL/INP/reports.htm. (This address is case sensitive.)

Editor's Note

This article is the second in a series that addresses the benefits of specific materials used in HPC. The benefits of silica fume were discussed in the previous edition of HPC Bridge Views.

COMPILATION OF RESULTS FROM HPC BRIDGES

Henry G. Russell, Henry G. Russell, Inc.

In 1993, the Federal Highway Administration initiated a national program to implement the use of high performance concrete in bridges. The program included the construction of demonstration bridges in each of the FHWA regions and the dissemination of the technology and results at showcase workshops. A total of 18 bridges in 13 states were included in the national program. Also, other states have implemented the use of HPC in various bridge elements. Articles on many of the bridges have been published in HPC Bridge Views.

The bridges were located in different climatic regions of the United States and used different types of superstructures. The bridges demonstrated practical applications of high performance concretes. In addition, construction of these bridges provided opportunities to learn more about the placement and actual behavior of HPC in bridges. Consequently, many of the bridges were instrumented to monitor their short- and long-term performance. Additionally, concrete material properties were measured for most of the bridges.

The superstructures for the bridges, generally, consisted of precast, prestressed concrete girders with cast-in-place concrete decks. A variety of cross sections were used for the girders. Span lengths ranged from 60 to 157 ft (18.3 to 47.9 m). Specified concrete compressive strengths at release of the strands ranged from 5500 to 8800 psi (38 to 61 MPa). Specified design compressive strengths ranged from 8000 (55 MPa) at 28 days to 14,000 psi (97 MPa) at 56 days.

The primary emphasis for concrete used in the cast-in-place decks has been to produce a concrete with low chloride permeability without specifying a high-strength concrete. Achievement of low permeability values required the use of a mineral admixture such as fly ash, silica fume, or ground granulated blast-furnace slag. Specified compressive strengths generally ranged from 4000 to 6000 psi (28 to 41 MPa) at 28 days.

As part of the FHWA implementation program, a research component was included in each bridge. The research objectives varied from bridge to bridge. On some projects, the research focused on concrete material properties. Measurements were made to determine compressive strength, modulus of elasticity, tensile strength, creep, shrinkage, chloride permeability, freeze-thaw resistance, deicer scaling resistance, and abrasion resistance. Concrete temperatures were measured during curing to determine the heat of hydration of the prestressed concrete beams. The use of match-cured cylinders compared to conventionally-cured cylinders for measurements of concrete compressive strengths was also investigated. On other projects, the research was used to determine prestress losses, temperature gradients in the deck and girders resulting from daily and seasonal temperature changes, strand transfer length, long-term camber, and load distribution.

HPC CD Compilation

Information from the showcase bridges is being collected by the FHWA and compiled onto a compact disc (CD) for easy retrieval and viewing. An interim version of the CD will soon be issued by the FHWA.

On the CD, the information is presented in two formats. The first format consists of the individual compilation for each bridge and includes a description of the bridge and information about the benefits of HPC, costs, structural design features, specified properties for HPC, approved concrete mix proportions, concrete material properties, research data measured during and after construction, sources of data, related research, and special provisions for HPC.

The second format consists of ten tables that contain a summary of the primary information from the individual bridge compilations. The tables may be used to compare data from different states and different bridges. The CD also contains a search option that allows information on a specific topic to be quickly located.

Copies of the CD may be obtained from the FHWA by contacting Terry D. Halkyard by phone: 202-366-6765, fax: 202-366-3077, or email: terry.halkyard@fhwa.dot.gov. The compilation can also be viewed and downloaded at www.nationalconcretebridge.org.

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