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LOUSIANA'S HPC DEVELOPMENT

Paul B. Fossier, Louisiana Department of Transportation and Development and Harold R. Paul, Louisiana Transportation Research Center

Louisiana's interest in high strength concrete (HSC) and high performance concrete (HPC) was initiated in the mid-1970s by the Louisiana Department of Transportation and Development's (LADOTD) Research Section. The early efforts to develop and produce 10,000 psi (69 MPa) compressive strength concrete were accomplished with in-house research.

Feasibility Investigation

In the late 1980s, the feasibility of using high strength concrete in the design and construction of highway bridges in Louisiana was examined by a research group consisting of LADOTD, Louisiana Transportation Research Center (LTRC), Tulane University, and Construction Technology Laboratories, Inc. (CTL). The feasibility investigation stipulated that 10,000 psi (69 MPa) concrete had to be produced with local materials using existing local production methods.

The investigation included the design, fabrication, and testing of HSC prestressed concrete piles and prestressed concrete bridge girders. A prestressed concrete pile 130 ft (40 m) long was tested under driving conditions, while other pile lengths were tested statically in flexure. Five full-size, 70-ft (21-m) long, prestressed concrete bulb-tee girders were fabricated and tested as part of this project. As a result of the feasibility investigation, the research group recommended that high strength, prestressed concrete girders having a concrete compressive strength of 10,000 psi (69 MPa) should be used in the design and construction of a prototype bridge, and that the bridge should be instrumented and monitored to determine long-term behavior. While the focus was on concrete strength, the project resulted in HSC having many properties of HPC. The project received the Engineering News Record Medal of Excellence in 1992.

Implementation

LADOTD accepted the recommendation to utilize high strength concrete in a prototype bridge, and, in 1997, launched a major implementation effort that led to the design and construction of Louisiana's first bridge designed and constructed entirely of HPC — HSC was used in the piles and

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Fatigue testing of full-size HPC girder.

girders and HPC for durability was used in the other superstructure and substructure members. Two efforts, one research and one design/construction, proceeded concurrently over a four-year period. The prototype bridge was built across the Charenton Canal at Charenton, Louisiana.* The overall effort was successful, gaining international recognition and receiving awards from the American Concrete Institute. The Charenton Canal Bridge continues to be monitored for camber growth, concrete strains, and prestress losses.

Fatigue and Shear Behavior

In 2000, LTRC launched a new research investigation into the fatigue and shear behavior of 72-in. (1.83-m) deep, 96-ft (29.3-m) long, prestressed HSC concrete bulb-tee girders. Gulf Coast Pre-Stress Inc. fabricated the girders in Pass Christian, MS, and shipped them to CTL in Skokie, IL, for testing.

The five girders had a design concrete compressive strength of 10,000 psi (69 MPa) and incorporated 0.6-in. (15.2-mm) diameter Grade 270 low-relaxation prestressing strands. The shear reinforcement quantities were selected to evaluate the applicability of the shear strength provisions of the AASHTO Standard Specifications for Highway Bridges and AASHTO LRFD Bridge Design Specifications. Shear reinforcement consisted of conventional bars or deformed welded wire reinforcement. Measured shear strengths of six bulb-tee girder ends consistently exceeded the strengths calculated by both AASHTO specifications, using both design and measured material properties.**

The intentionally pre-cracked bulb-tee girders performed satisfactorily under five million cycles of flexural loading when the design tensile stress in the extreme fiber of the bottom flange was limited to a maximum value of 610 psi (4.21 MPa). When the concrete design tensile stress was 750 psi (5.17 MPa) or larger, fatigue fractures of the prestressing strand in the cracked girders occurred, and the fatigue life was reduced. However, two uncracked girders performed satisfactorily under five million cycles of flexural fatigue loading when the design tensile stress was 600 and 750 psi (4.14 and 5.17 MPa).

Other Applications

The results of the fatigue and shear investigation were utilized in the design of the Rigolets Pass Bridge on U.S. 90 east of New Orleans. The original design used 130-ft (40-m) long, 72-in (1.83-m) deep, HPC bulb-tee girders spaced at 7.87 ft (2.40 m). A redesign of the bridge uses the same girders spaced at 12.6 ft (3.83 m). The bridge is presently under construction. One of the HPC spans will be instrumented and monitored to determine bridge behavior.

Two other projects have used HPC girders in their design and construction. The Union Pacific Railroad Overpass on U.S. 165 uses 54-in. (1.37-m) deep AASHTO Type IV girders with a span length of 115 ft (35 m). The LA 27 Overpass in Calcasieu Parish uses AASHTO Type IV girders with a span length of 112 ft (34 m).

**See HPC Bridge Views Issue No. 8, March/April 2000.*
***See HPC Bridge Views Issue No. 21, May/June 2002.*

ATLANTA'S FIFTH RUNWAY BRIDGES

John A. Heath, Heath & Lineback Engineers, Inc.

Hartsfield-Jackson Atlanta International Airport is in the midst of a major upgrade and facilities enhancement. The work includes a new parallel runway designed to accommodate the largest airplanes in service, design, or development. The new runway is located to the south of the existing four runways and requires a skewed crossing of I-285. The crossing includes bridges to carry the main runway, parallel taxiway, and a parallel non-licensed vehicle roadway.

High-strength concrete was used in the precast, prestressed concrete beams across the interstate.

The bridges are now nearing completion. They utilize a special prestressed concrete bulb-tee beam as one component of a unique design to support the large wheel loads anticipated for the next generation of wide-body passenger aircraft.

The bridges, which cross the existing eight lanes of traffic, are designed for a future expansion of the interstate to 18 lanes. The bridges were originally conceived as tunnels because the runway is as high as 70 ft (21.3 m) above the interstate elevation. The city of Atlanta elected to procure the project through a design-build process. The successful contractor, Archer Western Contractors, submitted a bridge design developed by Heath & Lineback Engineers, Inc.

The performance criteria for the design were based on loads assumed for the Airbus A380-900, which is currently under development. This airplane will have a total weight of 1,340,800 lb (5.96 MN) with a maximum load of 389,000 lb (1.73 MN) on each of six sets of wheels. Impact loads of 40 percent and longitudinal braking loads of 80 percent of live load were specified by the owner. The project includes a 500-ft (152-m) wide main runway structure and a 250-ft (76-m) wide taxiway structure. The design-build team elected to span the interstate using a four-span arrangement with beams set normal to I-285. This results in the saw-tooth pattern of the deck due to the skew of the runway as it crosses the interstate.

The design-build team selected precast, prestressed concrete beams as the primary superstructure members because of constructability and economy relative to other options. One consideration was that the design met the required four-hour fire rating without additional fire protection coatings or shields.

In order to carry such large live loads, the design used special 81- and 83-in. (2.06- and 2.11-m) deep bulb-tee beams with a top flange width of 93 in. (2.36 m) set on a beam spacing of 8 ft 0 in. (2.44 m) to achieve the maximum span length of 133 ft 0 in. (40.54 m) normal to the interstate. The beams contain as many as seventy-eight 0.6-in. (152-mm) diameter strands and are based on design concrete compressive strengths up to 10,000 psi (69 MPa) at 56 days with release strengths up to 7,000 psi (48 MPa). The subcontractor, Standard Concrete Products (SCP), produced a total of 788 beams over a two year period. Their mix design was capable of achieving the required 7,000 psi (48 MPa) strength in 18 hours. The mix used Type III cement, and a low water-cement ratio achieved by using high-range water-reducing and retarding admixtures. Steam curing was typically used during the winter months. SCP used new stressing beds, forms, and handling equipment for the project.

Elastomeric bearings are used throughout and the beams are framed together with diaphragms at the ends and midspan. The large live loads led to the diaphragms being designed to include post tensioning for load distribution in the transverse direction. Cast-in-place concrete with a 28-day compressive strength of 6000 psi (41 MPa) was used for the 30-in. (760-mm) wide diaphragms that contain up to six tendons composed of twenty-seven 0.6-in. (152-mm) diameter strands. The deck used reinforced concrete with a 5000 psi (34.5 MPa) design compressive strength and included shear reinforcement for load distribution from the wheel loads. The combination of wide flanged beams placed side by side and cast-in-place diaphragms required the flanges to be blocked out for constructibility purposes in the region of the diaphragms, leading to the unusual shape shown in the photograph.

During the construction effort, the airport authority requested the addition of a maintenance vehicle bridge adjacent to the runway and taxiway structures. This bridge required spans of almost 170 ft (51.8 m) to cross the interstate. It was quickly determined that the beams used for aircraft loads with span lengths of 133 ft (40.5 m) were capable of carrying vehicular loads for the 170-ft (51.8-m) span lengths and a new design was developed for this configuration.

Key Statistics

Prestressing Force/Beam	3,248,000 lb	14.4 MN
Deck Area	17 acres	368,800 m^2
0.6-in. dia. 270 ksi Strand	1150 miles	1850 km
PC Beams	18 miles	29 km
Reinforcing Steel	14,000,000 lb	6.342 Gg
Concrete	135,000 yd^3	103,000 m^3

CREEP TESTING

Jerzy Zemajtis, CTLGroup

For long-span bridges, predictions of long-term deflections and prestress losses are important design considerations. The accuracy of these predictions can be improved when measured values of modulus of elasticity, creep, and shrinkage of the concrete to be used in the structure are determined. This article describes the ASTM test for concrete creep.

The creep test procedure is defined in ASTM C 512. In the procedure, time-dependent strains are measured on concrete cylinders in compression and under laboratory-controlled conditions. The stress level is constant throughout the test and its magnitude is up to 40 percent of the concrete compressive strength. The 40 percent limit is due to the linear relationship between creep and stress in that range. The cylinders are usually loaded at a concrete age of 28 days; however, loading at other ages is also used depending on the application.

One of the assumptions of the method is that the total measured strain is the algebraic sum of elastic strain, drying shrinkage and autogenous shrinkage strains, and the creep strain. The corresponding drying shrinkage and autogenous shrinkage strains are measured on companion non-loaded cylinders that are stored under the same temperature and humidity conditions. It must be emphasized that the companion cylinders are not "shrinkage test cylinders." When specifications call for a shrinkage test, AASHTO T 160 (ASTM C 157) is usually specified.

Another assumption is that the elastic strain is the initial strain developed on load application. The creep strain is obtained by subtracting the elastic strains and strains measured on companion non-loaded cylin-

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ders from the total strains measured on the loaded cylinders.

The concrete specimens used in creep testing are 6-in. (150-mm) diameter by 12-in. (300-mm) long cylinders. The standard provides tight tolerances for the diameter and the length of the test cylinders; thus, special care must be exercised during specimen fabrication and preparation for testing. The gage length is usually equal to 10 in. (250 mm) and cannot be less than 6 in. (150 mm). A minimum of two cylinders are placed into a creep frame and stressed to a desired level. In addition, two non-instrumented half-length cylinders are placed at each end of a stack to eliminate end effects on the strain measurements.

Typical frames are capable of stressing cylinders to about 2500 psi (17 MPa). This means that the compressive strength of these cylinders, if stressed up to 40 percent of their strength, cannot be more than 6200 psi (43 MPa). For concretes with strengths greater than this, high-strength frames must be used. These frames can accommodate concrete with compressive strengths as high as 23,000 psi (159 MPa).

The standard curing requirements for the creep specimens are as follows:

- Remove from molds at 20 to 48 h after casting
- Store in a moist condition at 73.4 ± 3.0°F (23.0 ± 1.7°C) until the age of 7 days (storage in water is not permitted)
- Store and test at 73.4 ± 2.0°F (23.0 ± 1.1°C) and at a relative humidity of 50 ± 4 percent until completion of the test

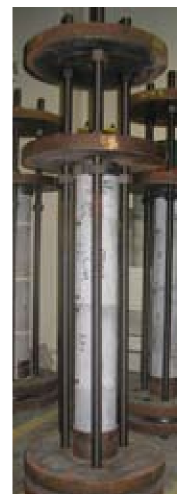
Other curing conditions and temperature regimes are also permissible, provided they are properly detailed in the report. Simulation of hot or cold weather or different humidity conditions can be accomplished by placing the creep frames in environmental rooms.

The measured strains, after subtraction of the initial loading strains and the shrinkage strains measured on the companion specimens, represent the sum of basic creep and drying creep. Basic creep occurs in concrete exposed to conditions that do not allow any moisture movement between the concrete and the environment (i.e. mass concrete structures). When basic creep is of primary interest, the specimens are sealed in moistureproof jackets at the time of fabrication or stripping. They are sealed throughout the period of storage and testing. Drying creep is the additional creep that is caused by drying and is measured on unsealed specimens. Note that drying creep is not the same as shrinkage.

The test must be run for at least 90 days for useable results. Longer periods, such as one to three years, are often specified for major structures. The test results are often presented in the form of specific creep or creep coefficient. The specific creep or unit strain is defined as creep per unit stress, and the creep coefficient is the ratio of creep strain to initial strain.

Editor's Note

This article is the fifth in a series that describes tests for use with HPC. Previous articles appeared in Issue Nos. 36, 37, 39, and 40.



Typical creep frames (left) and high-strength frames (right).

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