LTRC Technical Summary Report 438
LTRC Proj. No. 05-5C ~ State Proj. No. 736-99-1298

December 2009

Louisiana Transportation Research Center
4101 Gourrier Ave., Baton Rouge, LA 70808

Flexural Strength and Fatigue of Steel Fiber Reinforced Concrete (SFRC) (2004 Hale Boggs Deck)

Introduction

The Luling Bridge (Hale Boggs Memorial Bridge) traverses the Mississippi River in St. Charles Parish, Louisiana. It was one of the first cable-stayed bridges in the United States and opened to traffic in 1983. Unique to its design are relatively few cables, the deck resembles a box girder more than a suspended deck, and the first major use of weathering steel on such a large bridge.

A concrete test section was constructed in 2004 utilizing an SFRC mixture. It was thought that the omnidirectional reinforcing effect provided by steel fibers would be superior in resisting the myriad of stresses inflicted on the concrete from the bridge. This test section demonstrated the most promising design for a possible future decking of the complete bridge; an investigation into the SFRC, epoxy, and steel decking system was appropriate.

Objective

The objective of this research was to study the Luling Bridge SFRC test section. The main focus was to analyze the SFRC with a range of steel fiber addition amounts and their affect on the performance of the whole steel, epoxy, and SFRC composite system. It was desired that a better comprehension of the decking system be attained with specific emphasis on the effects of the steel fiber additional amounts and flexural strength of the concrete.

Scope

To accomplish the objectives of this support study, both field and laboratory studies were undertaken. The laboratory study evaluated compressive and flexural properties of concrete incorporating steel fibers at differing rates. The following ASTM standards were utilized in the laboratory study.

- ASTM C-78 Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
- ASTM C1018 Flexural Toughness and First-Crack Strength of Fiber-Reinforced Concrete (Using Beam with Third-Point Loading)
- ASTM C-1202 Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration
- ASTM C-39 Compressive Strength of Cylindrical Concrete Specimens
- A Cyclic Load Testing Regime

From both a dynamic (wind and traffic) and thermal (expansion and contraction) perspective, stresses applied to the deck of the Luling Bridge are diverse and complex. This research concentrated on flexural characteristics of the steel, epoxy, and SFRC decking system, considering them to be the most significant in resisting applied stresses.

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Principal Investigators:

John Eggers, P.E.
Tyson Rupnow, Ph.D., P.E.

LTRC Contact:

Chris Abadie, P.E.
Phone: (225) 767-9109

Louisiana Transportation Research Center

Sponsored jointly by the Louisiana Department of Transportation and Development and Louisiana State University

4101 Gourrier Avenue
Baton Rouge, LA 70808-4443

www.ltrc.lsu.edu

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Methodology

Twenty 6-in. × 6-in. × 20-in. flexural beams were produced at the construction site from SFRC as delivered by the ready-mix trucks. These 18 beams were tested over a 57-day period at intervals of 1.5, 2.5, 3.5, 4.5, 8, 15, 29, and 57 days to develop a strength gain over time curve. These tests were conducted as per ASTM C-78 with flexural beams being moist cured after 18 hours of field cure at the job site.

All laboratory testing was conducted at 28 days of age. All concrete mixtures imitated the original concrete mixture design as used on the 2004 test section. Steel fiber additional amounts were divided into four groups of: no steel fiber addition, 65 lb/yd^3, 85 lb/yd^3, and 100 lb/yd^3.

For the SFRC specimens that modeled the actual bridge deck (steel, epoxy, and SFRC), a total of six specimens were produced. This involved a 4-in. × 16-in. × ½-in. thick steel plate onto which a thin, 1/8-in. layer of Concresive® 1090 epoxy was applied and ½-in. limestone broadcast onto it. The remainder of the 4-in. tall mold was then consolidated with the SFRC. For the SFRC deck models, steel fiber additional amounts were modified based on initial results to: 65 lb/yd^3, 85 lb/yd^3, and 95 lb/yd^3.

Conclusions and Recommendations

The most significant discovery from the testing was the revelation that the bending failure mechanism of the steel, epoxy, and SFRC deck model was shear, developed at the epoxy interface, specifically at the epoxy/steel interface. Although limited to six specimens, it was apparent that this was the controlling failure mechanism under a bending load. This was unknown to the designers and should be of vital importance if a future concrete deck is built on the Luling Bridge or any orthotropic deck. If an epoxy interface or bonding layer is used, it is imperative that strict specifications be prescribed concerning the cleanliness of the steel deck to facilitate the best bond possible. Since the majority of failures were at the steel/epoxy interface, this bond is critical not only for bending stress failure, but also for possible delamination.

Another point of interest is the quantity, size, and quality of aggregate broadcast onto the epoxy after its application to the deck. Although sufficient shear resistance was developed in the deck model specimens, as evidenced from the location of shear failure, this should be a point of interest for future applications.

The fatigue testing results were inconclusive, and no correlations to current or expected field performance can be made. It is recommended that if the Department wants to consider this type of deck in the future, much larger model specimens should be constructed and tested in a repeated load manner.

This in-place test section showed signs of random cracking shortly after construction though these cracks have held tight without any significant detrimental effect on the test section.

Figure 1
The Luling Bridge (The Hale Boggs Memorial Bridge)