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EXPERIMENTAL STUDY ON SHEAR BEHAVIOR OF DIFFERENT TYPES OF FIBERS IN REINFORCED CONCRETE BEAMS

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Abstract - *This study presents a series of tests for characterizing the structural behavior of fiber reinforced concrete beams subjected to shear loading. The experimental program involves two types of fibers, steel fiber and a polypropylene fiber. As a reference, plain concrete and conventionally reinforced concrete specimens have also been casted and tested in the laboratory as per ASTM standards. The ultimate shear carrying capacities of the beams are calculated. The study confirms that the shear crack resistance of the material is greatly enhanced by the fibers. Fibers reduced the crack width to approximately a fifth of that in beams with stirrups. The use of steel fibers raises the ductility and fracture energy of concrete. Addition of steel fibers to concrete improves its post cracking behavior in tension. The shear resistance increased with increasing aspect ratio of fibers and volume fraction of fibers.*

Key Words: Steel fiber, Polypropylene fiber, Cracking, Shear resistance.

1. INTRODUCTION

Both steel and polymeric fibers have been used to reinforce concrete and consequently increase its toughness and crack resistance. Fiber reinforced concrete can be used in some structural applications with a reduced amount or even without any conventional reinforcement. One application of the fibers is to increase the load-carrying capacity of concrete subjected to shear.

Several design methods have been proposed that take into account the increase in shear strength due to fibers (Al-Tann and Al-Feel, 1990; Casanova and Rossi, 1997; Campione and Mindess, 1999; RILEM 2000a; Dupont and Vandewalle, 2000; Italian Guidelines CNR-DT 204/2006, 2006; among others). Each of the methods accounts for the fiber contribution by means of an index based on the toughness of the material. However, each formula uses a different index, obtained from different types of test conurations. Thus the application of the design methods can be difficult. Moreover, most of the design methods and test procedures have been developed only for the evaluation of steel fiber reinforced concrete.

The purpose of this work is to present the results of a study carried out to characterize the structural behavior of FRC beams under shear loading, considering fibers of different materials (steel and polymeric). Further, the study aims to evaluate the ability of predicting the ultimate shear capacity through code provisions or by correlations with results from other tests. At the same time, it is verified whether the design methods for SFRC can be extrapolated to polypropylene fiber reinforced concrete (PFRC).

2. MATERIALS

A concrete with 25 Mpa compressive strength was considered for the mixes. Two types of fibers were considered, Dramix 80/60 BN hook-ended steel fibers, and polypropylene fibers. In all cases fiber volume was fixed at 0.4% based on literature review.

Fig- 1: Steel Fiber with Hooked-end and Polypropylene Fiber

3. SHEAR RESISTANT MECHANISMS OF FRC BEAMS

In a FRC beam, it seems logical to consider that, during failure; the shear force transferred along the web, due to aggregate interlocking is increased since the crack opening is reduced by the fiber action. Also, due to the toughness of FRC, tensile stresses can be resisted across the crack (through fiber bridging) once the shear crack appears; giving rise to a vertical force component that contributes to balancing the shear force acting on the beam. For the shear design of beams, the European and American Codes consider that the ultimate shear capacity, Vu, is the sum of the contributions of the concrete and the stirrups, Vcd and Vwd, respectively:

$$Vu = Vcd + Vwd$$

Accordingly, several authors (Al-Tann & Al-Feel, 1990; Casanova & Rossi, 1997; Compione & Mindess, 1999; RILEM, 2000a) have suggested the addition of another factor, Vfd, to take into account the fiber contribution:

$$Vu = Vcd + Vwd + Vfd$$

Where Vfd is a function of different parameters. For example, RILEM (2000) defines the contribution of steel fibers to the ultimate shear capacity as:

$$Vfd = kf\, k1 \tau fd\, bw\, d$$

Where kf = takes into account the contribution of the flanges of a T-section:

$$Kf = 1+[hf/bw][hf/d]\, n,$$

$$Kf \leq 1.5$$

Hf = flange thickness (mm)

Bf = flange width (mm)

Bw = web width (mm)

N = Bf- Bw/ hf ;

$K1 = 1600\text{-}d / 1000 \quad k1 \geq 1$; (d in mm); k1 accounts for the size effect

τfd = design value of the maximum tangential stress due to fibers;

$\tau fd = 0.12\, f\ (N/mm^2)$; Where f is the equivalent residual stress.

4. MATERIAL-SCALE CHARACTERIZATION TESTS

The concrete compressive strength was evaluated for each mix by tests on 150×150×150 mm cubes. Two-point loading tests were conducted on beam specimens of 150 × 250 × 2000 mm to study the shear capacity. Two-point flexural tests were conducted on beam specimens of 100 × 100 × 500 mm according to the ASTM C1018 (1998) standard. The test configuration and typical mean responses can be observed in Figure..2

As it can be seen from .6 that toughness clearly increases with the incorporation of fibers; to a greater extent with steel fibers, followed by HPP fibers

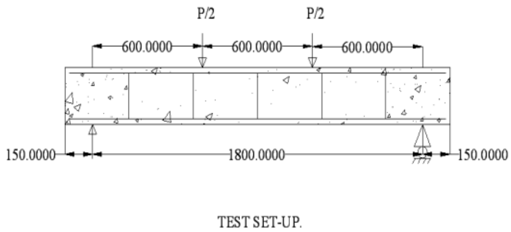

Fig-2: Shear Test Configuration

5. TESTS RESULTS AND DISCUSSION

The structural-scale beams were tested under shear loading through the two-point load conuration, with a shear span to depth ratio equal to 2.67. The smaller anchorage length provided for the longitudinal reinforcement did not allow the development of arch effect, which caused failure by debonding of the flexural reinforcement in the case of beams without conventional shear reinforcement.

Figure.6 shows the typical load-deflection responses, where the shear ductility increase induced by fiber action is appreciable. Beam PC-SR exhibited flexural failure. In SFRC beams, the maximum load is higher by approximately 20% of that of plain concrete, with increase the deflection at maximum load. An increase of ductility under shear loading can be clearly observed for all FRCs with respect to plain concrete beam specimens, indicated by the significant increase in the deformability of the elements either at maximum load or along the post-peak regime.

Nevertheless, the load carrying capacity of beams reinforced with fibers is always lower than that of the beams with the same volume of steel in the form of stirrups. This is attributed to the distributed nature of the fiber reinforcement where only some fibers are favorably oriented to resist cracking, whereas all the stirrups actively prevent crack opening.

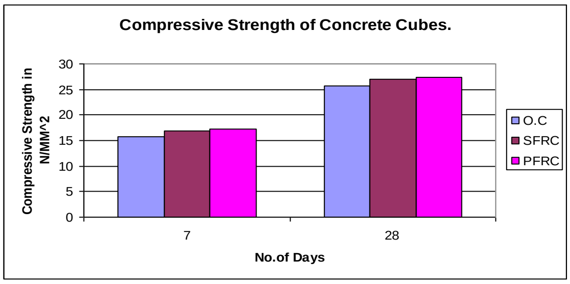

Fig-3: Compressive Strength of Concrete Cubes

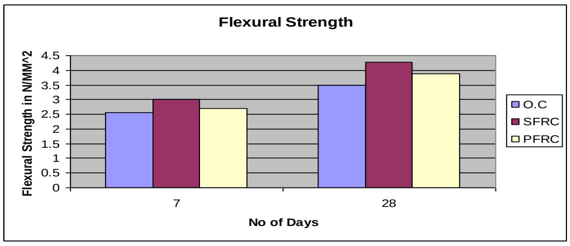

Fig-.4: Flexural strength of concrete

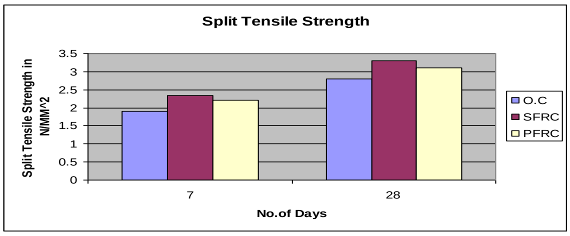

Fig 5: Split Tensile Strength of Concrete

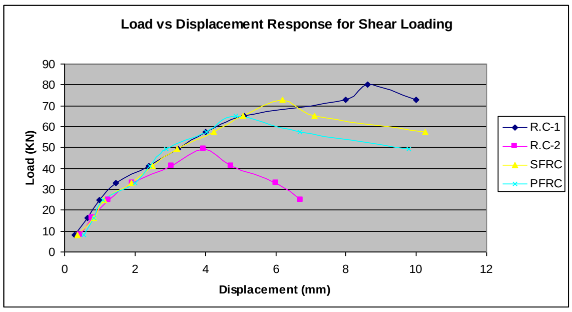

Fig-6: Load-Displacement Response Under Shear Loading

6. CONCLUSIONS

- It has been observed that the incorporation of fibers to the mix increases the material toughness both in tension and compression, as represented by the toughness indexes of the ASTM and JSCE standards.
- The toughness increases results in higher shear strength of the concrete and better deformability, i.e. the deflection at maximum load is significantly higher for FRC beams than plain concrete specimens.
- The compressive strength increase only marginally due to fiber incorporation in concrete.
- First crack occurs earlier in PFRC when compared to SFRC.
- In SFRC beams, the maximum load increased by approximately 20% of the plain concrete.
- The length and width of the crack is reduced due to the incorporation of fibers in the concrete.

7. REFERENCES

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