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Experimental investigation on flexural behaviour of various steel fibre reinforced concrete beam

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ABSTRACT

The performance of concrete made with commercially available steel fibres has been investigated. In this study examines the flexural strength of concrete with two different types of steel fibre, short crimped of length 15 mm, another of long hooked ends of length 30 mm and were used in the present study. The overall volume fractions of steel fibres were restricted to 1 per cent by the volume of concrete. M25 grade of concrete was used to cast the specimens. Reinforced concrete beams of 1.5 m length and 100 x 150 mm in cross-section were cast with different percentages of micro and macro steel fibres and the specimens were tested under single point loading after 28 days of curing. The results are to be compared between conventional concrete to fibre reinforced concrete.

Keywords— *Flexural behaviour of steel fibre reinforced concrete beam*

1. INTRODUCTION

Steel fibrous concrete is a composite material that contains randomly distributed steel fibres in the conventional concrete with the brittle nature. The inclusion of steel fibres significantly improves the tensile strength, post cracking characteristics, and toughness of concrete due to the crack-bridging of added steel fibres. Over the last 40 years, extensive efforts have been devoted to investigating the effects of the incorporation of steel fires on the mechanical properties of normal-strength concrete as well as the effectiveness of still fibres as shear reinforcement in the structural elements.

Concrete's versatility, durability, and economy have made it the world's most used construction material. India uses about 7.3 million cubic meters of ready-mixed concrete each year. Engineers are continually working on it, to improve its performance with the help of innovative supplementary or replacement materials. Cement, sand and aggregate are essential needs for and by the construction industry. Sand is a major material used for the preparation of mortar and concrete and plays a most important role in the mix design. Fiber Reinforced Concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibers. Incorporation of fiber in concrete has found to improve server properties like tensile strength, cracking resistance, impact and wear resistance, ductility and fatigue resistance.

Fibre reinforced concrete is a composite material made with Portland cement, aggregate, water and incorporating discrete discontinuous fibres. The significance of Steel Fibre Reinforced Concrete (SFRC) is resistance to cracking and crack propagation. Fibres are to hold the matrix together even after extensive cracking.

The main role of the randomly distributed steel fibres is to bridge across the crack openings both at the micro and macro levels of crack and also provides a better post cracking ductility. Micro steel fibres combined with macro steel fibres produces an increase in strength and energy absorption far beyond what was achievable in macro fibre alone. The micro fibre bridges the macro cracks and therefore controls their growth. This leads to a higher tensile strength of the concrete. The macro fibre is indented to arrest the propagation of macro cracks. The combination of these two fibres results in a considerable enhancement in the fracture toughness of the concrete. The micro fibres influence crack growth at various stages of failure. When the fibres are used along with longitudinal steel reinforcement, large ductility of the structural elements is attained.

The workability of concrete reduces as the amount of steel fibres increases in the mixture. The steel fibres do not increase the compressive strength significantly. The maximum increase in compressive strength was observed to be 11% compared to that of conventional

1.1 Objectives

The objective of this research is

- To investigate the flexural behavior of high-performance fibre reinforced concrete beams using micro and macro fibre.
- Compressive strength of concrete. And these test results are compared with conventional concrete of M25 grade.

1.2 Scope of the project

- Sustainable increase in strength of the building.
- To control the dowel cracking, deflection, strains and rotation due to shear loads.
- To increase strength and energy absorption.

2. EFFECTS OF STEEL FIBRES IN CONCRETE

Fibres are usually used in concrete to control cracking due to both plastic shrinkage and drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibres produced greater impact, abrasion and shatter resistance in concrete. Generally, fibres do not increase the flexural strength of concrete and so cannot replace moment resisting or structural steel reinforcement. Indeed, some fibres actually reduce the strength of concrete. The amount of fibres added to the concrete mix is expressed as a percentage of the total volume of the composite (concrete and fibres), termed volume fraction (Vf). Vf typically ranges from 0.1 to 3%. Aspect ratio (1/d) is calculated by dividing fibre length (l) by its diameter (d). Fibres with a non-circular cross-section use an equivalent diameter for the calculation of aspect ratio. If the modulus of elasticity of the fibre is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Increase in the aspect ratio of the fibre usually segments the flexural strength and the toughness of the matrix. However, fibres which are too long tend to ball in the mix and create workability problems. Some recent research indicated that using fibres in concrete has a limited effect on the impact resistance of the materials. This finding is very important since traditionally, people think that the ductility increases when concrete is reinforced with fibres. The results also indicated out that the use of micro fibres offers better impact resistance compared with the longer fibres.

2.1 Advantage of SFRC

- Fast and perfect mixable fibres and High performance and crack resistance.
- Optimize costs with lower fiber dosages.
- Steel fibres reinforced concrete against impact forces, thereby improving the toughness characteristics of hardened concrete.

3. MATERIALS USED AND ITS PROPERTIES

3.1 Cement

- Ordinary Portland cement (OPC) is by far the most important type of cement. The OPC was classified into three grades namely, 33 grade, 43 grade and 53 grade depending upon the strength of the cement at 28 days.
- The ordinary Portland cement of 53 grade and a specific gravity of 3.15 conforming to IS12269-1987 was used to cast the specimens. Conforming weight of each cement beg was 50 kg

3.2 Fine aggregates

Locally available river sand with a specific gravity of 2.61 conforming to zone II grading as per the Indian standard IS 383-1970 was used. It should be passed through IS Sieve 4.75 mm. It should have fineness modulus 2.50-3.50 and silt contents should not be more than 4%.

3.3 Coarse aggregates

It should be hard, strong, dense, durable and clean. It must be free from a vein, adherent coatings and injurious amount of disintegrated pieces, alkalis, vegetable matters and other deleterious substances. It should be roughly cubical in shape. Flaky pieces are avoided. Coarse aggregate of crushed granite stone with a specific gravity of 2.75 and has a maximum size of 12.5 mm and well graded as per the IS 383-1970 was used.

3.4 Water

Portable water was used for casting and curing the concrete specimens. Water should be free from acids, oils, alkalis, vegetables or other organic impurities. Soft waters also produce weaker concrete. Water has two functions in a concrete mix. Firstly, it reacts chemically with the cement to form the cement paste in which the inert aggregates are held in suspension until the cement paste has hardened. Secondly, it serves as a lubricant in the mixture of fine aggregates and cement.

3.5 Admixture

Silica fume, also known as micro silica, is an amorphous (non-crystalline) polymorph of silicon_dioxide, silica. It is an ultrafine powder collected as a byproduct of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 mm. The main field of application is as pozzolanic material for high-performance concrete. The silica fume used in this study is purchased from a reputed trader in Chennai.

3.6 Steel Fibres

Two different types of steel fibres were used. Micro steel fibre is round shaped and crimped in the geometry of length 15 mm, dia 0.4 mm. Macro stee fibre is hooked ended of length 30 mm, dia 0.5 mm. The overall volume fraction of steel fibres was restricted to 1% by volume of concrete.

3.7 Reinforcement

Steel is an alloy of iron and carbon. Apart from carbon by adding a small percentage of manganese, sulphur, phosphorus, chrome nickel and copper special properties can be imparted to iron and a variety of steels can be produced. Fe415 grade steel rods are used during the casting of beams. The diameter of mains rod 12 mm. Stirrups used in beams is 6 mm in diameter.

4. EXPERIMENTAL SETUP

The beam specimens were placed in the loading frame. The specimens were tested under single point loading. Linear Variable Differential Transformer (LVDT) was used to measure the mid-span deflection during loading as well as unloading.

The load was applied by using hydraulic jack up to the failure of the specimen and the crack patterns were observed. At each load increment, cracks were inspected, marked and the beam specimen was photographed. Continuous monitoring was carried out all through the testing. Concrete cubes were tested on a Compressive Testing Machine (CTM).

5. RESULT AND DISCUSSION

5.1 Slump test

The workability test is carried out by a slump cone apparatus. The slump cone apparatus used for the test had height 300mm, diameter at top 200mm and diameter at bottom 100mm. place the concrete in the mould in three layers, compact each layer 25 times with a tamping rod. Then remove the mould by raising it vertically. Then allow the concrete to subside. This subsidence is referred to the slump of concrete. Measure the difference in level between the height of the mould and that of the highest point of subsided concrete. Take the difference in height in mm is taken as a slump of concrete.

Table 1: Slump test

Mix	Slump value (mm)
Conventional Concrete	88
Hookended Steel Fibre	83
Crimped Steel Fibre	85

5.2 Compression strength test

The compression test is carried out on specimens cubical in shape. The cube specimen is of the size 15 x 15 x 15 cm. If the largest nominal size of the aggregate does not exceed 20 mm. The mould was then filled with concrete in three layers and compacted using a tamping rod. Further, the moulds were placed on the vibrating table for 60 seconds to achieve proper compaction and subsequently maintained on a plane and level surface in the laboratory for 24 hours. The cubes were demoulded and set aside for curing.

The compressive strength was calculated as follows:

Table 2: Compressive strength (Mpa) = Failure load / cross-sectional area

Mix	7 days Compressive Strength N/mm^2	28 days Compressive Strength N/mm^2
Conventional concrete	19.50	25.87
Hookended steel fibre	25.33	42.56
Crimped steel fibre	23.74	37.89

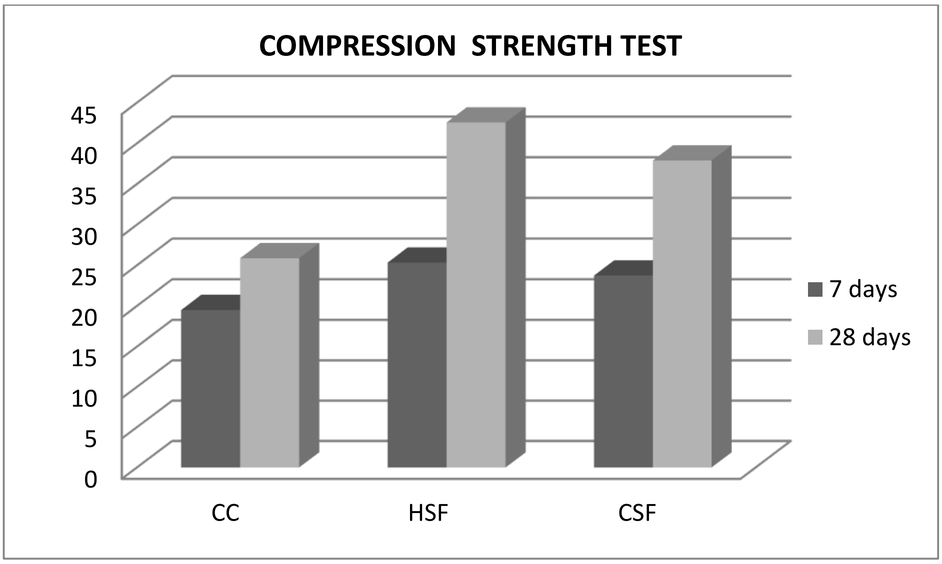

Fig. 1: Compressive strength test

5.3 Flexural strength test

Concrete, as we know, is relatively strong in compression and weak in tension. In reinforced concrete members, little dependence is placed on the tensile strength of concrete since steel reinforcing bars are provided to resist all tensile forces. Beam had 1500mm length, 100mm wide and depth 150mm. 2no's 12mm dia bars at bottom and 2no's 8mm dia bars at the top and 130mm spacing 8mm dia stirrups are used as reinforcement.

The cured specimens were tested under a load frame instrument. The beam specimens were tested for midpoint loading and their deflection was observed with LVDT attached to the specimen. The readings were recorded in data logger attached to the loading frame instrument. Gradual loading has been imposed on the specimen through a load cell 100tons capacity until failure. The beam is tested and the ultimate load carrying capacity of beam is finding out by using test results. The variation between load and deformation is plotted as a graph.

Table 3: Flexural initial strength test

Mix	First crack load (KN)	First crack deflection (mm)
Conventional concrete	20	2.14
Hookended steel fibre	32	4.2
Crimped steel fibre	28	3.1

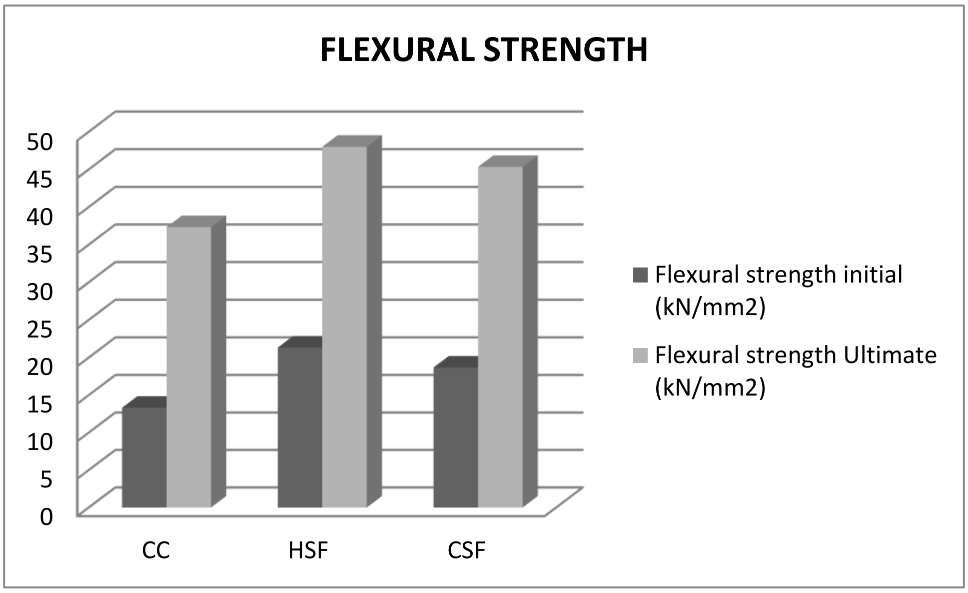

Fig. 2: Flexural initial strength trest

5.4 Flexural ultimate strength test

Table 4: Flexural ultimate strength test

Mix	Ultimate load (KN)	Ultimate deflection (mm)
Conventional concrete	56	10.90
Hookended steel fibre	72	21.21
Crimped steel fibre	68	19.22

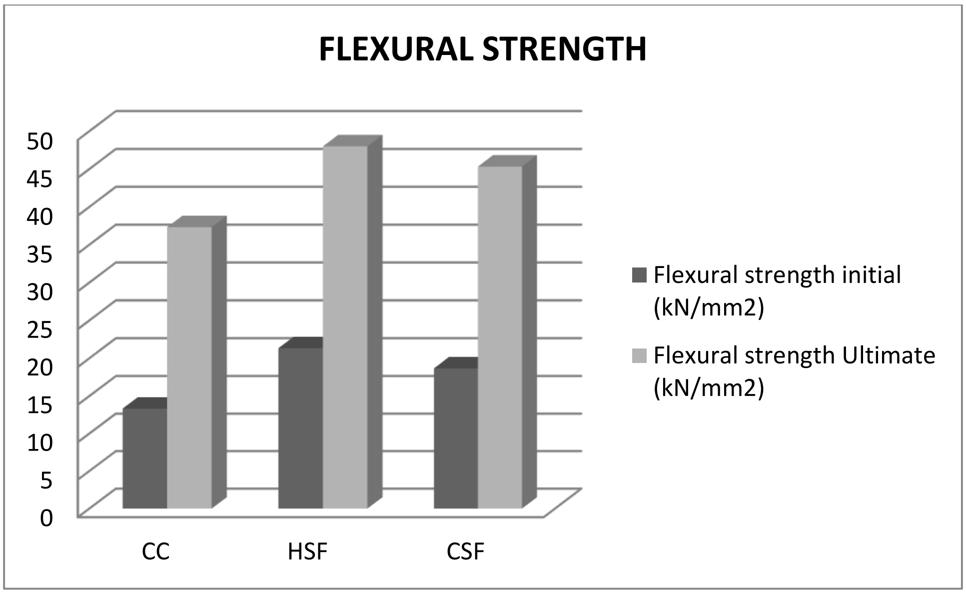

Fig. 3: Flexural Ultimate Strength Test

5.5 Flexural strength

Table 5: Flexural strength

Mix	Flexural strength Initial (KN/mm^2)	Flexural strength Ultimate (KN/mm^2)
Conventional concrete	13.33	37.33
Hookended steel fibre	21.33	48
Crimped steel fibre	18.67	45.33

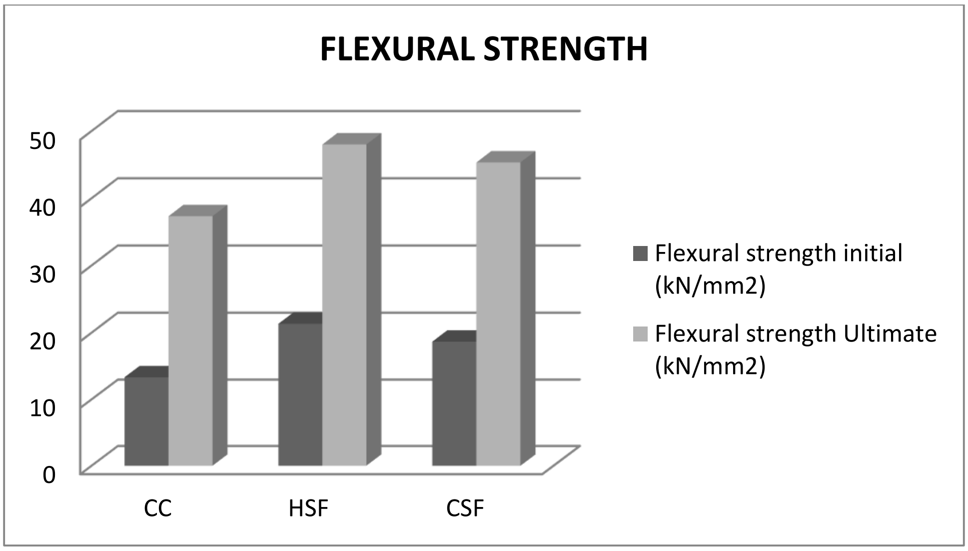

Fig. 4: Flexural Strength

6. CONCLUSION

From my experimental investigation, I concluded that Fiber addition affects the workability of concrete and enhances the mechanical properties considerably. There is an improvement in compressive strength of fibre reinforced concrete to conventional because of the addition of fibres. The maximum increase in compressive strength observed at hooked ended steel fibre concrete when compared with others. Flexural strength is maximum in fibre reinforced concrete when compared with conventional concrete. Hooked ended steel fibre reinforced concrete has more strength when compared with other steel fibre reinforced concrete. Flexural strength increases with the addition of steel fibre in the mix.

Finally, I conclude that usage of hooked ended steel fibre reinforced concrete has maximum strength when compared with crimped steel fibre and conventional concrete.

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