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Use of High Performance, High Strength Concrete (HPC) Bulb-Tee Girders Saves Millions on I-10 Twin Span Bridge in New Orleans District

Applied Research Pays Dividends: \$14,688,267 Saved on One Project

By using high performance, high strength concrete, wider girder spacing was achieved for the I-10 Twin Span Bridge. The use of 8,500 psi (59 MPa) design compressive strength concrete allowed the use of six lines of girders spaced at 10 ft.-9 in. (3.28 m) rather than seven spaced at 8 ft.-10 in. (2.69 m), which would have been required with a concrete compressive strength of 6,500 psi (45 MPa). Furthermore, the use of 8,500 psi (59 MPa) concrete allowed the BT-78 girder to span a length of 135 ft. (41 m). The BT-78 girders spanned a cumulative length of 25,920 ft. (7,900 m) in each direction. In addition, with the lower permeability

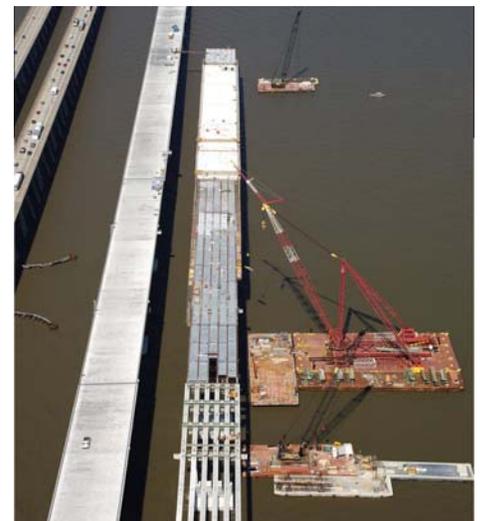
associated with high performance concrete, the Louisiana Department of Transportation and Development (LADOTD) expects a minimum 75-year service life for the bridge instead of the standard 50-year service life for concrete structures. Over the last 20 years, the Louisiana Transportation Research Center (LTRC) has experimented with high strength concrete, and over the last 10 years, LADOTD Bridge Design through LTRC and partners Tulane, CTL, Henry Russell consulting services, and Gulf Coast Prestressed conducted research that has enabled bridge design to effectively apply the research.

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I-10 Twin Span Bridge Construction



IMPLEMENTATION UPDATE

HISTORY

LADOTD has been gradually introducing high performance, high strength concrete into its bridge construction program. At the same time, LTRC has been sponsoring research work to address design and construction issues related to the utilization of high performance concrete.

In 1988, a bridge project was used as an experiment to determine if a concrete compressive strength of 8,000 psi (55 MPa) could be obtained on a production project. The contractor achieved strengths above 6,000 psi (41 MPa), an improvement over standard strengths, but generally fell short of the 8,000 psi (55 MPa) target. Work was done in the lab and with concrete mixtures to ensure better field reliability.

In 1992, a 130-ft (39.6-m) long, square, prestressed concrete pile with a compressive strength of 10,453 psi (72 MPa) was produced, shipped, and successfully driven without damage as part of the State Route 415 Bridge over the Missouri Pacific Railroad.

In 1993, two bridges on the Inner Loop Expressway near Shreveport were built using AASHTO Type IV

girders with a 28-day specified compressive strength of 8,500 psi (59 MPa). A 1994 LTRC report recommended that LADOTD consider the implementation of concrete with compressive strengths up to 10,000 psi (69 MPa) in a bridge and that the bridge should be instrumented to measure long-term behavior [1]. This recommendation was implemented with the design and construction of the Charenton Canal Bridge, which opened to traffic November 1999 [2]. The successful construction of the Charenton Canal Bridge demonstrated that a high performance concrete bridge could be designed and built in Louisiana using locally available materials. Prior to the start of the research projects, LADOTD was considering the use of 72-in. (1.83-m) deep bulb-tee girders for a future bridge project. The girders were expected to require the use of concrete with a specified compressive strength of 10,000 psi (69 MPa) and 0.6-in. (15.2-mm) diameter pre-stressing strands. During the course of this project, several other bridges with a specified strength of 10,000 psi (69 MPa) for the prestressed concrete girders were also designed. To obtain test data that would provide assurance that these girders would perform satisfactorily, a research program was initiated to evaluate the structural performance of



Flexural Strength Test Setup



Shear Test at CTL

full-size bulb-tee girders under flexural fatigue and static shear loading conditions.

RESEARCH PERFORMED

Five 96-ft. (29.3-m) long, 72-in. (1.83-m) deep, precast, and pretensioned bulb-tee girders were tested to evaluate behavior under flexural fatigue and static shear loadings. Three of the tested girders were also tested to measure their static shear strength. One girder was tested after the fatigue test to measure its flexural strength. 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 at the ends of the three girders were selected to evaluate the applicability of the shear strength design provisions of the *AASHTO Standard Specifications for Highway Bridges* and the *AASHTO LRFD Bridge Design Specifications*. Shear reinforcement consisted of conventional bars or deformed welded wire reinforcement.

The five prestressed concrete girders were produced in a commercial plant. Prior to testing, a 10-ft. (3.05-m) wide reinforced concrete deck slab was

added to each girder. Three girders were intentionally cracked at midspan before the start of the fatigue test. Two girders were uncracked. After completion of fatigue testing, the three intentionally cracked girders were cut in half and the six girder ends were tested to evaluate static shear strength.

RESEARCH RESULTS

The cracked bulb-tee girders performed satisfactorily under 5 million cycles of flexural fatigue loading when the tensile stress in the extreme fiber of the bottom flange was limited to a maximum value of 610 psi (4 MPa). When the tensile stress was 750 psi (5 MPa) or larger, fatigue fractures of the prestressing strand in the cracked girders occurred, and the fatigue life of the girder was reduced. However, the uncracked girders performed satisfactorily under 5 million cycles of flexural fatigue loading when the tensile stress was 600 and 750 psi (4 and 5 MPa). The measured flexural strength of one girder, after being subjected to 5 million cycles of flexural fatigue loading, exceeded the strengths calculated according to the *AASHTO Standard Specifications for Highway Bridges* and the *AASHTO LRFD Bridge Design Specifications* using both design and measured material properties. Measured shear strengths of six bulb-tee girder ends consistently exceeded the strengths calculated according to the *AASHTO Standard Specifications for Highway Bridges* and the *AASHTO LRFD Bridge Design Specifications* using both design and measured material properties. Based on the results of the shear tests, it was determined that the existing limitation of 60,000 psi (414 MPa) for the design yield stress of transverse reinforcement cited in both AASHTO specifications is conservative. Higher reinforcement yield strengths can be utilized in the



Fatigue Test Setup

design of prestressed concrete beams. Welded wire deformed reinforcement can be used as an equally effective alternate to deformed bars as shear reinforcement.

CONCLUSION AND RECOMMENDATIONS

This research, along with national research efforts in this area, gave the designers the information necessary to apply the new high strength concrete in the bulb-tee girder design for the I-10 twin spans. Detailed recommendations from the three studies can be found in the reports listed in the Reference section and are also available for download at http://www.ltrc.lsu.edu/pubs_final_reports.html on LTRC's Web site.

BENEFIT/COST ANALYSIS

The value of research is sometimes hard to quantify. But in this case, using just one project, researchers found huge savings. The calculations below are based on initial cost savings in bulb-tee girders alone and do not include the reduction in bent locations and increase in structure design life.

The total cost in performing the studies are:

$$\$255,831 + \$1,048,542 = \$1,304,373.$$

Knowing that cost of BT 78 is \$308.50/LF, the savings will be:

$$2 \text{ (twin spans)} \times 25,920 \text{ LF} \times \$308.50/\text{LF} = \$15,992,640.$$

Total savings:

$$\$15,992,640 - \$1,304,373 = \$14,688,267.$$

Benefits realized/cost of research:

$$\$14,688,267/\$1,304,373 \rightarrow \text{B/C} = 11.3:1$$



Full-size Bulb-Tee Girder Test

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3. Bruce, R. N.; Russell, H. G.; and Roller, J. J. "Fatigue and Shear Behavior of HPC Bulb-Tee Girders," Final Report - Louisiana Transportation Research Center, Research Report No. 395, Baton Rouge, LA, 2005, 75 pp.

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For more information about LTRC's research program, please visit our Web site. www.ltrc.lsu.edu