LOUISIANA TRANSPORTATION RESEARCH CENTER
LTRC

TECHSUMMARY *April 2016*

SIO No. 30001504 / LTRC Project No. 14-3C

Evaluation of the Fatigue and Toughness of Fiber Reinforced Concrete for use as a New Highway Pavement Design

INTRODUCTION

Currently the concrete industry has two options when it comes to concrete pavement: jointed plain concrete pavement (JPCP) and continuously reinforced concrete pavement (CRCP). Both have their strengths and drawbacks. The research presented herein represents a first step in determining the feasibility of utilizing a new pavement structure. The proposed continuously fiber reinforced concrete pavement (CFRCP) will conceivably merge the cost effectiveness of a jointed plain concrete pavement (JPCP) with the smooth ride and superior longevity of a CRCP. The initial laboratory results include flexural, fatigue, and toughness testing for a variety of concrete mixtures containing polypropylene fibrillated, polypropylene macro, carbon macro, and steel fibers.

OBJECTIVE

This study presents the first approach to develop a new concrete pavement structure reinforced only with fibers. This research will identify probable combinations of fibers (dosage and length combinations) that will adequately perform in repeated load fatigue tests. While fibers and high dosage fiber combinations have been previously used in concrete, these combinations have never before been used in a Department of Transportation (DOT) pavement structure. The major difference between previous applications and the current objective is number and level of load applications. The fundamental objective of this research is to determine how CFRCPs behave under highway-type loading.

The specific objectives of the study include:

1. Characterize the fresh and hardened properties of CFRCP concrete.
2. Determine the comparative fatigue resistance of different fibers, and differing fiber blends and dosage rates.
3. Provide recommendations for future research, including full scale loading and possible field implementation sites.

SCOPE

Much of the focus in recent years has been to create crackless industrial floors; the previous interest in fiber reinforcing for highways has dwindled. The fiber market now includes many more types, shapes, and applications for fiber-reinforced concrete, and, with the increasing cost of steel, these options have become cost-effective. The objective of this research is to develop a CFRCP system that will ultimately produce a series of normal, random cracks similar to a CRCP pavement but without the cost of steel materials and construction. The first step is to determine how various types and dosages of the currently available fibers impact fatigue and toughness when used in a standard DOT concrete pavement mixture.

The driving motivation for this project was to determine if fiber reinforcement could be used as a viable alternative to steel reinforcement in pavement design. The fiber dosages used in this project were selected for their cost relative to that of steel currently used in CRCP and JPCP.

LTRC Report 559

Read online summary or final report:
www.ltrc.lsu.edu/publications.html

PRINCIPAL INVESTIGATOR:

Tyson Rupnow, Ph.D., P.E.
225.767.9124

LTRC CONTACT:

Tyson Rupnow, Ph.D., P.E.
225.767.9124

FUNDING:

SPR: TT-Fed/TT-Reg

Louisiana Transportation Research Center

4101 Gourrier Ave
Baton Rouge, LA 70808-4443

www.ltrc.lsu.edu

METHODOLOGY

The testing was performed on concrete beams with a 6-in. by 6-in. cross section that was 20 in. in length. The beams were prepared in accordance with ASTM C192 using a vibrator for consolidation. The concrete mixture proportions used for this study were a standard DOTD highway mix design used for JPCP. A polycarboxylate high range water reducer was used to ensure workability of the mixtures.

The fiber dosages were selected based on cost compared to the difference in construction and materials between JPCP and CRCP. Each of the mixtures, except for the steel fiber mixture (added at a rate of 0.9 percent or 85 pounds per cubic yard), included one dosage rate above that commonly used or previously investigated. Three dosage rates for the polypropylene fibrillated fiber were used, 0.1, 0.2, and 0.3 percent corresponding to 1.5, 3.0, and 4.5 pounds per cubic yard, respectively.

Four dosage rates of the polypropylene macro fibers, 0.3, 0.5, 0.7, and 1.0 percent, were included because a wider range of dosages is common in practice. This corresponds to 4.5, 7.5, 10.5, and 15.0 pounds per cubic yard, respectively. The polypropylene macro fiber was a twisted bundle which dispersed during mixing.

Three dosage rates for the carbon fiber were used, 0.3, 0.7, and 1.02 percent corresponding to 9.0, 21.0, and 30.5 pounds per cubic yard, respectively. The carbon fibers contained a large number of individual fibers held together with a nylon mesh.

To prevent any balling concerns, all fibers were added by hand to the fresh concrete once all of the other components had been incorporated. Concrete properties were measured with ASTM C39, ASTM C78, ASSTM C138, ASTM C134, ASTM C231, ASTM C1609, and repeated load fatigue testing.

CONCLUSIONS & RECOMMENDATIONS

The results of this laboratory evaluation of fiber reinforced concrete led to the following conclusions. Test results showed that the use of fiber reinforcement improves the performance of portland cement concrete with respect to fatigue. The results showed that polypropylene, both fibrillated and macro, increase the fatigue performance of fiber reinforced concrete more than steel fiber reinforced concrete, when used in the correct dosages. The results also showed that carbon fibers increase the fatigue performance, when dosed above 21 pcy. There is, however, a point at which the fiber reinforcement inhibits fatigue performance of the concrete. The performance was not reduced below that of unreinforced concrete, but was reduced below the performance of steel fiber reinforced concrete.

Toughness testing showed that tensile strength and dosage rate were critical components in the ductility of the sample. Fibers with high tensile strengths had a greater residual load carrying capability and carried greater loads at larger deflections. Not unlike the fatigue testing, there was a point where the fiber dosage offered diminishing returns for the performance of the sample. The diminishing returns are hypothesized to be a result of the fibers interfering with the aggregate interlock that occurs in concrete.

Pre-cracked fatigue testing showed that tensile strength is not the only component that contributes to the performance of fiber reinforced concrete. The length of the fiber is also crucial to the performance. The shorter polypropylene fibrillated fiber did not develop a strong enough bond with the concrete to prevent pull out, even though the fibrillated fiber had the same tensile strength as the polypropylene macro fiber. The pre-cracked fatigue test did not show the same diminishing returns for overly reinforced samples because the fibers were supporting the entire loading.

Figure 1
Polypropylene fibrillated fiber (left), polypropylene macro fiber (left middle), carbon fiber (right middle) and steel fiber (right)

Louisiana Transportation Research Center sponsored jointly by the Louisiana Department of Transportation & Development and Louisiana State University