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Experimental Study of Shear Behaviour of Hybrid Fiber Reinforced Concrete Beams

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***Abstract*: This paper 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.**

***Keywords*: Hybrid fiber, Polypropylene fibers, Reinforced concrete beams strengthening, Steel fibers.**

1. Introduction

Beam is a structural element that primarily resists the load applied laterally to the Beam axis. Beams are the vertical or sloping bearing elements of the structural system that connect Columns and Support Slabs. To determine the shear behavior of steel and polypropylene fibers reinforced concrete beams and to compare the results with ordinary reinforced concrete with stirrups. In this paper we will discuss about the following. 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. The addition of fibers to concrete effectively improves the shear strength of concrete, as the fiber transfer tensile stresses across crack surfaces.

A. Polypropylene Fibers

Polypropylene fiber is a fiber and can be divided into small particles then formed into continues fibers. Polypropylene fiber has a good resistance to chemical attack, impact load, and fire. Some of the potential applications of these polypropylene composites are: soil strengthening, bridges and highways, industrial floors, heat and sound insulation for residential and industrial buildings, bullet proof vests and retrofitting and rehabilitation of structures.

Polypropylene fiber is fine-grained, extrusive composed of with or without and containing not more than 53 Weight percentages of SiO2 and less than 5 weight percentages of total alkalis. Many types of polypropylene fiber are monofilament polypropylene fiber, fibrillated polypropylene fiber and microfilament polypropylene fiber. The production of polypropylene fibers gives more significance than any other synthetic fibers.

B. Steel Fibers

Steel fiber (SF) is the most popular type of fiber used as concrete reinforcement. Initially, SFs are used to prevent/control plastic and drying shrinkage in concrete. Further research and development revealed that addition of SFs in concrete significantly increases its flexural toughness, the energy absorption capacity, ductile behaviour prior to the ultimate failure, reduced cracking, and improved durability.

2. Literature Review

Criswell (1976) [1] conducted a number of shear tests, all of which demonstrated an increased shear capacity with the use of steel fibers. All of his tests were made with concrete containing 1.0 percent by volume of straight fibers. The results of four shear-friction specimens showed a 20 percent increase in shear strength

Williamson (1978) [2] casted beam of size (305×546×7010 mm), found that when 1.66 percent by volume of straight steel fibers were used in place of stirrups, the shear capacity of the beams was increased 45 percent over a beam without stirrups. Nevertheless, the beams failed in shear. This is consistent with the results of other investigators. When steel fibers with deformed ends were used (1.1 percent by volume), the shear capacity of the beams was increased 45 to 67 percent but fails in flexure.

Sharma (1986) [3] tested 7 beams with steel fiber reinforcement, of which 4 also contained stirrups. The fibers had deformed ends. Based on these tests he proposed the following equation for predicting the average shear stress Vcf in the SFRC beams.

$$Vcf=2/3ft'(d/a)^0.25$$

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ft' – Tensile strength of concrete obtained from results of tension tests.

d/a – Effective depth-to-shear-span ratio.

Lakshmipathy and Santhakumar (1987) [4] conducted an experimental analytical investigation on two span continuous beams with steel fibres. The important characteristics such as cracking behaviour, ductility and energy absorption were ascertained from experimental investigation and compared with analytical results. The fibrous concrete beams served to be superior to conventional concrete

Rao, Sasidhar C. H, Gnaneswara K (1987) [5] conducted an experimental investigation on deformation characteristics and strength of reinforced concrete beams made with steel fibres in pure bending. A number of beams each with 1.85m span were cast and tested under static flexural loading. The increase in depth of neutral axis and hence flexural stiffness of fibre reinforced concrete beams at all stages of loading reflected the ability of fibres in arresting the crack growth. The inclusion of steel fibres in the concrete significantly increased the post cracking stiffness at all the stages upto failure.

3. Beam Strengthening

Table 1
Concrete mix ratio = 1: 1.4: 2.54

Material	By weight	By proportion
Cement	447kg/m^3	1
Fine Aggregate	625kg/m^3	1.4
Coarse Aggregate	1139kg/m^3	2.54
Water Content	197 litres	
Steel Fiber (0.2%)	4kg/m^3	
Polypropylene Fiber (0.2%)	4kg/m^3	

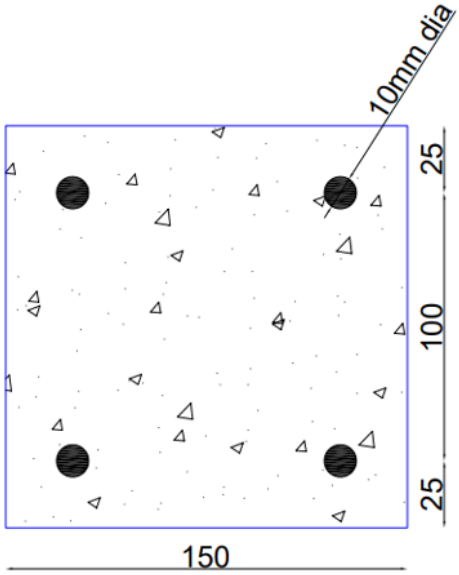

Fig. 1. Beam main bar setup

A. *Test on beams*

- The casted three beams are tested for flexure in the load frame structure.
- All the beams are tested individually and the value is noted Normal.

B. *Type of beams*

Three types of beams are to be casted,

- Conventional RC Beam
- RC beam with Steel fiber
- RC beam with Polypropylene fiber.

C. *Beam physical properties*

- Three beams are of same size = 1000mm x 150mm x 150mm
- The three beams are casted as per given reinforcement details.
- The steel fiber and polypropylene fibers are added in correct proportion to the concrete mix.
- All three beams are casted and cured for 28 days to attain its full strength.

D. *Test on beams*

- The casted three beams are tested for flexure in the load frame structure.
- All the beams are tested individually and the value is noted.

E. *Test setup*

- The beams are kept in one-point loading at the mid-span and tested.
- The ultimate load of all the three beams are noted.

4. Test Results

A. *Shear behaviour of the conventional beam*

- The ultimate load on the mid span of the conventional RC beam is = 41.0KN

B. *Shear behaviour of the steel fiber RC beam*

- The ultimate load on the mid span of the Steel fiber RC beam is = 44.5 KN

C. *Shear behaviour of the polypropylene fiber RC beam*

- The ultimate load on the mid span of the Steel fiber RC beam is = 46.5 KN

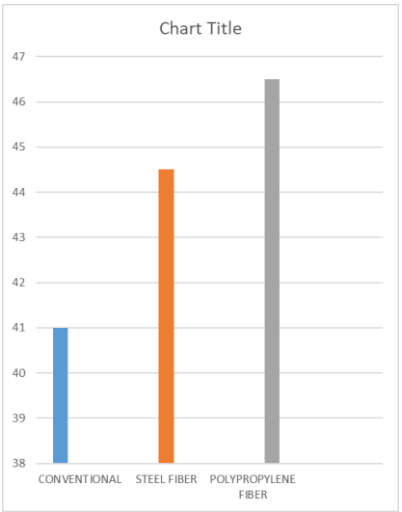

Fig. 2. Graph representation of test results

Table 2
Comparison of results

Type of beam	Ultimate load (KN)	Increase in strength compared to conventional beam
Conventional RC Beam	41.0	0%
Steel Fiber (0.2%)	44.5	108%
Polypropylene Fiber (0.2%)	46.5	113%

5. Conclusion

A. Results and Discussion

- From the results, it is clear that the usage of polypropylene fibers in the RC beam has increase the shear behaviour of the beam when compared to the Conventional and Steel fiber RC beam.
- It is clear the bond strength between the concrete and polypropylene is very high and will be very effective when used in correct proportion.
- Even Steel fiber has also showed increase in Shear strength compared to conventional RC beam.
- Steel fiber increase the shear strength of the beam immediately and arrests the flexural cracks forming initially.
- Hence, I would like to conclude that both Polypropylene fiber and Steel fiber incorporated RC beams showed good improvement in the shear behaviour.
- Both the Hybrid fiber have their own advantages.
- Both fibers can be used where the beam has to resist more shear load based on the site conditions and the availability of materials.

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