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Flexural And Compressional Behavior Of Steel Fiber Reinforced Concrete.

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ABSTRACT

This paper describes the use of steel fiber as as reinforcing material in plain cement concrete of M30 grade. Varied proportions of steel fiber was used say 0%, 0.5% and 1% to the concrete cubes and beams to conduct compressive and flexural strength tests after 28 days curing. It was observed upon addition of steel fiber upto 0.5%, the compressive strength of the cube increases. Beam was casted and test were conducted for flexural strength for single point load method. The load carrying capacity of the steel reinforced for an aspect ratio of 50 increased with increase in percentage of fiber and there was reduction of deflection. The flexural strength and flexural rigidity of the reinforced concrete increased with the increase in percentage of fiber in a larger amount.

Keywords: Steel fiber, Reinforced concrete, Compressive strength, Flexural strength, Flexural rigidity

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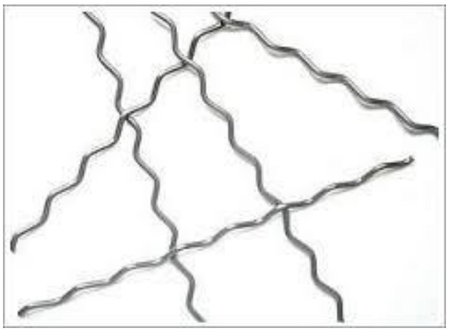
INTRODUCTION

Concrete, a composite material with a combination of cement, fine aggregate and coarse aggregate which is widely used in the construction field. As it is strong in compression and weak in tension, concrete is usually reinforced. Recently, fibers are used to reinforce the concrete to provide good cohesion. These fibers can be of metallic or polymer fibers, which provide high resistance (Figure 1). The shape of the fiber either circular or flat, but it is generally denoted in aspect ratio (length to its diameter); the typical value range between 30 to 150. These fibers are uniformly disturbed and the orientation is random.



a. Steel Fiber

b. Glass fiber

c. Synthetic Fiber

d.Natural Fiber

Figure1: Different types of fiber

The behavior of fiber reinforced concrete (FBC) depends on character, material, geometries, distribution, orientation, and densities of fibers. The proportion of fibers added to the composite mix is termed as " volume ratio (v_f)". Depending upon the volume ratio, the composite is classified as follows;

- Low volume fraction (<1%)
- Moderate volume fraction (between 1% and 2%)
- High volume fraction (greater than 2%)

In steel reinforced concrete mix, the final cracking phase got changed (XU and Reinhard, 1998). When steel fibers (SF) were mixed with concrete, the impact strength and ductility of concrete increase (Kazemi et al., 2007 and Sahin, Fuat Köksal, 2011) but don't show significant improvement in tensile strength, which was very useful in the construction of high raised building and bridges with a long span.

When steel fiber was used in high-performance concrete, it improves the brittle behaviour and energy absorption capacity (Kittinun et al.,2010 and Kazemi et al.2017). To understand the performance of the steel fiber in concrete for larger content, broader size and number of specimens were required to estimate the fracture parameters (Kazemi et al.,2017). In addition to that, the fiber crossing the crack surface was broken due to high bond strength.

Song and Hwang (2004) found that the compressive strength of High strength concrete increased with the intrusion of steel fiber at a volume fraction of 1.5%. Upon adding SF in the concrete beam, the depth of neutral axis increases and post-cracking stiffness too (Rao et al., 1987). Short steel fibers increase the maximum tensile strength and higher strain was observed for long fibers (Olivito and Zuccarelo, 2010).

However, choosing the right mix and aspect ratio to have good results (Chang et al., 1991, kim et al., 1994,Tat-Seng Lok, Jin-Song Pei ,1998 and Barros, Figueiras, 1999).

Hence a study was attempted to understand the variation in bending tensile stress, deflection, compressive strength and flexural rigidity with steel fibers in the concrete mix.

Material and Mix design with Methodology

Figure 2: shows the methodology adopted.

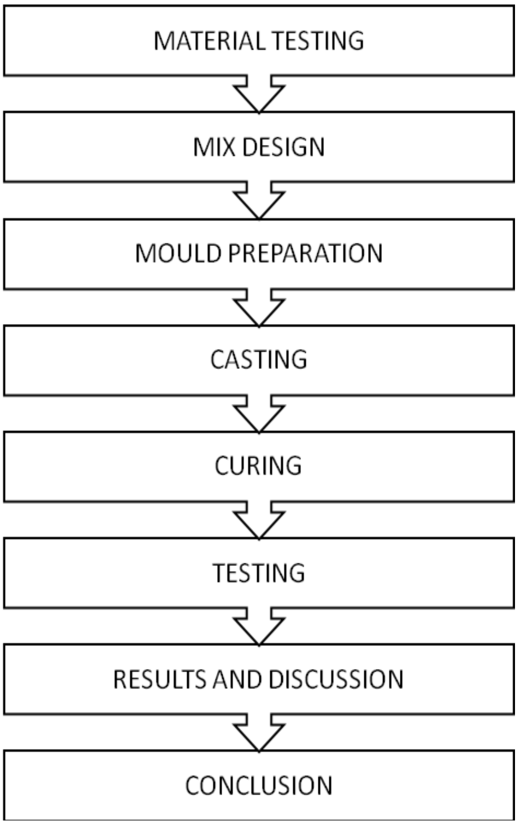


Figure 2: Methodology

Material Property

The specific gravity of fine, coarse aggregate and cement were found as 2.7, 2.74 and 3.14 respectively. A concrete mix of M30 was adopted to find cube compressive strength and flexural properties of the concrete. Three different mixesare adopted say 0.5 and 1%of SF mixed in concrete and it was compared with 0% SF concrete. Figure 3 shows the steel fiber used in the experiments.

Figure 3: Steel Fiber

The mean target strength of concrete was calculated using equation1,

$$f_t = f_{ck} + kS \qquad 1$$

Where, f_t – mean target strength N/mm^2, f_{ck} – characteristic compressive strength N/mm^2, K -a statistic, depending upon the accepted proportion of low results and the number of tests, S - standard deviation, [from table1, IS 10262]

The f_t values is calculated as 38.25 N/mm^2 ,water / cement content ratio is taken as 0.45 and air content for 12 mm aggregate was calculated as 2.5 %. Table 1 shows the volume of materilas used.

Table 1: Shows the detail proportion of materials.

% of Fiber	Mass of steel fiber, kg/m^3	Volume of steel fibers, m^3	Volume of coarse aggregates, m^3	Volume of fine aggregates, m^3
0	0	0	0.346	0.283
0.5	39.25	0.005	0.343	0.281
1	78.5	0.01	0.3405	0.278

Sample preparation

Mould for 9 cubes and 9 beams (Figure 4) were made using wooden planks and nails. Wooden planks of size 15cm in height and length of 210cm was used to make mould for beams and cubes. Tests were carried out for 0%, 0.5% and 1% of fiber for reinforced concrete in beams and cubes;an average value of three test value was considered for the above said proportions.

Once the sample is prepared (Figure 5), it was cured using wet gunny bags to enhance the hydration process of the specimen (Figure 6).

Figure 4: Mould Fabricated

Figure 5: Casting of specimen

Figure 6: Curing of Specimen

RESULTS AND DISCUSSION

For an aspect ratio of 50 with length of the fibre as 50 mm and diameter of the fibre as 1 mm tests were conducted to find the flexural stress, rigidity and compression behaviour of the reinforced concrete of M30 grade.

Compressive Strength

The compressive strength of the plain and reinforced concrete were conducted for 0%, 0.5% and % of steel fibre following Indian standard code IS 456-2000. An average of three cubes wascast for each trial with mould size of 7 cm cube. A standard concrete strength of M30 was chosen and the materials were proportioned accordingly. For M30 plain concrete, mass of concrete as 450.45 kg/m^3,mass of fine aggregate as 769.39 kg/m^3,massofcoarse aggregate as 940.368 kg/m^3 and the mix proportions was 1:1.708:2.08. Similarly, the mix design was designed for 0.5% and 1% of steel fiber as 1:1.708:2.08 and 1:1.69:2.07 respectively. The cubes were cured for 28 days and it was tested. The sample was loaded till failure and the ratio of the failure load to surface area of sample is termed as compressive strength. It was observed that the maximum compressive strength was observed for 0.5% of fiber intrusion and the value had show a slight increase in strength from 35.77 to 36.32 N/mm^2. With further intrusion of fiber to the concrete by another 0.5% the compressive strength reduces to 36.15 N/mm^2 (Figure 7).

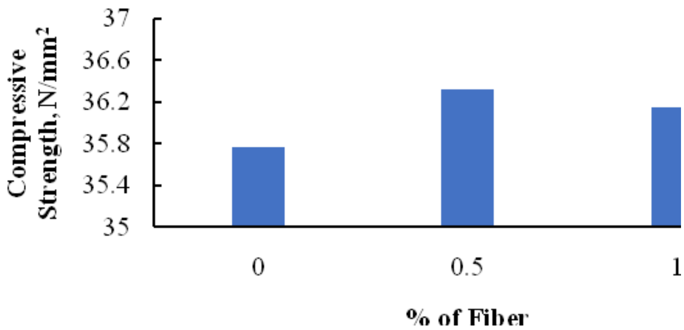


Figure 7: Effect of fiber in compressive strength

Flexural Behaviour

The load is applied at the centre of the beam (Figure 8); deflection at the failure load is noted and inferred. With the applied load, the load carrying capacity, deflection, flexural stress and rigidity were calculated.

In beam, flexural stress (σ) and flexural rigidity (EI) were calculated using the 2 and 3.

$$\frac{\sigma}{y} = \frac{M}{I} \quad (2)$$

$$\delta = \frac{wl^3}{48\,EI} + \frac{5wl^4}{384EI} \quad (3)$$

Where, M- moment (N.mm), y-distance of the centroid of Area from the neutral axis (mm), I- inertia (mm^4), W- load (N) and L- length (mm)

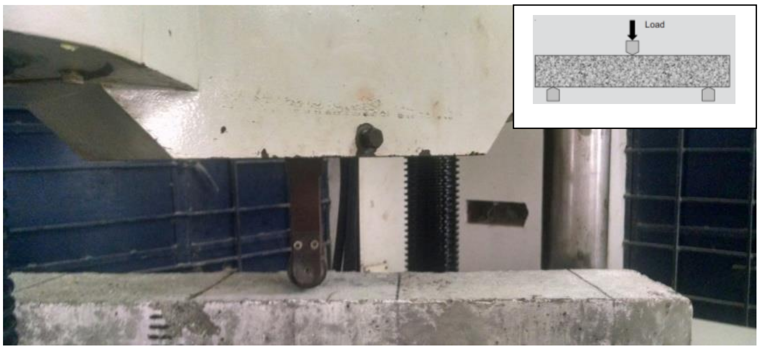
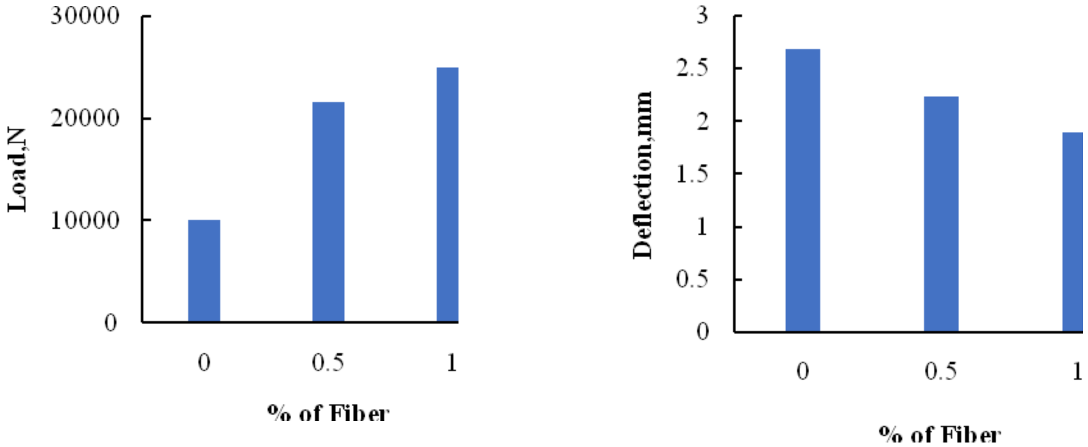


Figure 8: Testing of the specimen

Upon addition of fiber to the concrete from 0% to %, the load carrying capacity of the beam (Figure 9 a) increase with a reduction in deflection (Figure 9 b). The load carrying capacity increased to double the initial strength of the concrete. The deflection decreased to 16.42% with 0.5% of fiber and 29.48% for 1% of fiber.



a. Load Vs % of fiber

b. Deflection Vs % of fiber

Figure 9: Load and Deflection characteristics of beam with varying percentage fiber

With the increase in load carrying capacity the flexural stress of the reinforce beam increases. The flexural stress calculated for 0.5% and 1% fiber induced concrete were 7.72 and 8.9 N/mm^2, which shows the flexural strength doubles(Figure 10).

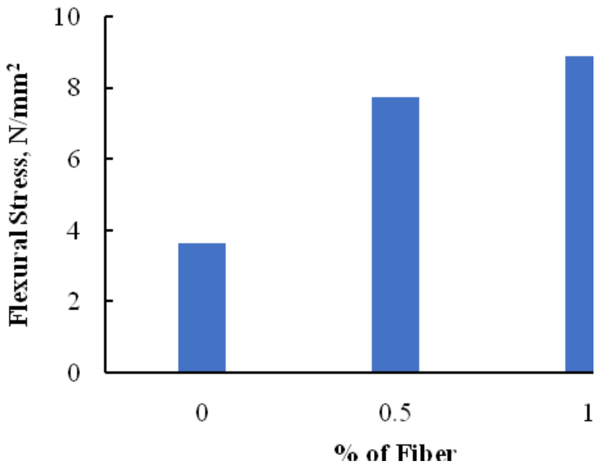


Figure 10: Effect of fiber on flexural strength

Flexural rigidity is the relation between bending moment and deflection. It was calculated using equation 3.The pattern was similar to that of the percentage of fiber with flexural strength (Figure 11).

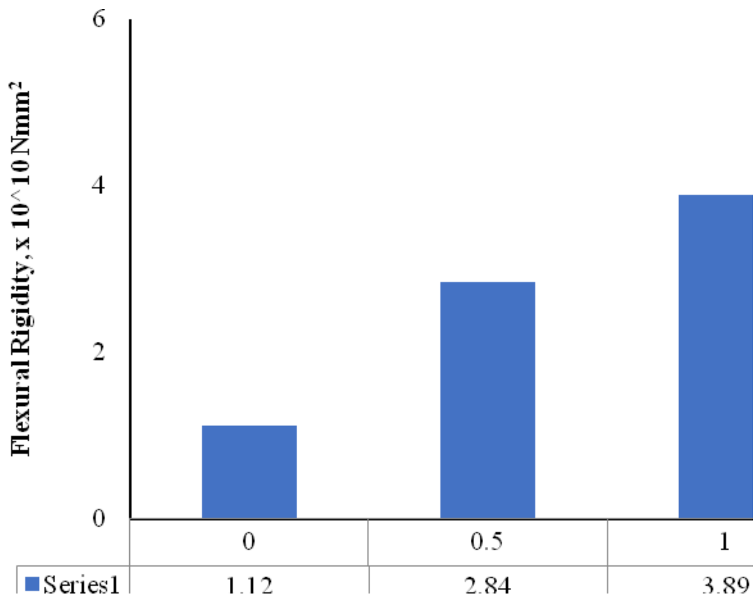


Figure 11: Effect of fiber on flexural rigidity

CONCLUSION

1. **Compressive strength**showed marginal increaseswith addition of fiber, howeverbeyong 0.5% there was no significant increase.
2. **Load carrying capacity** of the beam increases as the volume of steel fiber added increases. When comparing plain concrete and steel fiber reinforced concrete, the load carrying capacity of steel fiber reinforced concrete is 1.5 times of plain concrete
3. **Deflection** decreases as the volume fraction of fiber increases. When comparing plain concrete and FRC, the deflection of plain concrete is 1.39 times of steel fiberreinforced concrete. Hence we can say that increase in fiber volume decreases the deflection.

4. **Flexural stress** increases as the volume fraction of fiber increases. When comparing FRC with plain concrete, the tensile stress of steel fiber reinforced concrete is 2.45 times of plain concrete. Hence the variation in fiber proportion has a large impact in tensile stress of concrete
5. **Flexural rigidity** increases considerably with the increase in fiber content. It is found that the flexural rigidity increases by 2.9 times the flexural rigidity of plain concrete.

Upon, futher studies can be done for varied aspect ratio to infer the interaction of fibers in concrete.

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