HPC Bridge Views

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HPC IMPLEMENTATION STATUS

Louis N. Triandafilou, Federal Highway Administration

Since the initiation of the AASHTO/SHRP Lead States Team concept for high performance concrete (HPC) over 10 years ago, there has been an aggressive effort by the concrete industry, State DOTs, and the FHWA to achieve nationwide implementation of HPC on bridge projects. Outstanding progress has been made in response to the FHWA Executive Director's 1997 challenge to construct at least one HPC bridge in every state by 2002. HPC Bridge Views has reported on many of these projects as well as the efforts of the FHWA's HPC Technology Delivery Team to keep HPC in the forefront.* Recently, the Team conducted a 14-question national survey to track this progress and other related concrete issues.

On a preliminary basis, the map indicates which states have included HPC in bridge specifications in the last 10 years. Thirty-seven respondents selected HPC for low permeability, 30 for high strength, and 26 for both performance criteria.

As background on why HPC was being used, respondents ranked deck cracking at ages less than 5 years as the most common distress, followed by corrosion of reinforcing steel, cracking of girders and substructure elements, and freeze-thaw damage.

Preliminary results also indicate that, over the past 10 years, 77 percent of the respondents have made changes in their bridge deck curing requirements, 72 percent have made changes in their specified concrete strengths, and 64 percent have made changes in testing and acceptance requirements. Lightweight concrete has been used by 26 percent of the respondents, and self-consolidating concrete used on a limited basis by 36 percent. Admixture usage and specified permeability values are summarized in the tables on page 2.

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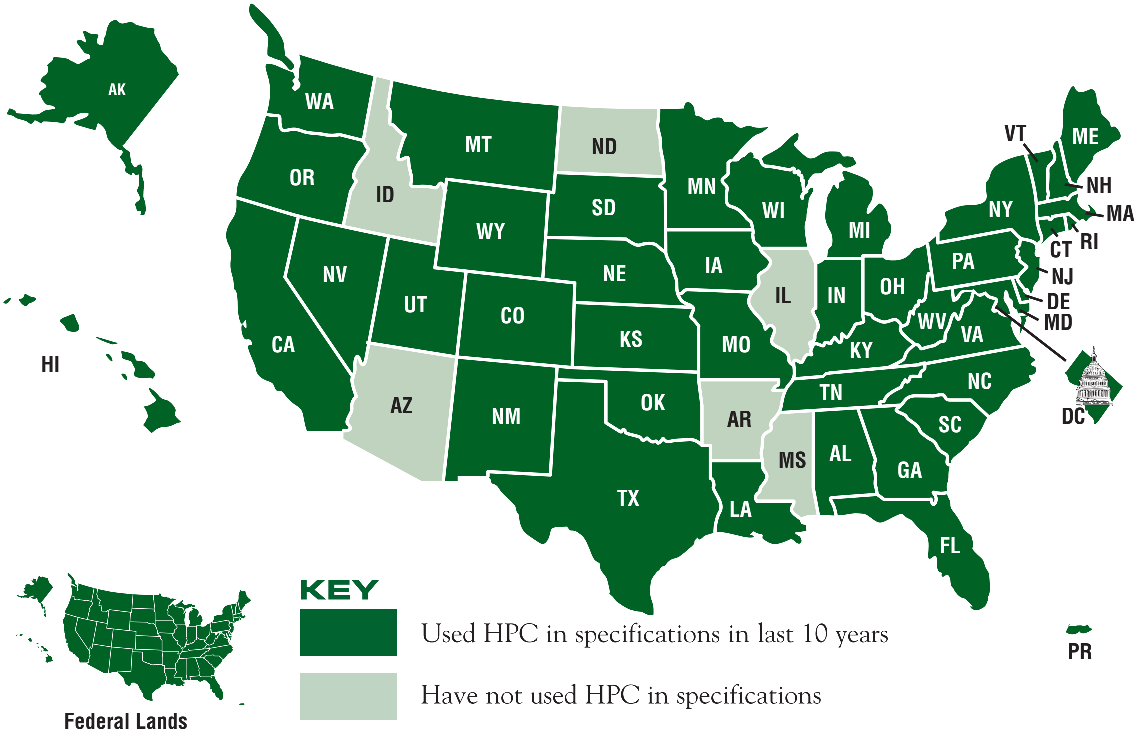
* *See HPC Bridge Views Issue Nos. 19 and 26.*



(continued on pg. 2)

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Admixture Usage, Percentage of Respondents

Admixture	Environment	
	Non-Aggressive	Aggressive
Air Entrainment	68	81
Water Reducer*	66	72
Fly Ash, Class F	60	70
Silica Fume	38	62
Slag	49	57
Corrosion Inhibitors	21	36

*Normal or high range

Deck concrete curing requirements have received much attention, particularly with increased usage of HPC. Seventy-nine percent of the respondents include these requirements in their specifications. Fifty-five percent are using curing compounds, 49 percent are using a fog mist, 60 percent are using wet burlap for periods of 3 to 14 days, 45 percent use an evaporation rate limit, and 87 percent specify an overall minimum curing time.

Specified Permeabilities, Percentage of Respondents

Coulomb Range	Environment	
	Non-Aggressive	Aggressive
Bridge Decks		
0-1000	4	11
1001-2000	15	23
2001-3000	4	2
3001-4000	3	2
Total	26	38
Precast, Prestressed Members		
1000-2500	11	—
800-2500	—	19

In summary, the state DOTs have made an enormous amount of progress over the past 10 years with implementing some form of HPC into their everyday usage on concrete bridge projects. They have taken advantage of the benefits related to higher strengths for prestressed concrete girder elements, and improved durability for reinforced concrete bridge decks. The widespread national use of this technology is consistent with industry, state, and FHWA goals of mitigating congestion and improving safety at construction sites. HPC addresses these goals by extending bridge service life, reducing costly maintenance activities, and lowering life cycle costs.

Further Information

Results are being compiled and will be summarized in detail on a CD for distribution in the near future, plus posting on the Team's website at: http://knowledge.fhwa.dot.gov/cops/hpcx.nsf/home. For questions or comments about the article, contact the author at lou.triandafilou@fhwa.dot.gov or 410-962-3648.

The author wishes to express his sincere appreciation to Rodolfo Maruri, Claude Napier, and Eric Spriggs of the FHWA for synthesizing a huge amount of data from the survey in a very short time period for use in this article.

HPC GUIDE SPECIFICATION FOR BRIDGES

Rachel Detwiler, Construction Technology Laboratories, Inc. and Shri Bhidé, Portland Cement Association

Greater emphasis is being placed on constructing public infrastructure, in particular bridges, using the best available technology to ensure that the resulting structures return the greatest benefit to the public at the lowest life-cycle cost. High performance concrete (HPC) has the potential both to provide extended service life and to reduce the number or size of load-carrying members, thereby increasing the return on the taxpayer's investment in the nation's infrastructure. The specific meaning of "high performance" depends on the concrete properties under consideration, and may or may not include strength. The Federal Highway Administration has proposed a definition for high performance concrete that enumerates several distinct categories of performance criteria for strength and durability. Based on this, many states have developed their own provisions for use with HPC because no national standard is available. To aid state highway departments and other bridge owners in effectively using high performance concrete, the Portland Cement Association plans to release Guide Specification for High Performance Concrete for Bridges in mid 2004.

The Guide Specification is intended to serve as an aid for developing specifications for high performance concrete for individual projects in all 50 states. The Guide Specification includes 11 performance criteria for high performance concrete: six durability criteria – resistance to abrasion, chloride penetration, freeze-thaw damage, scaling, sulfate attack, and alkali-silica reactivity; one workability criterion – consistency of concrete mixture; and four strength criteria – compressive strength, modulus of elasticity, creep, and shrinkage. The designer or specifier must select the criteria that are important for the specific application.

The intended user of the Guide Specification is an engineer or contractor working directly or indirectly for a state department of transportation, local highway authority, or other bridge owner. The user should be familiar with the characteristics of local materials and be aware of local durability concerns that may necessitate special measures to prevent premature deterioration of the concrete. The Guide Specification alerts the user to the types of questions that should be answered regarding local materials and exposure conditions. It is intended to be modified as needed to suit local conditions.

The Guide Specification is accompanied by a detailed commentary that provides explanatory notes, guidance for selecting appropriate performance criteria, and details about how to achieve the desired properties. It also discusses potential conflicts between criteria, such as high early strength and minimization of cracking. The intent is to provide guidance to both the engineer and contractor as to the measures that should be taken to accomplish the desired performance.

Further Information

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LIGHTWEIGHT HPC ON ROUTE 106 BRIDGE IN VIRGINIA

H. Celik Ozyildirim, Virginia Transportation Research Council

High performance concrete (HPC) bridges in Virginia have shown initial cost savings mainly due to the reduced number of beams per span, use of smaller cross-sections, and the ability to span longer distances. More benefits can be realized by reducing the dead load of the structures. The improved durability of HPC is also expected to lead to more savings over the life of the structure. Thus, the use of lightweight HPC (LWHPC) for the beams and deck for a bridge on Route 106 over the Chickahominy River, east of Richmond, Virginia, was proposed for the FHWA Innovative Bridge Research and Construction Program. The bridge, constructed in 2001, has three spans of 85 ft (25.9 m) and a width of 43.3 ft (13.2 m). The 7.9-in. (200-mm) thick deck is continuous over the two intermediate piers. Each span has five AASHTO Type IV beams spaced at 10 ft (3.05 m) centers.

Implementation of the LWHPC beams and deck was accomplished in three phases. In the first phase, a test program focused on fabricating and testing Type II and Type IV beams. In the second phase, the Type IV bridge beams were fabricated and erected. In the third phase, the concrete bridge deck was constructed. A portion of the deck over one of the piers contained synthetic fibers in the concrete for crack control. Condition surveys were performed after the placement of the deck and 2 years later.

The specified 28-day compressive strength and 28-day permeability were 8000 psi (55 MPa) and 1500 coulombs, respectively, for the beams and 4000 psi (28 MPa) and 2500 coulombs, respectively, for the deck. The specified concrete strength for detensioning the bridge beams was 4500 psi (31 MPa). The target density for the LWHPC for the beams and deck was 120 lb/cu ft (1.92 Mg/cu m). The concrete mixture proportions, which included both lightweight and normal weight aggregates, are given in Table 1. Grade 270 low-relaxation 0.5-in. (12.7-mm) diameter prestressing strands were used.

Workable concretes were obtained. The bridge beams had a concrete density about the same as that specified. Before pumping, the deck concrete had a density less than the specified value. However, samples taken after pumping had a higher density and lower air content. During sampling of the pumped concrete, there was a longer vertical drop than during the deck placement and flow of concrete was not continuous. This could have contributed to a large loss of air in the test samples, which would increase their density.

For the tests on hardened concrete, the beam samples were steam cured and the deck samples moist-cured. The measured compressive strength, flexural strength, permeability, and modulus of elasticity values are given in Table 2. The strength of the concrete with fibers was considerably lower than the strength of the concrete without fibers. This strength reduction is attributed to the addition of extra water to compensate for reduced workability due to fibers. To improve workability without adverse effect on strength, water-reducers should be used.

The results indicate that LWHPC can be produced such that the material is workable, strong, volumetrically stable, and resistant to cycles of freezing and thawing, thus leading to a long service life with minimal maintenance. Testing of prisms showed that the fibers provide residual strength expected to mitigate deck cracking. A condition survey after 2 years of exposure indicated only limited cracking including two transverse cracks above the piers in the sections with and without fibers. Based on the experience, more structures with LWHPC for beams and deck are expected to be built in the future. A 1.01-mile (1.63-km) long bridge with LWHPC beams and deck is currently under design in Virginia.

Further Information

For further information, contact the author at celik@virginia.edu or 434-293-1977.

Table 1 Concrete Mix Proportions

Material	Quantities per yd^3	
	Beams	Deck(1)
Portland Cement(2)	451 lb	489 lb
Slag	301 lb	—
Pozzolan Class N	—	163 lb
Fine Aggregate NW	541 lb	1228 lb
Fine Aggregate LW	390 lb	—
Coarse Aggregate NW	605 lb	—
Coarse Aggregate LW	696 lb	900 lb
Water	255 lb	292 lb
Water Reducer/Retarder	22 fl oz	20 fl oz
HRWR	56 fl oz	33 fl oz
Calcium Nitrite	3 gal/yd^3	—
Air Entrainment	5.5 + 1.5%	6.5 + 1.5%
w/cm ratio	0.34	0.45

(1) Without fibers. Fibers were added at 9 lb/yd^3 to the deck concrete used over one pier
(2) Type II
NW = normal weight, LW = lightweight

Table 2 Properties of LWHPC

Property	Age	Beams	Deck Control	Deck Fiber
Compressive Strength, psi	1 day	4720	4740	3275
	28 days	8100	7225	4940
	1 year	7890	8915	6570
Flexural Strength, psi	28 days	640	780	740
Permeability, coulombs	(1)	917	832	1372
Modulus of Elasticity, ksi	28 days	2980	2750	2790

(1) For the bridge beams, permeability measured at 1 year after initial steam curing and subsequent drying. For deck concrete, permeability measured at 28 days after 1 week moist curing at room temperature and 3 weeks at 100°F.

Question

What curing is necessary for HPC precast, prestressed concrete beams after the strands are detensioned?

Answer

Curing involves actions taken to maintain proper moisture and temperature conditions in freshly placed concrete. This allows cement hydration and pozzolanic reactions to occur so that the specified hardened concrete properties such as strength and durability can be developed. Accelerated initial curing of precast, prestressed concrete beams is usually necessary to obtain the specified release strength so that the strands can be detensioned within a reasonable time. The accelerated initial curing is achieved with an elevated temperature provided either by externally applied heat such as steam or from the internal heat of hydration. After this initial curing period, strength gain is much slower.

High performance concrete (HPC) differs from conventional concrete because HPC has a lower water-cementitious materials ratio and contains one or more supplementary cementitious materials (SCM). Therefore, HPC has a much lower volume of water-filled space per unit volume of cementitious materials. During the hydration process, the water-filled spaces or capillary pores are quickly filled with hydration products and discontinuity between the pores occurs. The cement and SCM particles are much closer to each other in HPC and the discontinuity of capillary pores can occur much faster because smaller pores need less hydration products to fill them. Accordingly, as the capillary pores become discontinuous, the permeability of the concrete is reduced and water migration within the concrete decreases significantly. This stage of hydration is achieved early by using elevated temperatures with retention of moisture. Because of the difficulty of water migration through the concrete, additional moist curing beyond this point provides minimal benefit except for possibly improving the durability of the surface concrete.

Experience with conventional strength, precast, prestressed concrete beams has shown that initial accelerated curing alone is adequate to provide both the required release strength and the specified design strength. Data recently collected from completed projects that used HPC for the precast, prestressed concrete beams also verify that adequate release strength and specified design strength can be achieved using the initial accelerated curing method followed by no further curing after the release strengths are obtained. The data also confirm that chloride permeability values below the specified values can be achieved using only the initial accelerated curing.

It is concluded that adequate curing of precast, prestressed concrete beams for strength and durability is provided by initial accelerated curing that is terminated after the release strength is obtained. Additional moist curing beyond the initial accelerated curing period is not necessary and provides only marginal benefits.

References

Related information about the effect of curing temperatures on strength development and data showing that match curing provides the most accurate strength verification method can be found in *HPC Bridge Views*, Issue No. 2, March/April 1999. Additional information is available in the following references:

Wang, C., Dilger, W. H., and Langley, W. S., "Curing of High Performance Concrete – An Overview," Symposium Proceedings, PCI/FHWA International Symposium on High Performance Concrete, New Orleans, Louisiana, Precast/Prestressed Concrete Institute, Chicago, IL, October 1997, pp. 283-293.

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Answer contributed by Jerry L. Potter with consultation by Jon Mullarky and Lou Triandafilou, all with FHWA. Jerry Potter may be contacted at jerry.potter@fhwa.dot.gov or 202-366-4596.

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