Bridge Views

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IMPLEMENTATION OF A STRATEGIC PLAN FOR HPC BRIDGES

Suneel N. Vanikar, Federal Highway Administration

In 2000, the HPC Lead States Team published a Transition Plan that listed several goals. One of the main goals was to "develop a long-term strategic plan for HPC bridges in partnership with government, industry, and academia." Under the leadership of the National Concrete Bridge Council (NCBC), a focus group of federal and state bridge engineers, professors, and industry representatives met to identify critical issues in the design and construction of long-life bridges to help solve the deficient bridge problem in the United States.

Discussions at the focus group meeting provided the foundation for a strategic plan prepared by NCBC. The strategic plan focuses on the public's expectations for the present and future. This outlook translates into the following four goals for high performance concrete bridges:

1. Reduce Congestion and Improve Safety

HPC products and methods can reduce the frequency of repairs, duration of construction, and length of maintenance work periods. The adoption of HPC techniques, therefore, eases roadway congestion and improves driver safety. Additional development is needed to reduce construction time including:

- Replacing bridge decks with minimal interference with traffic
- Constructing entire short-span bridges within one week
- Reducing the average user delay by 20 percent for typical urban bridge reconstruction projects

2. Train the Workforce

Not enough knowledge of high performance concrete bridges is currently in the hands of owners, engineers, and contractors. Additional activities are needed to educate and train key stakeholders including:

- Transferring HPC technologies to all 50 states by building several HPC bridges in each state
- Training 500 bridge engineers per year in HPC technology through seminars
- Training 2000 construction personnel per year in HPC bridge technology
- Adding HPC technology courses to the curricula at ten engineering universities

3. Reduce Life Cycle Cost

The nation's transportation system needs rehabilitation and improvements. Public officials must stretch capital resources to accommodate these needs in a speedy time frame. Therefore, bridges with low life cycle costs will help government agencies maximize limited resources. Life cycle cost reductions can be achieved through a variety of initiatives, including:

- Establishing a life cycle cost analysis procedure
- Improving service life prediction models
- Collecting cost data on various conventional bridge systems
- Developing tools to perform life cycle cost analyses

4. Ensure Bridges Meet Expectations

The use of advanced materials and new construction techniques requires the development of new tests and testing methods to ensure that specific bridge performance criteria are met. A variety of initiatives can be undertaken to ensure bridges meet expectations including:

- Developing reliable material tests
- Developing reliable quality assurance methods for construction
- Developing certification programs for products, procedures, and personnel

The successful implementation of the strategic plan and the subsequent action plan will require management support and resource commitments over several years. The public and private sector partnership in the implementation of HPC technology during the recent past has been highly successful. This partnership needs to be maintained so that the general public continues to benefit from HPC bridges.

More Information

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HPC was used in the girders and deck of the northbound and southbound bridges.

NCDOT'S EXPERIENCE WITH HPC

Tom Koch, North Carolina Department of Transportation

The first application of high performance concrete (HPC) by the North Carolina Department of Transportation (NCDOT) was on dual bridges on U.S. 401 over the Neuse River just north of Raleigh, NC. The project consists of two 4-span structures with precast, prestressed concrete girders made continuous for live load with a cast-in-place concrete deck. Each structure consists of two, 92-ft (28.0-m) long spans of AASHTO Type IV girders and two, 57-ft (17.5-m) long spans of AASHTO Type III girders. Use of 10,000 psi (69 MPa) HPC in the girders and 6000 psi (41 MPa) HPC in the deck allowed the designer to reduce the number of girder lines from six to five. Both northbound and southbound structures used HPC. The southbound structure was instrumented by NC State University (NCSU) researchers.

Once the project had been chosen, a team of NCSU researchers and NCDOT personnel met to establish target performance criteria for the HPC. It was agreed that the material characteristics of strength, modulus of elasticity, shrinkage, creep, and chloride permeability were the most important and the team established target values for these characteristics.

The girders were cast in October 2000. The fabricator was responsible for the concrete mix design, which used a 0.30 water-cementitious materials ratio, 900 lb/cu yd (534 kg/cu m) of Type I/II cement, and 50 lb/cu yd (30 kg/cu m) of silica fume. An initial requirement for a maximum slump of 6 in. (150 mm) was changed to 8 in. (200 mm) when the first casting had severe honeycombing that resulted in rejection of the girder. Cylinders for strength and modulus of elasticity tests were match cured to ensure that the test results accurately reflected the girder concrete properties.

The test results for all characteristics showed that with the exception of modulus of elasticity and chloride permeability, the girder concrete properties met the target values. The concrete strengths averaged 10,500 psi (72.4 MPa) at 28 days, compared to the specified value of 10,000 psi (69 MPa). The measured creep of the girder concrete after 120 days of loading was 0.25 and 0.21 millionths/psi (36 and 30 millionths/MPa) for the Type III and Type IV girders, respectively. This met the performance criteria of 0.31 to 0.21 millionths/psi (45 to 30 millionths/MPa). The measured shrinkage after 120 days was slightly above the target value of 400 millionths; the researchers felt that this was due to the relatively high cement content.

The modulus of elasticity had an average measured value of 5100 ksi (35 GPa) compared with a target value of 6000 to 7500 ksi (41 to 52 GPa). The rapid chloride permeability test values for the Type III and Type IV girders were 3700 and 4557 coulombs, respectively, at 56 days. The target value was between 800 and 2000 coulombs. The values had reduced to 2500 and 1250 coulombs, respectively, by the concrete age of 90 days.

Test results for the bridge deck concrete, which was designed by the ready-mixed concrete supplier for a concrete compressive strength of 6000 psi (41 MPa) at 28 days, were varied. The mix design required 587 lb/cu yd (348 kg/cu m) of Type I/II cement and 175 lb/cu yd (104 kg/cu m) of Class F fly ash. Test cylinders for the northbound structure had an average strength of 7150 psi (49.3 MPa). Cylinders for the southbound bridge, however, did not achieve the required strength. Results from three of the five sets of cylinders with an average strength of 5700 psi (39.3 MPa) were accepted in anticipation that the strengths would achieve 6000 psi (41 MPa) at 56 days. Results from the other two sets, one with an average strength of 4100 psi (28.3 MPa), were well below the required strength. It is unclear why the deck concrete for the southbound structure had low strengths.

Long-term monitoring of the deck and girders began at completion of the construction phase of the structure. This monitoring will take place over a three-year period and will measure girder stiffness and deflection, creep and shrinkage effects, and thermal effects. A live load test will be conducted prior to opening the bridge and again 12 months later to assess any changes in overall bridge performance due to service and thermal loads.

North Carolina's need for girders and bridge decks with low permeability in corrosive environments ensures that the use of HPC bridges will increase. In conjunction with this effort, North Carolina plans to increase the use of 0.6-in. (15.2-mm) diameter strands in the girders to more fully utilize the high strength attributes of HPC.

Further Information

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BENEFITS OF FLY ASH IN HPC

*American Coal Ash Association**

Fly ash is the fine material that results from the combustion of pulverized coal in a coal-fired power plant and is captured by electrostatic precipitators. Fly ash in concrete is frequently viewed as just a way to reduce the concrete material costs. However, the use of fly ash can improve concrete properties in many ways.

Improved Early Age Properties

The spherical particles of fly ash contribute to improved concrete workability and improved packing. Consequently, the use of fly ash as a cement replacement almost always reduces the water demand for a given concrete slump. The use of fly ash increases the amount of fines in the concrete. This helps to increase concrete's cohesiveness, improve pumpability, reduce segregation, and improve finishability. Cement replacement with fly ash reduces the build-up of heat in larger sections, thus reducing peak temperatures and the potential for thermal cracking.

Improved Hardened Concrete Properties

Fly ash improves the properties of hardened concrete by virtue of its pozzolanic reaction. The use of fly ash reduces permeability, chloride diffusivity, and increases resistivity of concrete thus making fly ash an essential component of concrete to protect reinforcement from corrosion. Fly ash also binds the cement alkalis, which helps concrete achieve excellent resistance to alkali silica reaction (ASR). Class F fly ash also provides increased resistance to concrete sulfate attack and contributes to the long-term strength gain of concrete.

Fly ash was used in the San Angelo HPC bridge girders to enhance strength.
(Photograph Courtesy of TXDOT)

Mix Design Considerations

Fly ash concrete can be designed to achieve a wide range of strengths at various ages. Some fly ashes may delay the concrete setting time. This can be offset, if necessary, by the use of an accelerating chemical admixture. Certain fly ashes, due to high amounts of un-burnt carbon may require a higher dosage of the air-entraining admixture to achieve a particular air content.

Ultra Fine Fly Ash

Ultra fine fly ash is an extremely fine material that has high pozzolanic reactivity. Its use in concrete increases concrete compressive strengths, reduces the rate of chloride diffusion, and lowers rapid chloride permeability values.(1)

High Volume Fly Ash Concrete

Fly ash is typically used in the range of 15 to 25 percent of the total cementitious materials content. High volume fly ash concretes, where the fly ash content is over 50 percent of the total cementitious materials, have been studied over the last two decades.(2) Adequate early strengths and setting times can be obtained by targeting a low water-cementitious materials ratio through the use of a HRWR. A number of structures have been built using high volume fly ash concretes.

Applications

Fly ash is frequently used in concrete for bridge decks to reduce the permeability of the concrete to penetration by chlorides. An FHWA compilation of HPC bridges lists information about materials used in 13 cast-in-place bridge decks.(3) Eight of the decks had fly ash in the concrete. For bridge deck overlays, the Washington State Department of Transportation specifies a concrete mix containing 31 percent fly ash and a total cementitious materials content of 885 lb/cu yd (525 kg/cu m).(4) For precast, prestressed concrete girders, fly ash is used to enhance the later age strength gains. In the San Angelo, TX, HPC bridge, fly ash at 32 percent of the total cementitious materials content was used in the girders to achieve a concrete compressive strength of 14,500 psi (100 MPa) at 28 days. In mass concrete bridge foundations and piers, fly ash is frequently used to reduce the heat of hydration while ensuring a low permeability concrete.

Further Information

Further information on the use of fly ash in HPC can be obtained from the American Coal Ash Association at 315-428-2400 or info@acaa-usa.org

References

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Editor's Note

This article is the fifth in a series that addresses the benefits of specific materials used in HPC. The benefits of silica fume, lightweight aggregate, different cements, and slag cement were discussed in previous issues of HPC Bridge Views.

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* *Written for the American Coal Ash Association by Karthik H. Obla of Boral Materials Technologies and Richard R. Halverson of ISG Resources with contributions from the Canadian Industries Recycling Coal Ash Association.*

Question

Does HPC need to be air entrained for frost resistance?

Answer

The primary purpose of air entrainment in concrete is to improve concrete's resistance to cycles of freezing and thawing when exposed to water or deicing chemicals. Consequently, concrete in an environment that does not experience freeze-thaw cycles, and hence the use of deicing chemicals, does not need to be frost resistant. Air entrainment, therefore, is not necessary for concrete in these locations. This is true for both HPC and conventional concretes.

Structures in locations that experience freeze-thaw cycles are also likely to be exposed to ice and snow storms and the use of deicing chemicals. In these locations, HPC members that have the potential for being critically saturated when exposed to freeze-thaw cycles must be frost resistant.

A recent PCA publication contains the results of tests on high-strength concrete for frost and scaling resistance.(1) All tests were made on concretes with portland cement as the only cementitious material. Tests for resistance of concrete to rapid freezing and thawing were made in accordance with ASTM C 666 Method A after 14 days of drying. Durability factors close to 100 were only achieved without air entrainment when the water-cement ratio was equal to or less than 0.35. Tests for scaling resistance of concrete surfaces exposed to deicing chemicals were made in accordance with ASTM C 672. Resistance to scaling of non-air-entrained concrete was only achieved when the water-cement ratio was reduced to 0.25.

Most bridge decks in locations that experience freezing and thawing are directly exposed to freezing rain, snow, and deicing chemicals. It is also likely that the concretes used in these bridge decks have water-cementitious materials ratios of about 0.40. No well-documented field experiments have been made to prove that air entrainment is not needed in HPC. Until such data are available, current practice for air entrainment should be followed for decks and other bridge elements exposed directly to deicing chemicals.

In contrast to decks, HPC bridge beams are generally made with high-strength concrete. This requires the use of a water-cementitious materials ratio of less than 0.40, which offers the potential for frost resistant concrete with a lower percentage of air entrainment or even no air entrainment. At the same time, bridge beams are protected by the bridge deck from direct exposure to moisture and deicing salts. High-strength concretes also have a lower permeability than conventional strength concretes and moisture penetration is likely to be less. Non-air-entrained girders used on the Illinois Toll Road bridges built in 1957-58 are still performing well. Since the use of air entrainment in high-strength concrete reduces the compressive strength by about 5 percent or about 500 psi (3.5 MPa) for each 1 percent increase in air content, it is desirable to minimize the air content in order to achieve the strength.

All of this indicates that the need for air entrainment is less critical in HPC bridge beams than in decks. As with all HPC applications, the specified properties must be consistent with the intended application and environment. The need for air entrainment in HPC bridge beams should be based on local conditions and practices.

Reference

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HPC BRIDGE CALENDAR

October 7-9, 2002
First Annual National Concrete Bridge Conference, Nashville, TN. Contact NCBC at ncbc@portcement.org.

October 19-22, 2003
Third International Symposium on High Performance Concrete, Orlando, FL. Jointly sponsored by FHWA and PCI. Contact Paul Johal, Precast/Prestressed Concrete Institute at 312-786-0300, info@pci.org or www.pci.org

ERRATA

HPC Bridge Views No. 19, Page 4, Table 3: The correct value of the Water/Cementitious Materials Ratio is 0.37.

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