Expanding the Capacity of Highway Bridges with High-Performance Concrete

Georgia's Experience

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Bridges are integral to the Interstate Highway System and must be strong and durable, providing acceptable performance throughout a design service-life of 100 years. The widening of highways to accommodate increased traffic often requires the replacement of overpass bridges with longer-span structures. Research and application by the Georgia Department of Transportation and the Georgia Institute of Technology have confirmed the benefits and cost savings of high-performance concrete in increasing the span length and in reducing the size of precast, prestressed concrete girders.

Problem

Highway agencies often replace overpass bridges with longer-span bridges to accommodate the increased lanes of traffic below. If the same girder dimensions can be used for the longer span, the embankments will not have to be raised, saving substantial construction.

The weight of a precast girder affects the costs of its transportation and erection, and the number of girders contributes to the cost of the bridge. New materials and technologies for bridge girders are needed to realize the benefits from reducing the number of girders or increasing the span, while either maintaining or reducing the girder's cross section. Such innovations would be part of an effective asset management strategy for the Interstate Highway System.

Solution

In 1993, the Federal Highway Administration (FHWA) initiated a national program to implement the use of high-performance concrete (HPC) in bridges. In comparison with conventional concrete, HPC exhibits increased durability and higher strength, allowing the construction of long-lasting bridges with longer spans, fewer girders with wider spacing, the same girder cross section, and less maintenance.

The Georgia Department of Transportation (DOT) participated in FHWA's HPC program. The program included the construction of 18 demonstration bridges in 13 states and the dissemination of the technology and results at showcase workshops.[1] In 1996, in cooperation with the Georgia Institute of Technology, Georgia DOT initiated an investigation of the feasibility of HPC for precast, prestressed concrete bridges. Lawrence Kahn of the School of Civil and Environmental Engineering directed the investigation, which included the following activities:

- Analytical investigation of increased span length and girder spacing,
- Development and evaluation of HPC mixtures,
- Evaluation of the capability for producing HPC,
- Study of 0.6-in.-diameter prestressing strands,
- Laboratory testing of bridge girders,
- Development of criteria for selecting bridges for HPC, and
- Monitoring of field performance.

The analytical investigation concluded that the maximum span length of girders meeting the standards of the American Association of State Highway and Transportation Officials (AASHTO) could be increased by 40 percent with concrete at a strength of 13,000 pounds per square inch (psi) in combination with 0.6-inch-diameter prestressing strands. This is in comparison with the 6,000-psi concrete and 0.5-inch strand commonly used in bridge girders and at the same girder spacing.

HPC mixtures with design strengths of 7,000, 10,000, and 14,000 psi and with less than 2,000 coulombs of chloride permeability were developed and produced without difficulty in the laboratory, in ready-mix trucks, and at precasting plants with locally available materials—limestone and gran-

[1] Information on the showcase bridges is available at www.tfhrc.gov/structur/hpc/hpc.htm.

ite–gneiss coarse aggregates from across Georgia.

Two properties that greatly influence the design of precast, prestressed concrete girders are creep and shrinkage. Creep is the gradual increase in strain when hardened concrete is subjected to sustained loads, and shrinkage is the reduction in the volume of concrete unloaded at a constant temperature. Laboratory tests showed that creep and shrinkage for 10,000- and 14,000-psi HPC were much less than those for conventional concrete. Georgia DOT subsequently standardized 7,000- and 10,000-psi mixtures in its Special Provisions; the 14,000-psi mixture will be considered if the need arises.

The research showed that 0.6-inch-diameter prestressing strands could be used in place of 0.5-inch diameter strands. Tests on precast concrete beams with commonly used cross sections revealed that the performance of 0.6-inch, 270,000-psi prestressing strand in HPC exceeded that predicted according to the AASHTO bridge design standards.

Georgia DOT built its first HPC bridge—the Jonesboro Road Bridge—in 2002 over I-75 in Henry County, south of Atlanta. An 82-foot-span steel bridge was demolished and replaced with the HPC bridge. The new four-span bridge was built with two 127-foot spans to accommodate more traffic lanes on the bridge and the future widening of I-75 under the bridge, a 53-foot span at one end, and a 45-foot span at the other. The girder spacing was 7.30 feet.

The design concrete strengths at 56 days were 10,150 psi for the girders and 7,250 psi for the 8-inch-thick HPC deck. The HPC design required four fewer rows of girders per span than a conventional design—13 girders instead of 17. Construction of the HPC bridge cost approximately $51.38 per square foot of finished bridge deck; the average cost for a typical, precast, prestressed, normal-strength concrete bridge in Georgia was $56.65 per square foot—a savings of approximately 10 percent. Field measurements over 3 years indicate the potential for enhanced long-term performance.

The research clearly demonstrates that high-quality, long-span, precast, prestressed girders can be built with HPC using Georgia materials and at a lower cost than those built with conventional concrete.

Applications

After construction of the Jonesboro Road Bridge, Georgia DOT approved designs of precast, prestressed girders using HPC with compressive strengths up to 10,000 psi, and the Bridge Office has adopted that as a standard design. Georgia DOT expects to construct 5 to 10 HPC bridges per year.

With the success of HPC, Georgia DOT has started research on high-performance, lightweight concrete (HPLC) and ultra-high-performance concrete with compressive strengths greater than 22,000 psi. The HPLC beams with a density of 120 pounds per cubic foot and a compressive strength of 9,000 to 10,000 psi will be used in the Bullsboro Road bridge scheduled for construction over SR 34 in Coweta County later this year.

HPC girders of the Jonesboro Road Bridge during construction.

Benefits

The research and application of HPC demonstrate the following benefits:

- The production of 10,000-psi and 7,000-psi concrete with locally available materials;
- A span increase of approximately 40 percent for the same cross section of girder;
- A reduction in the depth of the superstructure, eliminating such potential problems and costs as raising the grade or purchasing additional land;
- Reducing the number of prestressing strands and increasing span length and girder spacing with 0.6-inch-diameter strand instead of 0.5-inch strand for precast, prestressed girders;
- Enhanced durability and reduced cracking, leading to lower maintenance cost and longer service life; and
- Potential cost savings in comparison with conventional concrete, estimated at 10 percent for a recently constructed bridge in Georgia.

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