HPC Bridge Views

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Contents

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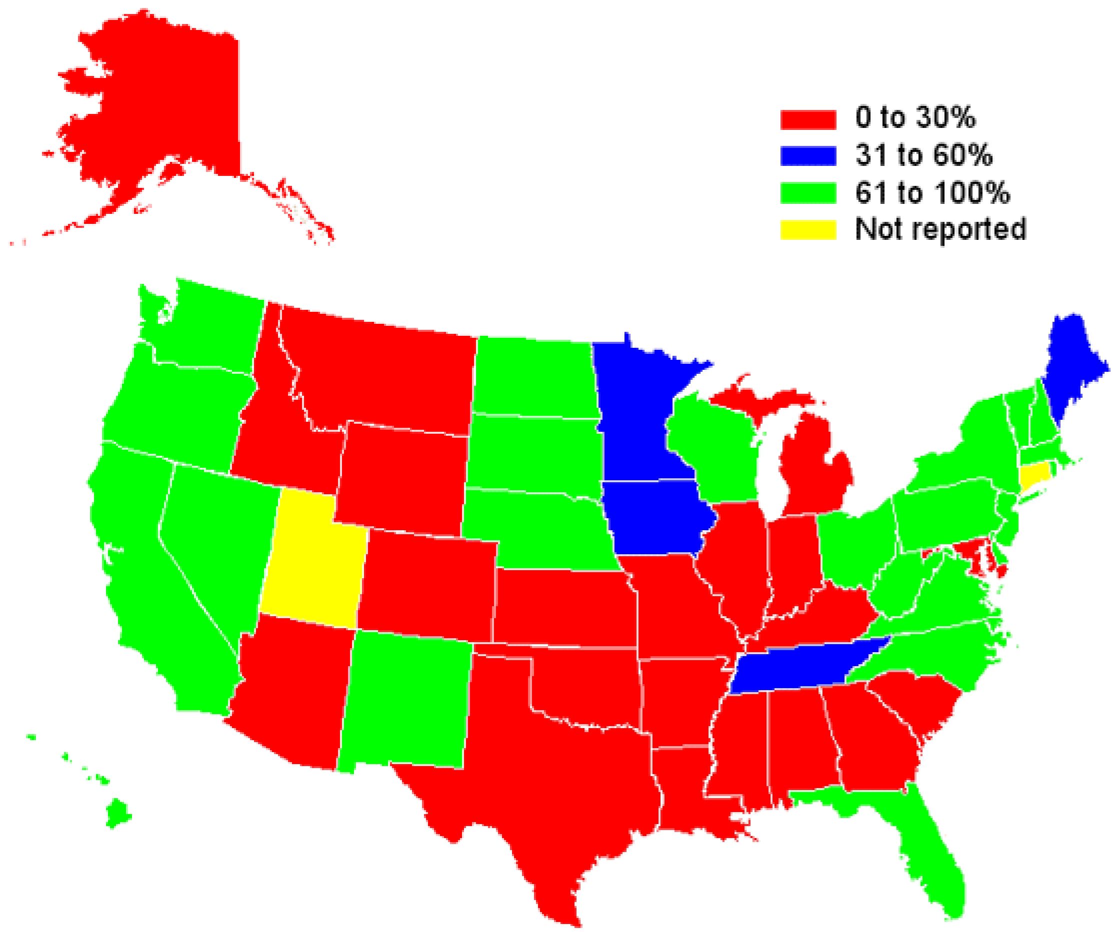


Estimated percentages of bridge projects bid in 2004 to 2006 that included an HPC element.

Updated FHWA HPC Survey

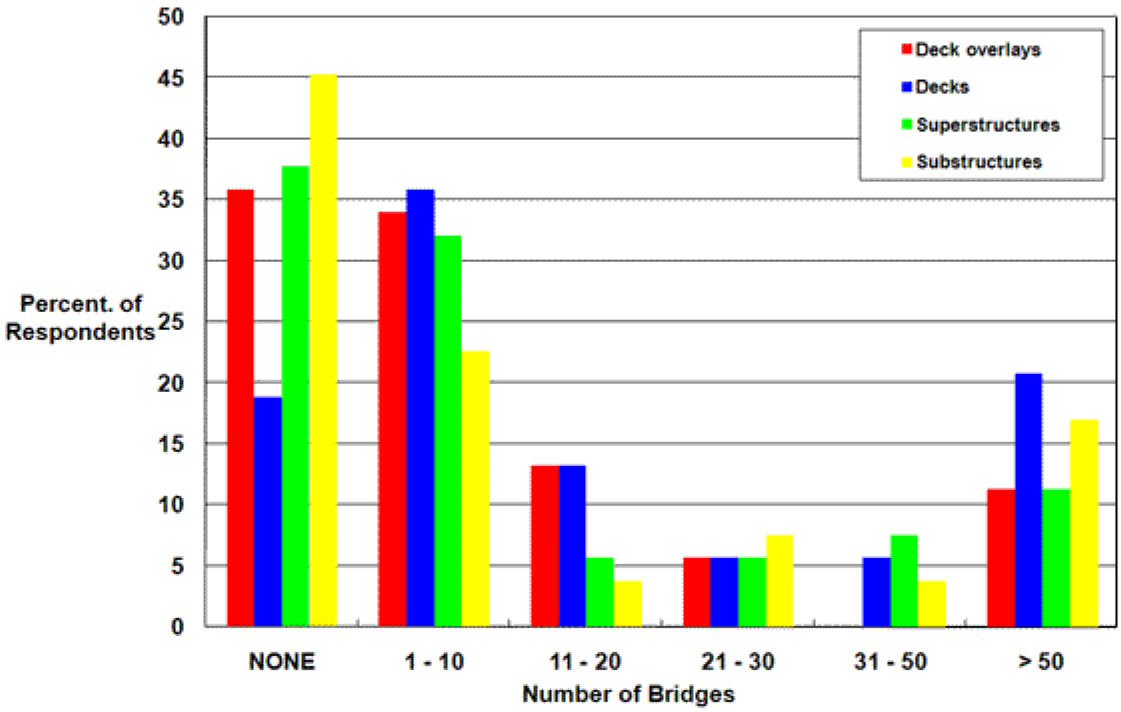
Louis N. Triandafilou, Federal Highway Administration

Created in 1997, the Federal Highway Administration's (FHWA) High Performance Concrete (HPC) Technology Deployment Team (TDT) assists state departments of transportation (DOTs) and other agencies with deploying HPC technology.* In 2003/04, the team conducted a national survey of HPC usage, and the results were summarized in HPC Bridge Views, Issue No. 32. A second survey was made in 2006/07. The results are summarized in this article.

The survey was distributed to all 50 state DOTs, Puerto Rico, the District of Columbia, and the Federal Lands Bridge Office. All 53 agencies returned the survey to the TDT for processing, although some agencies did not respond to all questions. The survey included sections on general usage of HPC, permeability benefits of HPC, strength benefits of HPC, self-consolidating concrete (SCC), lightweight HPC, and usage of various types of corrosion-resistant reinforcing bars.

General Usage of HPC

The recent survey asked about the usage since 2003 of HPC for major bridge components—deck overlays, deck slabs, superstructures, and/or substructures. On average, about 15% of the agencies used HPC for these components in more than 50 bridges, 20% in 10 to 50 bridges, 30% in 1 to 10 bridges, and the remainder not using it at all or not responding to the question.



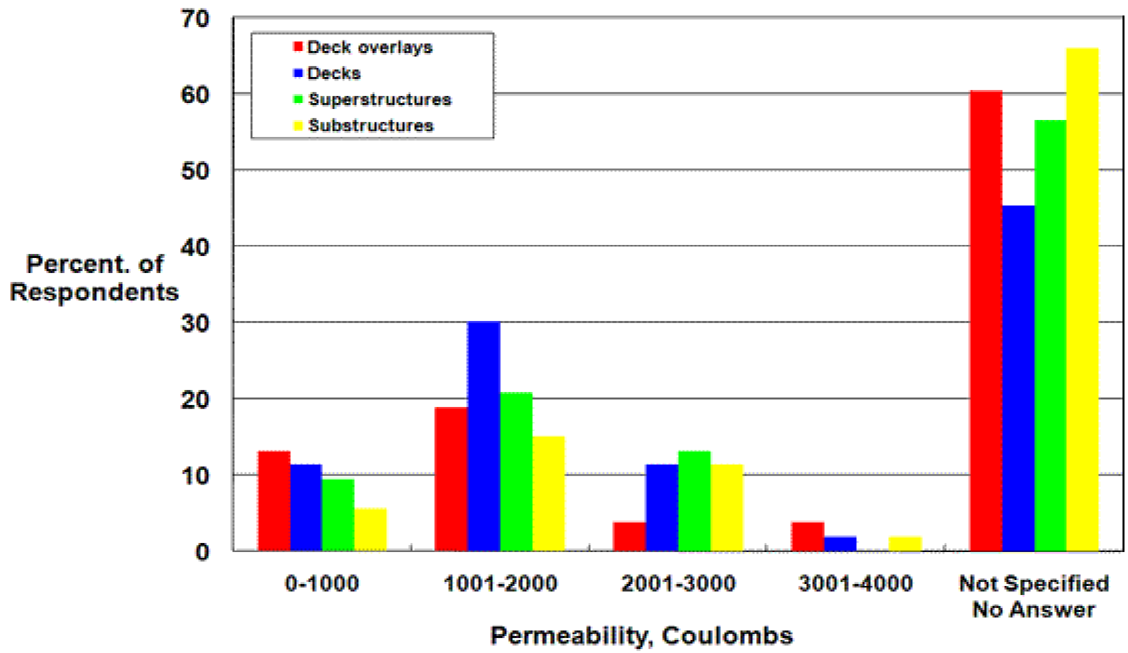
General usage of HPC from 2003 to 2007.

On a project basis, on average, 16 agencies used HPC on up to 10% of their bridge projects, 19 agencies used HPC on 10 to 80% of their projects, and 15 agencies used HPC on over 80% of their projects.

HPC for Permeability and Strength

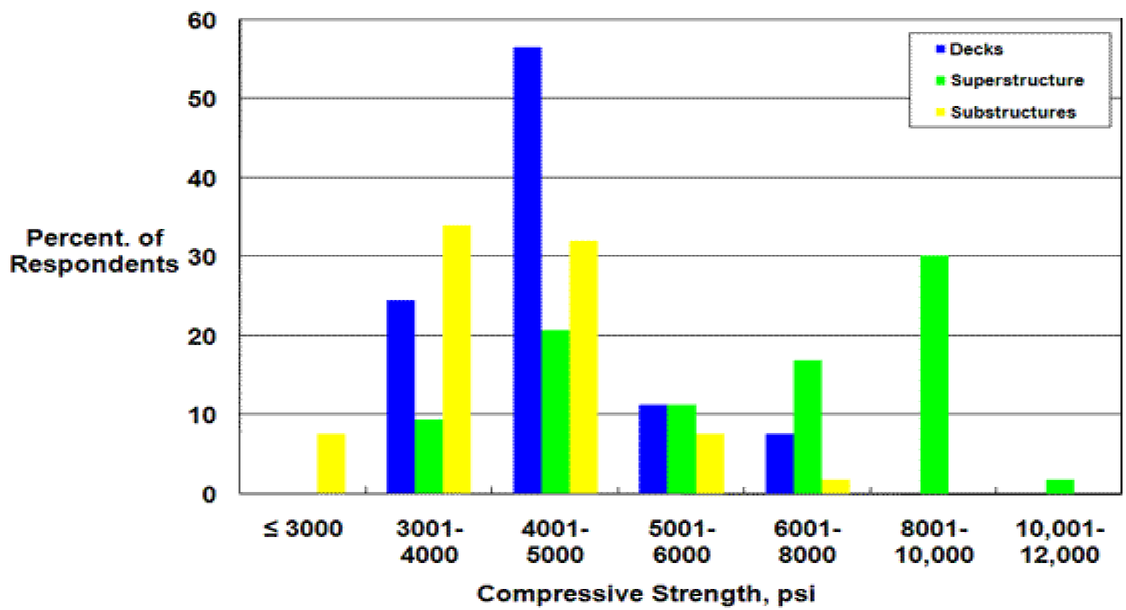
Similar to the earlier survey, the recent survey also tracked the agencies' use of HPC for permeability and strength benefits. Rapid chloride permeability values in the range of 1001 to

2000 coulombs were most commonly specified for overlays, decks, superstructures, and/or substructures.



HPC specified for permeability

A compressive strength range of 4001 to 5000 psi (28 to 34 MPa) was most commonly used for decks and substructures. The next most common range was 3001 to 4000 psi (21 to 34 MPa). For superstructures, the compressive strength range of 8001 to 10,000 psi (55 to 69 MPa) was most commonly specified. The next most common was 4001 to 5000 psi (28 to 34 MPa).



HPC specified for strength

Self-Consolidating Concrete

In the recent survey, the reported usage of SCC was categorized by superstructure and other precast members, and by various substructure elements. Eleven agencies responded that they had used SCC in up to 10 bridge superstructures and/or precast members. Three agencies reported using SCC in 11 to 20 bridge superstructures. One agency reported its use in 21 to 30 precast structural members, and one agency reported from 31 to 50 bridge superstructures with SCC.

SCC usage in substructure elements has been much less. Only five agencies reported such usage, in up to 10 bridges over the past 4 years. The usage was for pier caps and columns, footings, piles, and drilled shafts.

Lightweight HPC

As with other data noted above, the earlier survey tracked only generally whether an agency had tried lightweight HPC on an experimental basis, or whether the agency had progressed to the point of developing standard specifications for the technology. The recent survey tracked actual project experience. This time around, 11 agencies told us they had used lightweight HPC in up to 10 bridge decks, and three agencies used the material in the superstructure of up to 10 bridges. Two agencies used lightweight HPC in the range of 11 to 20 decks, and two agencies on more than 50 bridge decks. No agency reported using lightweight HPC in bridge substructures.

HPC Performance Characteristics

The survey obtained results on what HPC performance characteristics were being tested by the agencies. For durability, performance characteristics include freeze-thaw (F/T) durability, scaling resistance, abrasion resistance, chloride penetration, alkali-silica reactivity (ASR), and sulfate resistance. Strength-related performance characteristics include compressive strength, modulus of elasticity, shrinkage, and creep. In addition, flowability can also be specified as a conventional slump value or as a flow for self-consolidating concrete.

Not surprisingly, compressive strength tests were specified by the highest number of agencies with 48 out of 53 reporting their use. The next highest was rapid chloride permeability, tested by 34 agencies followed by shrinkage, tested by 20 agencies. Flowability, ASR, and F/T were grouped fairly close together and tested by 17 agencies. Scaling and sulfate resistance were the least specified tests, and by only six agencies.

Methods of Specifying HPC

The most common methods of specifying HPC for bridges was either by (a) special provision for a particular project, or (b) a combination of special provisions and general specifications. Twenty-two agencies reported the use of Method (a) and 22 agencies the use of Method (b). Only eight agencies used general specifications. Slightly over half the agencies had neither built nor planned HPC bridge projects using end-result, performance-based specifications (ERS). Eleven agencies had one to five bridges either planned or built using ERS. Only one agency had made substantial progress with ERS being used on over 100 bridges.

High-Performance Corrosion-Resistant Reinforcing Bars

For many years, agencies have been experimenting with corrosion-resistant alternatives to epoxy-coated reinforcement for bridge decks. A long-term research study has been performed for the FHWA and the Florida DOT by Florida Atlantic University to evaluate alloys previously identified as candidates for corrosion-resistant reinforcement. Details of the results of this portion of the survey and the remainder of the survey, as well as results of the earlier survey, may be found on the Team's website at http://knowledge.fhwa.dot.gov/hpc.

Conclusions

The HPC TDT's survey of 2003/04 showed that almost every agency had either incorporated HPC into their standard specifications, or had at least tried it during the previous 10 years. However, the results were inconclusive as to the extent of HPC usage by each agency. The 2006/07 survey attempted to bridge that gap by soliciting information as to number of bridges constructed with an HPC element, as well as percentages of projects built since the first survey with an HPC bridge element.

The map at the beginning of this article shows that there is still much work to be done if HPC is to successfully impact the new and rehabilitated U.S. bridge infrastructure in the 21st century. An aggressive training effort will still be necessary for the total work force involved with bridge design and construction—engineers, inspectors, and contractors. Undergraduate and graduate school curricula must also adapt to give students the tools needed to understand the behavior of HPC constituent materials.

The 1990s laid the groundwork for HPC technology to develop and blossom into a bona fide bridge material through the efforts of FHWA, state agencies, consulting engineers, the concrete industry, and academia. It is this continuing dedicated partnership that will play a critical role in the widespread use of HPC.

Acknowledgement

The author wishes to express his sincere appreciation to Rodolfo F. Maruri and Claude S. Napier of the FHWA for synthesizing a huge amount of data from the survey in a very timely manner.

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* See *HPC Bridge Views, Issue No. 19, January/February 2002*.

Iowa interchange with tapered piers and pier caps.

HPC in Iowa

Ahmad Abu-Hawash and Norman McDonald, Iowa Department of Transportation

In the September/October 2003 issue of HPC Bridge Views, the Iowa Department of Transportation (DOT) discussed its strategy and performance requirements for using high performance concrete (HPC) on one of the biggest reconstruction projects in Iowa. With over 70 bridges, the reconstruction of I-235, an urban interstate through Des Moines, gave the Iowa DOT the opportunity to introduce innovative materials, such as HPC and self-consolidating concrete (SCC)—both newcomers at the time to Iowa.

HPC Development

Although HPC has been used widely in the United States since early 2000, implementing the use of HPC mixes in Des Moines was not a simple task. A group of Iowa DOT engineers from the disciplines of design, materials, and construction, along with staff from the Federal Highway Administration, collaborated on developing mix designs and construction specifications that were suitable for central Iowa. The HPC mixes had to utilize locally available aggregates and meet new design requirements in terms of strength and permeability (see HPC Bridge Views, Issue No. 29, September/October 2003).

Many challenges were encountered along the way including a lack of local supplier experience in producing high performance mixes, implementation of a new aggressive Iowa DOT policy on curing concrete within minutes of casting, and dealing with harsh winter temperatures

Cooperation among Iowa DOT staff, contractors, and material suppliers helped overcome these challenges. The end result was improved structural concrete in terms of higher strength and lower permeability, with significant reduction in shrinkage cracking in bridge decks.

The I-235 experience has allowed the Iowa DOT to expand usage of HPC to other areas of the state. Design specifications for two new Mississippi River crossings in Dubuque and Bettendorf require the use of HPC for the bridge decks and substructure components, and precast, prestressed concrete beams on the approach spans.

HPC is also currently being used on the Council Bluffs Interstate System improvement project, which includes a new Missouri River crossing. Although the Iowa DOT has not officially adopted HPC for statewide use, many requirements associated with it are being added to the traditional mixes. This can be attributed to the successes achieved on the I-235 project. Furthermore, some changes to Iowa's construction specifications are being introduced to take advantage of the proven practices, such as improved concrete curing.

Iowa HPC mixes have specified target values for both compressive strength and permeability, which are defined in the Iowa DOT's "Special, Developmental or Supplemental Specifications." The minimum 28-day compressive strength for cast-in-place concrete is set at 5000 psi (34 MPa), while rapid chloride permeability values for the deck and substructure concretes are 1500 and 2500 coulombs, respectively. Contractors have not had any problems meeting these target values.

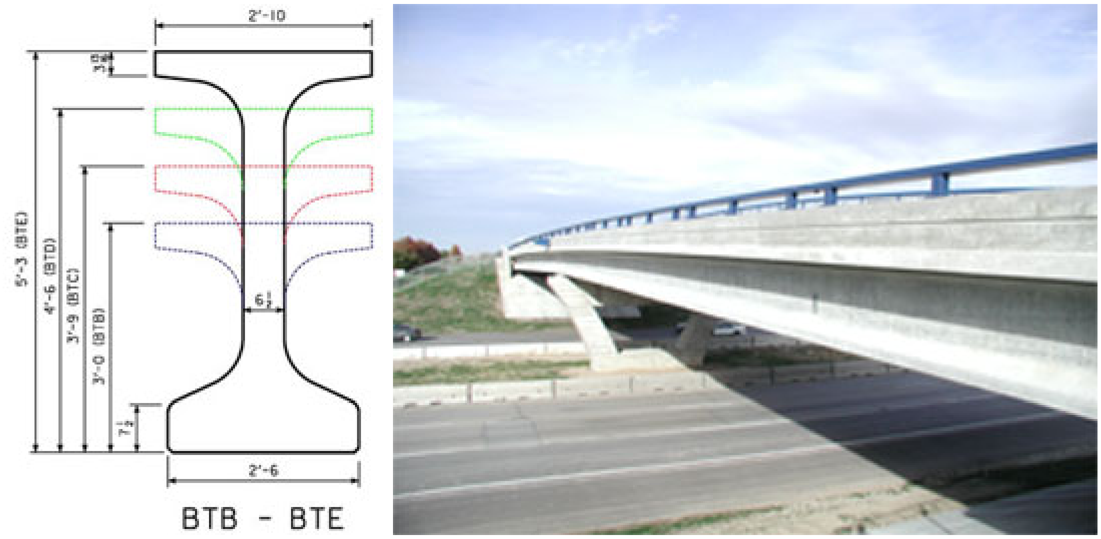
Although the specifications give the contractors the flexibility to design their own HPC mixes, they generally choose Iowa DOT mixes proven to produce the desired characteristics.

New Family of HPC Beams

To introduce a new family of precast, prestressed HPC beams, the Iowa DOT collaborated with the prestressed concrete industry in the state. The new set of bulb-tee beams provides a competitive alternate for medium-span bridges, which are typically constructed using steel girders. These beams have proven to be a perfect fit for many two-span bridges; multiple-span, urban viaducts; and approach spans of major river crossings.

Attributes of the new beams include compliance with the AASHTO Load and Resistance Factor Design (LRFD) Specifications, permeability less than 2500 coulombs, compressive strengths up to 9000 psi (62 MPa), efficient design with span lengths up to 155 ft (47 m), beam spacings up to 9 ft 3 in. (2.8 m), and an aesthetically pleasing shape.

The new bulb-tee beam family was initially limited to two unique beam sections, designated the BTC and BTD beams, to meet the immediate I-235 project needs. It was then expanded to include shorter and longer span lengths (BTB and BTE beams). The expanded beam family now has overall depths that range from 36 to 63 in. (915 to 1600 to mm) and features the use of 0.6-in. (15-mm) diameter strands at 2 in. (50 mm) centers.



Bulb-tee beam cross section and BT beam as installed.

Other Applications

In addition to the medium-span HPC beams, the Iowa DOT introduced an alternative to the state's traditional low-slump concrete deck overlay mix. The new HPC deck overlay mix, unlike the low-slump overlay mix, does not require specialized mixing and casting equipment because it can be cast using standard deck construction techniques and equipment, thus reducing cost. The biggest advantage of using HPC in deck overlays is the elimination of nuclear density testing, which involved security issues. For interstate and primary projects, prewetted burlap must be placed within 10 minutes of finishing.

Another application of HPC in Iowa has been for mass concrete, where the use of slag proved to be beneficial in controlling the heat of hydration and reducing the potential for shrinkage cracking.

Self-consolidating concrete (SCC) has proved to be an attractive use of HPC for precast applications and for casting aesthetic features and components with a complex geometry. Currently, SCC is being used for deck panels, noise walls, mechanically stabilized earth (MSE) walls, and in some precast, prestressed concrete beams.

Iowa continues to advance the use of HPC in structural applications and is leading the way in introducing the use of ultra-high performance concrete (UHPC) in precast, prestressed concrete beams for county bridges.

Further Information

For further information, contact the lead author at ahmad.abu-hawash@dot.iowa.gov.

Route 52 bridge over the Wallkill River.

SCC for the Route 52 Bridge over the Wallkill River

Mathew Royce, New York State Department of Transportation

The Route 52 bridge over the Wallkill River is located in the village of Walden, NY, 50 miles (80 km) north of New York City. This new bridge was completed in 2005, replacing a 176-ft (53.6-m) long steel truss bridge built in 1934.

The main span of the bridge consists of two cast-in-place concrete arches with a clear span of 148.8 ft (45.4 m). The arches support precast concrete spandrel columns, cap beams, and prestressed concrete adjacent box beams, with a cast-in-place concrete composite deck slab. Precast and cast-in-place components were efficiently combined in the bridge to build an aesthetically pleasing structure within a reasonable cost. The bridge is expected to have a service life of 75 years with low maintenance.

The cast-in-place concrete elements for the bridge were made using conventional concrete. The precast elements contained self-consolidating, high performance concrete (SCHPC). This was the first use of SCHPC in precast concrete components by the New York State Department of Transportation. The SCHPC resulted in improved production efficiency with minimal repairs to the components after removal from the forms. The surface textures of the components were significantly better than those of components made using conventional concrete. No treatment for filling 'bug holes' was necessary.

SCHPC Specifications

The concrete mix requirements for the SCHPC included the following:

Entrained air content ≥ 3%
Silica fume content ≥ 5% of the total cementitious material
Water-cementitious materials ratio < 0.40
Calcium nitrite corrosion inhibitor at a dosage rate of 25 L/m^3 (4.04 gal/yd^3)
Concrete spread of 560 to 760 mm (22 to 30 in.)
Visual stability index ≤ 2
Only materials from the NYSDOT approved list to be used

The hardened concrete performance criteria were as follows:

Concrete compressive strength (f'_c) at 56 days per AASHTO T 22 ≥ 70 MPa (10,150 psi)
Modulus of elasticity per ASTM C469 ≥ 30 GPa (4351 ksi) when f'_c ≥ 70 MPa (10,150 psi)
Shrinkage after 56 days of drying per AASHTO T 160 < 600 millionths
Specific creep at 56 days per ASTM C512 ≤ 60 millionths/MPa (0.41 millionths/psi)
Freeze-thaw durability per AASHTO T 161 Proc. A ≥ 80%
Scaling resistance per ASTM C672 ≤ Rating of 3
Chloride penetration per AASHTO T 259 modified < 0.025% at 25 mm (1 in.)

In addition to the above requirements, reinforcement in the substructure components was epoxy-coated and the precast components and top surface of the concrete deck were coated with a penetrating sealer to prevent chloride and water ingress. Uncoated reinforcement was used in the prestressed concrete beams.

Cost of SCHPC

NYSDOT did not incur any additional cost for the use of SCHPC for the precast components. Based on the feedback from the precaster, cost savings in fabrication labor offset the additional material costs associated with use of SCHPC. Improved appearance of the components and reduction in repair needs were added benefits.

Conclusion

In general, the use of SCHPC concrete bridge components for the Route 52 bridge over the Wallkill River has been a remarkable success. Based on the current specifications, producers are now free to choose SCHPC or conventional HPC for bridge components. Due to the labor savings associated with SCHPC, more and more producers are now opting for SCHPC.

Further Information

A more detailed description of this bridge is provided in the article titled "Wallkill River Arch Bridge" published in the PCI Journal, July-August 2008, pp. 44-50.