Project Summary

Texas Department of Transportation

0-5255: Steel Fiber Replacement of Mild Steel in Prestressed Concrete Beams

Background

In prestressed concrete beams, prestressing tendons primarily resist bending moment and mild steel stirrups are used to provide shear capacity. Placing stirrups is time consuming and labor intensive. In an attempt to improve the efficiency of Prestressed beam fabrication, it was proposed to replace the stirrups with steel fibers. This was shown to be possible in TxDOT project 0-4819.

Before the cost effectiveness could be evaluated, shear design guidelines for Prestressed Steel Fiber Concrete (PSFC) beams had to be developed. In order for these shear provisions to be widely applicable, they must be rational, guided by a mechanics-based shear theory, and be validated by experimental tests on actual beams used in industry.

What the Researchers Did

The following tasks were carried out to develop new shear design provisions for PSFC beams in order to achieve the objectives of this project.

1) PSFC Panel Tests: PSFC panels were tested to establish the constitutive models for PSFC membrane elements and inform the development of an analytical model for predicting the shear behavior of such elements. This objective was accomplished by performing biaxial load tests on two groups of PSFC panels. The test panels were divided into two groups designated as Group TEF (to find constitutive models) and Group TAF (to perform pure shear tests). The constitutive models were incorporated into the Softening Membrane Model (SMM) for prestressed concrete membrane elements to simulate the response of PSFC elements subjected to pure shear. The SMM for PSFC showed a close fit with the experimental results of panels in Group TAF tested under pure shear.

2) PSFC Beam Tests: A total of twelve 25-foot long full-scale PSFC bridge beams were cast and tested to study the shear behavior of the beams. Six TxDOT Type-A beams and six box beams were tested. The main variables studied were Fiber-Factor and shear span to effective depth ratio (*a/d* ratio). The beams were designed to fail in web-shear and flexure-shear failure modes. All of the beams were tested until failure. Loads, displacements and strains were continuously monitored to document the shear behavior of the beams.

The test results in conjunction with the constitutive models established in task1 were used to develop a simple equation for shear design of PSFC beams.

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In the proposed equation, the shear capacity of PSFC beam is represented as a function of the compressive strength of concrete, the *a/d* ratio of the beams and the Fiber-Factor. The amount of prestressing force and the angle of the failure planes were neglected because they were found to have insignificant effect on the ultimate shear capacity.

Four design examples were prepared to illustrate the application of the new shear equation for PSFC beams.

What They Found

The following are the major findings from this study:

- PSFC panel tests showed that the tensile stiffness and concrete softening characteristics of PSFC improves with an increased Fiber-Factor.
- PSFC I-beam tests showed that steel fibers were very effective in resisting the shear loads. PSFC beams had higher ductility and smaller crack widths than mild steel reinforced beams. It was found that mild steel shear reinforcement can be completely replaced with steel fibers. 1% by volume of Dramix short steel fibers (ZP 305) was determined to be an optimum dosage in prestress concrete beams for shear reinforcement.
- Using the constitutive laws of PSFC established in this research, an analytical model was developed and implemented in the finite element program framework OpenSees to simulate the shear behavior of the PSFC beams. Using this computer program, the load-deflection curves of all the beams were simulated with acceptable accuracy.
- A new shear design equation was developed using the results of the PSFC beam tests performed in this research.

What This Means

The researchers developed a simple design concept of modifying the concrete contribution term of any shear design equation with a factor to account for presence of steel fibers. Mild steel shear reinforcement can be completely replaced with steel fibers to resist shear forces in prestressed concrete beams and the PSFC beams show improved behavior; however, the required percentage of fibers by volume may not be economical with commercially available fibers available at this time. The total weight of steel fibers is greater than the total weight of stirrups in a typical beam. The cost of the steel fibers may not be offset by the savings in labor and time from eliminating stirrups. The higher cost steel fiber reinforced beams can be justified in cases where improved impact resistance, ductility and corrosion protection is needed.

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