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Experimental Investigation of Steel Fibre Reinforced Concrete

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Abstract:

Concrete is a brittle material which has a low strength and limited ductility. These weak points of concrete can be resolved by including fibers made of different materials with high technical specifications. This special type of concrete is known as Steel Fiber Reinforced Concrete (SFRC) which exhibits superior properties in terms of ductility, fracture energy, toughness, strength and durability due to the addition of steel fibers when compared to conventional concrete. The project presents results of an experimental investigation carried out to study the properties of reinforced cement concrete and steel fibre reinforced concrete (SFRC) containing mixed fibres of different aspect ratio. An experimental programme was planned in which workability tests were conducted to investigate the properties of the fresh concrete mixes. The properties of the hardened concrete were investigated using compressive tests, split tensile tests and flexural strength tests. Effect of fibres when it is distributed in hinged zone of structural element was also examined to achieve economy by reducing steel fibre content in concrete mix. The results indicate that the Mixed steel fibre reinforced concrete (at volume fraction of 1.5%, consisting of 75% macro fibres and 25% micro fibres) can be adjusted as the most appropriate combination to be employed in SFRC for compressive strength, split tensile strength and flexural strength. However, better workability was obtained as the percentage of shorter fibres increased in the concrete mix. And there is little amount of variation in properties of concrete between fibres in full length of the beam and fibres in hinged zone of the beam.

Keywords: Steel fiber reinforced concrete(SFRC), Split tensile strength

1.INTRODUCTION

Mostly, all the structures are made of concrete which around us, but now also there is some problem to use concrete as a building material. Generally, the Concrete structures having very low tensile strength and limited ductility, because of that using steel reinforcement is a

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necessary one to bridge the cracks and increase the tensile capacity of concrete. The self weight of concrete structure is greater than the steel structures with the same load carrying capacity which requires large support, the transportation and handling cost will be increased.To overcome the disadvantage of concrete, the Steel fibre reinforced concrete (SFRC) can be used. Steel fibre reinforced concretes are designed in such a way that, which may satisfy all the demands during production, construction and service life of structure. It has been proved that steel fibres can be used to control cracking and deflection in structural member. Addition of steel fibres to concrete structures makes it highly ductile and improves the energy absorption capacity. It has high potential application in building frames due to its high seismic energy absorption capacity. The combination of both macro and micro steel fibres in a concrete mix offer more attractive engineering properties rather than single type of fibres.

2. OBJECTIVE

- To increase the strength of the concrete
- To prevent the widening of micro cracks
- To prevent sudden failure

3. MATERIAL SPECIFICATION

CEMENT:

Table 3.1 Properties of cement

Type of cement	Specific gravity	Initial setting time
OPC-53 grade	3.15	30 minutes

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COARSE AGGREGATE

Table 3.2.Properties of coarse aggregate

Size of aggregate	Specific gravity	Fineness
Passing through 20mm sieve	2.70	1.5

FINE AGGREGATE

Table 3.3.Properties of fine aggregate

Size of aggregate	Specific gravity	Zone
Passing through 4.75mm sieve	2.64	II

MIX PROPORTION

Table 3.4.Mix proportion of M30 grade concrete

Cement	Fine aggregate	Coarse aggregate	Water content
1	1.48	2.47	0.44

4.PREPARATION OF SPECIMEN

The specimens such as cubes, cylinders and beams were casted and tested for optimize the proportion of macro and micro steel fibres and effect of fibres in hinged zone of structural element were also examined. For all the concrete mixes 1.5 % volume fractions of steel fibres were used. Specimen Identification for all the beams given in Table 4.1.

Table 4.1 Specimen identification for all the beam specimens

Specimen Identification	Proportions by weight in %		Distribution Zone
	Micro Fibres	Macro Fibres	
C	0	0	-
S1	100	0	Full length of the beam
S2	75	25	Full length of the beam
S3	50	50	Full length of the beam
S4	25	75	Full length of the beam
S5	0	100	Full length of the beam
SH	25	75	Hinged zone of the beam

5. TEST ON CONCRETE

The concrete mix has been tested for workability by using slump cone. After curing , hardened concrete is tested for various tests such as compressive strength test, Split tensile strength test and flexural strength test.

5.3.1 Slump Cone Test

The slump cone test was conducted based on IS: 1199-1959, which is used to measure the workability of the concrete. This test has been specifically developed to obtain the workability of fibre reinforced concrete and measures its mobility or fluidity under internal vibrations.First cement and sand are mixed thoroughly and then mixed with aggregate in dry state. Add water and mix thoroughly to get uniform colour. Place the concrete in the mould in three layers, compact each layer 25 times with a tamping rod. Then remove themould by raising it vertically. Then allow the moulded concrete to subside. This subsidence is referred to a slump of concrete.

5.3.2 Compressive Strength Test

It is the most common test conducted on hardened concrete based onIS: 516 - 1959. The procedure for compressive strength test is explained in the following.After 28 days curing, the cube specimen was taken out from the curing tank and allowed to dry for about few hours. Then the specimen

was placed in 2000kN capacity of compression testing machine. The load was applied in uniform rate until the specimen is failed. Then load at failure has been noted.Testing of cubes shown in Figure 5.1.

The compressive strength can be calculated from the following formula,

Compressive strength $=\frac{Load}{Area}$

Figure 5.1Testing of cubes

5.3.3 Split Tensile Strength Test

Concrete is strong in compression and weak in tension. Tensile stresses are developed in concrete due to drying shrinkage, in adequate steel reinforcement, temperature gradient etc. So the determination of tensile strength is most important one but there is no direct method available to determine the tensile strength of the concrete. One of the indirect methods available is split tensile test conducted based on IS: 516 - 1959. After 28 days curing, the cylinder specimen was taken out form the curing tank and allowed to dry for about few hours. Then the testing specimen was placed in hydraulic compressive testing machine in horizontal position. In order to reduce the high compressive stress near the points of application of the load, marrow packing strips of suitable material such as supplementary steel bar and plywood strip was placed between the specimen and loading patterns. Then load was applied at the uniform rate until the specimen

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fails, along the vertical diameter. The load at which the specimen fails should be noted.Testing of cylinder shown in Figure 5.2.

The tensile strength was calculated by the following formula,

Tensile strength $=\frac{2P}{\pi DL}$

Where, P = Load at failure

D = Diameter of the cylinder

L = Length of the cylinder

Figure 5.2 Testing of cylinder

5.3.4 Flexural Strength Test

The objective of flexural strength test was to determine the first crack and ultimate load, ductility factor and energy absorption capacity of concrete specimen. Cracking is mostly due to restrained shrinkage and temperature gradients. Beams are tested under two point loading based on IS: 516 - 1959. After 28 days curing of concrete, the test specimen was allowed to dry then placed in the universal testing machine. Beams were simply supported over a span of 1100 mm. The load was applied to the upper most surface as cast in the mould along two lines spaced one third of the span apart. The axis of the specimen was aligned carefully with the axis of the loading device. The load was applied without shock and increased continuously at a uniform rate 2kN/min until the specimen fails. For finding the deflections under the two point loading , the dial gauge were placed in the centre of the beam to measure the mid-deflection at each stage of loading.The maximum load at failure, deflection and cracking pattern was noted. Loading arrangement and test setup were shown in Figure 5.3 and 5.4 respectively.

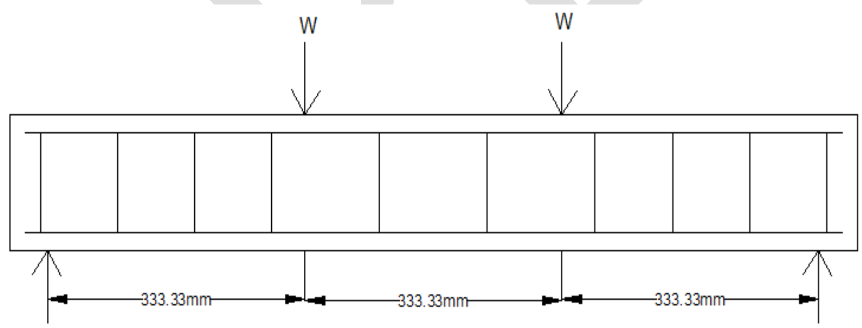

Figure 5.3 Loading arrangement

Figure 5.4 Testing of beams

6. LOAD DEFLECTION CURVE

It can be noted that fibres in hinged zone have about the same deformational characteristics as that for fibres in full length of reinforced concrete beams. From test results of beam under two point load the various parameters for above three types of beams specimens are tabulated and shown in Table 6.1. Comparison of Load deflection behavior of three types of beams ie. C, S4 and SH beams shown in Figure 6.2. From this, by fiber inclusion only in hinged zone, an economical and efficient use of expensive steel fibers can be realized.

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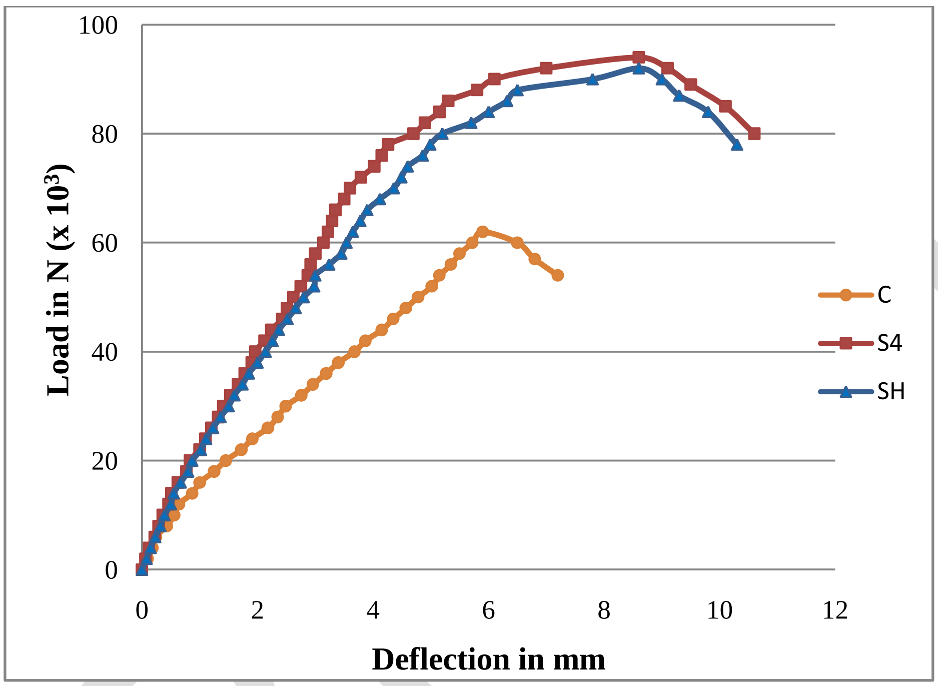

Figure 6.2 Comparison of Load deflection behavior of three types of beams

Table 6.1Comparison of three types of beam results

Specimen Identification	First crack load kN	Ultimate load kN	Ductility factor	Energy absorption Capacity Nmm (x 103)	Stiffness N/mm (x 103)
C	11	62	1.55	290.14	8.33

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S4	16	94	2.38	740.32	13.79
SH	16	92	2.38	678.48	12.5

7. LOAD CARRYING CAPACITY

The first crack load for the SH and S4 beam is same, and which is 50% greater than conventional concrete beam. Where as the ultimate load for the SH beam is 2.17% less than S4 beam and 48% greater than C beam. The variation of the first crack load and ultimate load for the three types beams were shown in Figure 7.1 & Figure 7.2 respectively

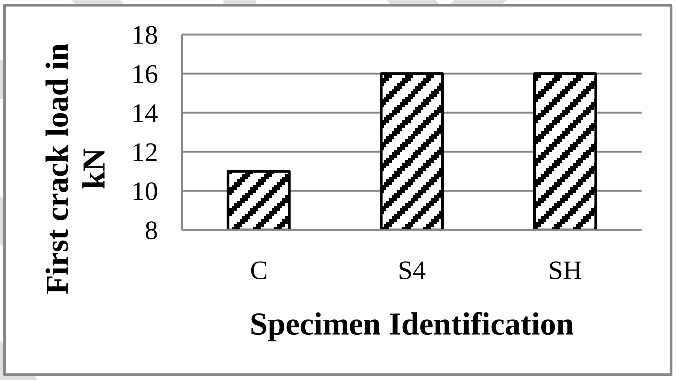

Figure 7.1 Variation in First crack load for the three types of beams

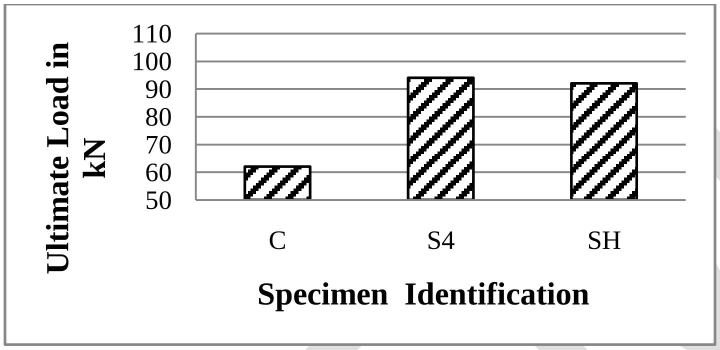

Figure 7.2 Variation in Ultimate load for the three types of beam

8. DUCTILITY FACTOR

Ductility factor for the SH beam and S4 beam is to be equal and which is 53.5% greater than concrete beam without fibres. Variation in ductility factor for three types of beams were shown in Figure 8.1.

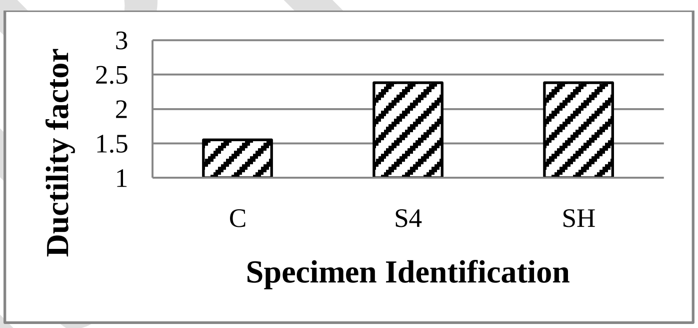

Figure 8.1 Variation in Ductility factor for the three types of beam

9.STIFFNESS

The stiffness for the SH beam is 10% less than the S4 beam and 50% greater than C beam.The variation in stiffness characteristics shown in Figure 9.1.

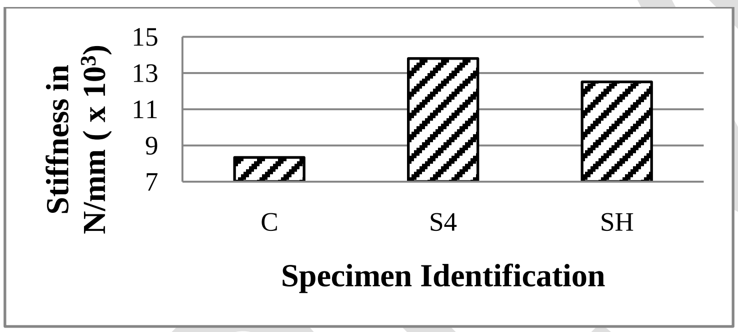

Figure 9.1 Variation in Stiffness for the three types of beams

10. CONCLUSION AND SCOPE FOR FUTURE STUDY

This study provided a thorough understanding of the flexural behavior of fibre reinforced concrete beams. However, it is useful to extend the work for further study as follows.

- ✓ The fatigue strength analysis of mixed steel fibre reinforced concrete could be investigated.
- ✓ Shear strength of fibre reinforced concrete beam could be investigated.
- ✓ Durability studies could be carried out to investigate the fibre reinforced concrete.
- ✓ Corrosion studies could be carried out for the steel fibres present in concrete.
- ✓ This study can be extended for 2D and 3D frames to investigate the influence of fibres on the behaviour of structural members subjected to seismic forces.

- ✓ Due to the limitation of using high volume of fibres to avoid the balling effect of fibres in concrete, usage of simcon instead of steel fibres in concrete could be investigated.
- ✓ The present thesis work restricted to use of fibres only in beam hinges, in order to improve the over all behaviour of the structure, investigation on the use of fibres in beam-column joint for improving the ductility could be under taken.
- ✓ Regression analysis could be carried out to derive an expression for various properties of concrete.

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