HPC Bridge Views

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HPC IN WASHINGTON STATE

Jerry Weigel, Washington State Department of Transportation

Since our 1997 HPC Showcase, state and local agencies in Washington State have constructed eight bridges with high performance concrete (HPC) girders, have ten ready to be advertised, and have eight being designed. Environmental requirements to keep piers out of waterways and the necessity of providing for future widening to accommodate increasing traffic demands are creating an ever-growing need for longer spans. The use of HPC improves construction economy by providing for longer spans, increased girder spacings, and shallower girders.

Experience gained through the design and fabrication of HPC girders has shown that release strength is the critical parameter. A specified release compressive strength of 7500 psi (52 MPa) and a specified design compressive strength of 8500 psi (59 MPa) result in an optimum design economy. While compressive strengths of 10,000 psi (69 MPa) are possible, the extended in-form curing time and design mix complexities are uneconomical and difficult.

Super Girders

Washington State Department of Transportation (WSDOT), partnering with industry, has developed two deep precast, prestressed concrete I-girder sections called "Super Girders." An article in the July-August 1998 PCI Journal provides technical data and describes the development of these sections. These new sections, using HPC and 0.6-in. (15.2-mm) diameter prestressing strands will span up to 225 ft (69 m). WSDOT has a project, Twisp River Bridge, under contract using "Super Girders" with a single span length of 197 ft (60 m). The girder concrete has a specified release compressive strength of 5000 psi (34 MPa) and a design compressive strength of 8000 psi (55 MPa). Because of their weight, these girders were fabricated in three sections for transportation to the site and will be post-tensioned together on site.

Due to constructibility concerns, the girder sections will be placed on temporary falsework and the girder wet joints completed after the placement of the deck concrete. The inability to consistently produce high strength concrete at a remote project site was one of the major concerns. With this construction sequence, the required compressive strength of the joint concrete is 4400 psi (30 MPa). If the joints were completed and the girders stressed before deck concrete placement, the joint concrete compressive strength would need to be 7500 psi (52 MPa) and the design compressive strength of the girder concrete would need to be 10,000 psi (69 MPa). However, when the deck concrete is placed before the girders are stressed, the falsework must support the weight of the girders and the deck. Consequently, the construction sequence has a significant impact on the design requirements and falsework costs.

Materials

Except for microsilica and corrosion inhibitors, HPC uses similar materials and admixtures as conventional concrete. The amount and type of each component are selected in order to achieve the required durability and strength properties. In addition to prestressed concrete girders, WSDOT has used HPC for bridge deck concrete; cast-in-place piling concrete; and deck overlays of latex modified concrete, microsilica modified concrete, and fly ash modified concrete.

The Future

Through our effort as a member of the "Lead States Program," our participation in a showcase, and working with HPC, we have learned a great deal and are convinced that the future of high performance concrete is very bright. This learning experience has confirmed that we can build bridges that are durable, cost effective, and will require minimal maintenance.

Further Information

For further information about HPC in Washington State, contact the author at (360) 705-7207 or weigelj@wsdot.wa.gov.

Editor's Note: An article about Washington State's first HPC bridge was included in HPC Bridge Views No. 2.

HPC was used on the Admiral Clarey Bridge to meet the Navy's requirement for a durable structure.

USE OF HPC ON ADMIRAL CLAREY BRIDGE, HAWAII

Michael J. Abrahams, Parsons Brinckerhoff Quade & Douglas, Inc.

The Admiral Clarey Bridge was a design/build project for the US Navy to improve access to the largely undeveloped Ford Island in Pearl Harbor. Due to the need to provide an opening large enough to allow the passage of aircraft carriers while minimizing the impact on the nearby Arizona Memorial, a unique solution was developed that utilized a low-level fixed concrete trestle span combined with a floating concrete draw span.

The almost one-mile (1.6-km) long structure made extensive use of precast and prestressed concrete for both economy and durability. Given the aggressive marine environment of Hawaii, the Navy's requirement for a durable structure included the use of high performance concrete (HPC) throughout the project. Except for some incidental concrete, all concrete was required to contain a minimum of 5 percent silica fume by weight of cementitious materials, and to have a maximum water/cementitious material ratio of 0.38. Other means to improve durability included increased concrete cover to the reinforcement, zero tensile stress in all prestressed concrete except for extreme load cases, a pipeline-type epoxy for coating reinforcing bars, and a maximum tricalcium aluminate content for the cement of 8 percent to improve sulfate resistance.

The concrete came from several sources. The pontoons and precast, prestressed concrete beams came from Tacoma, Washington. The precast piles and deck panels were produced in Hawaii. The cast-in-place concrete was produced locally. While there were initial concerns that concrete from such different sources would have non-uniform colors, this was not the case and the color was uniform throughout.

In Hawaii, there are some limitations to achieving HPC strengths above 9000 psi (62 MPa). These include the Hawaiian DOT Standard Specifications limiting the cement content to 900 lb/cu yd (534 kg/cu m) and the type of available aggregates. All aggregate in Hawaii is manufactured and the angular shape of the aggregate takes away from the concrete workability. For the 24-in. (610 mm) octagonal prestressed concrete piles, the water/cement ratio was 0.36 or less and a special mix using 3/8-in. (10-mm) maximum aggregate size was needed because of the close spacing of the reinforcement.

In Hawaii, summer temperatures can exceed 90°F (32°C) with a hot sun and prevailing trade winds. We were aware of the lack of bleed water and finishing problems that are associated with the use of silica fume concrete. To sort out these issues, a test pour was used to demonstrate finishing techniques. A 7-day wet cure was mandatory for all concrete. The use of fogging and wind screens was recommended.

Finishing of HPC provides a challenge to be overcome in the field. The fresh concrete mix has a sticky texture and develops very little bleed water. Misting or fogging were required to provide surface moisture when finishing. Otherwise, floating had a tendency to cause tearing of the surface. A curing compound was applied to try and retain the moisture and to allow the concrete to set prior to starting the wet cure. The mixes also had varying consistency when placed. Concrete from the same truck or from one truck to the next truck had a wetter or drier mix consistency.

In Tacoma, the concrete for the pontoons had similar problems with a lack of bleed water. The use of fly ash in the mixture helped to promote bleed water and ease the finishing problems. An evaporation retarder was sprayed on the surface of the wet concrete after screeding to help retain the surface moisture.

Further Information

For further information, see: Abrahams, M. J. and Wilson, G. "*Precast Prestressed Segmental Floating Drawspan for Admiral Clarey Bridge*," PCI JOURNAL, July/August 1998, pp. 60-79.

Component	Concrete Strength, psi	
	Design	Actual
Precast Piles	7000	7980
Bridge Precast Deck Panels	5000	>7000
Precast Beams	5000 to 7500	8300
Pontoons, Precast and Cast-in-Place	6000	6900
Pontoon Deck Panels	7500	8300

IMPROVED PERFORMANCE OF NEW YORK STATE BRIDGE DECKS

Sreenivas Alampalli and Frank T. Owens, New York State Department of Transportation

When the New York State Department of Transportation (NYSDOT) decided to improve the quality of its bridge decks, it developed a three-phase program to achieve the desired results. The first phase was to enhance the deck material itself, making it more durable for a longer service life. The second phase focused on optimizing bridge deck design. The third, and probably the most important phase, was to develop practical and effective construction practices to ensure realization of the material's enhanced properties.

In Phase 1, the existing New York State bridge deck concrete mix was modified to enhance its durability characteristics. The new high performance mix takes advantage of a reduced water/cementitious material ratio and contains fly ash and silica fume substitutions for a portion of the portland cement. Designated Class HP concrete for Class H modified with Pozzolanic substitutions, this material has been specified as the standard for use on all structural slabs and approach slabs since April 1996. By June 1998, more than 80 bridge decks had been constructed using this more durable concrete.

Reports of material performance and workability of Class HP concrete were favorable, and theoretical estimates of service life were very encouraging. Based on an analytical model that assumed 3 in. (76 mm) of cover and the use of uncoated reinforcing steel, it was estimated that corrosion might be expected to commence after 62 years for Class HP concrete decks. This age is over 2.5 times longer than that for previous concrete mixes used in bridge decks. Late in 1998, a study was undertaken to quantify these enhanced performance characteristics.

Study Approach

All new and replacement bridge decks built using the HP concrete mix from 1995 through early 1998 were inspected. Number, length, and plan location of all non load-related transverse cracks were charted. Results were compared with the performance of concrete decks conforming to previous specifications. Crack initiation time and effects of staged construction on deck cracking were also investigated.

Deck Cracking by Year

Year Built	Deck Age, years	Decks Inspected	Decks with Transverse Cracking		Decks with Longitudinal Cracking	
			Number	Percent	Number	Percent
1995	4	10	5	50	4	40
1996	3	17	12	70	13	76
1997	2	33	15	45	14	42
1998	1	24*	8	33	6	25
Total		**84**	**40**	**48**	**37**	**44**

**Built through June 1998*

Survey Results

The results of the study revealed that 49 percent of the 84 inspected decks exhibited no cracking. Transverse cracking was found on 48 percent of the decks and longitudinal cracking on 44 percent. Forty percent of the bridge decks exhibited both transverse and longitudinal cracking. Although it might be expected that years-of-service would have a significant negative effect on deck condition, the data revealed no influence of deck age on deck cracking.

Staged lane construction is used to minimize disruption of traffic flow in New York State and the study examined possible influences of this type of construction on deck cracking. The results indicated that staged construction has no negative effects on the deck. Average transverse crack density of cracked HP decks was found to be 6.9 cm/m^2, with a maximum density of 26.8 cm/m^2 which is comparable to the lower end of crack densities referenced in earlier NYSDOT studies. Of these cracked decks, over fifty percent began cracking within 14 days of the concrete placement.

Inspectors were asked to qualitatively compare Class HP decks to previously specified concrete decks. More than eighty percent of the responses reported that HP decks performed about the same or better than the previously specified concrete in resisting transverse and longitudinal cracking. Based on a statistical analysis, cracking densities were found to be independent of superstructure type, material, span length, or support condition.

Conclusions

Results of this study indicated that performance of deck material has improved since the introduction of Class HP concrete for New York State bridge decks. "Performance" is measured in terms of increased crack resistance without compromise in workability, construction practices, or cost. It was reported, through visual inspection, that Class HP bridge decks cracked with less frequency, and exhibited narrower and shorter cracks than their non "high performance" counterparts. It was also observed that most cracks occurred within two weeks of the deck pour and were not influenced by staged lane construction.

Further Information

For further information about New York State Bridge Decks, see HPC Bridge Views No. 6 for a companion article or contact the author at (518) 457-5826 or salampalli@gw.dot.state.ny.us.

Q&A

Many questions arise about HPC and its applications. If you have a question that you would like answered in HPC Bridge Views, please submit it to the Editor.

HPC BRIDGE CALENDAR

April 3-5, 2000
5th International Bridge Engineering Conference, Tampa, FL
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.

Question:

Can I use a higher ratio between release strength and 28- or 56-day strength when using HPC in prestressed concrete girders?

Answer:

There are two approaches that can be used to answer this question. The first approach is from the perspective of what has been specified and achieved to date. The second approach is to look at what can be achieved with today's technology.

In the first approach, consider data from the FHWA showcase bridge projects. Specified strengths at release ranged from 5500 to 10,800 psi (38 to 74 MPa). Specified design strengths ranged from 8000 to 14,700 psi (55 to 101 MPa). The ratio of specified strengths at release to specified design strengths ranged from 0.60 to 0.81. The ratio of measured strengths at release to measured strengths at 28 or 56 days ranged from 0.61 to 0.83. Based on these data, the ratios between release strength and 28- or 56- day strengths are similar to those specified and achieved with conventional strength concretes in prestressed concrete girders. On the other hand, Jerry Weigel reports on Page 1 of this newsletter that Washington State has found that release strength controls the design and that release and design strengths of 7500 and 8500 psi (52 and 59 MPa), respectively, provide optimum economy. This is equivalent to a ratio of 0.88.

In the second approach, consider methods that can be used to influence and control the rate of strength gain. Concrete that is heat cured exhibits a more rapid strength gain at early ages and a slower strength gain at later ages compared to the same concrete that is not heat cured. The heat may be provided by the internal heat of hydration or by an external source such as steam or radiant heat. The amount of internal heat and strength gain is also influenced by the properties of the cementitious materials. A finer cement will produce more heat of hydration than a coarser cement. The use of silica fume will produce higher earlier strengths whereas the use of fly ash will result in more strength gain at later ages.

Consequently, a higher ratio of release strength to 28- or 56-day strength is technically possible to achieve by selection of the cementitious materials and an appropriate curing temperature. However, depending on the application, it may be desirable to limit the maximum concrete temperature to 160°F (71°C) to reduce the likelihood of delayed ettringite formation. In addition, the selection of materials may be limited by those locally available. Therefore, consult your local producers to see what they can produce economically to meet the release strength in an acceptable time without greatly exceeding the specified design strength at a later age.

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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.

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