Effects of Hybrid Steel Fibers on the Mechanical Properties of Steel Fiber Reinforced Concrete

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Abstract - *Cement concrete is the most extensively used construction material in the world. The reason for its extensive use is that it provides good workability and can be moulded to any shape. Ordinary cement concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Internal micro cracks, leading to brittle failure of concrete. In this modern age, civil engineering constructions have their own structural and durability requirements, every structure has its own intended purpose and hence to meet this purpose, modification in traditional cement concrete has become mandatory. It has been found that different type of fibers added in specific percentage to concrete improves the mechanical properties, durability and serviceability of the structure. It is now established that one of the important properties of Steel Fiber Reinforced Concrete (SFRC) is its superior resistance to cracking and crack propagation. In this project effect of steel fibers on the strength of concrete for M 40 grade will be studied by varying the percentage of fibers in concrete and types of fibers. Compressive strength, Split Tensile Strength & Flexural strength will be compared and tabulated. Fibers addition to concrete results in more closely spaced and improved resistance to the cracks. Improvement observed in mechanical properties of controlled concrete due to present of steel fibers. There is a significant increase in Compressive Strength of concrete with addition of Crimped Steel Fiber when compared to Straight and Hooked Steel Fiber. The percentage increase in Compressive Strengths of Straight Steel Fiber (2%), Hooked Steel Fiber (2%) and Crimped Steel Fiber (2%) are 9.84%, 5.9% & 16.92% respectively. Similar trend is followed for other mechanical properties.*

Key Words: Crimped Steel Fiber, Straight Steel Fiber, Hooked Steel Fiber, Compressive strength, Split Tensile strength.

1. INTRODUCTION

Civil engineers and construction experts are aware of the fact that plain concrete exhibits very low tensile strength, limited ductility and little resistance to cracking, but are forced to use plain concrete due to the exigency. Hence there is an urgent need to reinforce the conventional concrete to cope up with tensile loads and strains suited to our needs. The presence of micro cracks at the mortar-aggregate interface is the inherent weakness of plain concrete. The application of load leads to propagation of cracks and brittle fractures in conventional concrete due to its poor tensile strength. Normally micro cracks appear in concrete during hardening stage. When load is applied, micro cracks start developing along the planes which may experience relatively low tensile strains at about 25-30% of the ultimate strength in compression. Further application of load leads to uncontrolled formation of the micro cracks. Concrete mix that contains short, discrete fibers that are uniformly distributed and randomly oriented is called Fiber reinforced concrete. The fibers used are steel fibers, synthetic fibers, glass fibers and natural fibers. The fibers in members resist the opening of the cracks due to micro cracking and increase the ability of the members to withstand loads.

2. LITERATURE REVIEW

Ali Amin and Stephen J. Foster [2016], Despite the increased awareness of Steel Fibre Reinforced Concrete (SFRC) in practice and research, SFRC is yet to find common application in load bearing or shear critical building structural elements. Although the far majority of studies on SFRC have focused on members containing fibres only, in most practical applications of SFRC construction, structural members made of SFRC are also reinforced with conventional reinforcing steel for shear ligatures. In this paper, results are presented on shear tests which have been conducted on ten 5 m long by 0.3 m wide by 0.7 m high rectangular simply supported beams with varying transverse and steel fibre reinforcement ratios. The tests have been analysed along with complete material characterisation which quantify the post-cracking behaviour of the SFRC.

Rubén Serrano et al; [2016], The decrease in concrete resistance and the expansion generated in reinforced concrete structures by direct exposure to fire at 400 C maximum temperatures serves as the basis for the present research. The aim is to improve these problems by the addition of steel fibers or of polypropylene fibers in concrete. From the results analysis of compression fracture tests on cylindrical concrete specimens, it can be concluded that concrete with addition of polypropylene fibers or steel fibers are a good alternative to traditional concrete, because both its strength, and its behavior in case of fire are improved, delaying the appearance of fissures and explosive concrete spalling.

G. Murali, A. S. Santhi and G. Mohan Ganesh[2019], It is well known that concrete is characterized by its high compressive strength, yet its brittle mode of failure is considered as a drawback of high strength concrete when it is subjected to impact and dynamic loads. This study aims to investigate the impact resistance of fibre reinforced concrete (FRC), incorporated with steel fibres at various dosages. For this, a drop weight test was performed on the 28 days cured plain and fibre reinforced concrete samples as per the testing procedure recommended by ACI committee 544. Crimped and hooked end steel fibre of length 50 mm and an aspect ratio equal to 50 was added to concrete in different proportions i.e. 0%, 0.5%, 1.0% and 1.5% with water cement ratioof 0.42. From the test results, it was proved that the (FRC) was effective under the impact loads thus improving the impact resistance. Also, the reduction of strength under impact load in each specimen for every three blows was determined by ultrasonic pulse velocity (UPV) test. Further, a statistical correlation between (UPV) and number of blows under impact load was developed using regression analysis. The developed regression model predicts the reduction in strength of concrete under impact load accurately.

Patil Shweta and Rupali Kavilkar, [2014], Concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Various types of fibre reinforced concrete are being used against plain concrete due to their higher flexural strength, better tensile strength, modulus of rupture and crack resistance. In the present investigation properties of steel fiber reinforced concrete like flexure and compressive strength are studied. Tests were conducted to study the flexural and compressive strength of steel fibre reinforced concrete with varying aspect and varying percentage of fibre. In the experiments conducted four aspect ratio were selected i.e. 40,50,60,70 and percentage of steel in each case varied from 0.5% to 2.5% at interval of 0.5%. The various strength parameters studied are compressive strength and flexural strength as per the relevant IS standards. The experimental results indicate that the addition of steel fibre into concrete significantly increases the flexural strength. It also indicates that at constant percentage of fibre, that is 1.5% by increasing the aspect ratioof fibre from 40 to 70, flexural strength increased from 36.7% to 58.65%. The research paper proposes that due to these properties of steel fibre reinforced concrete, it can be used for the design of curvilinear forms.

3. OBJECTIVE

The objective of this research was to investigate the following aspects of fiber reinforced beams made of medium-high concrete capacity. To assess the effectiveness of each type of fibers (hooked-end steel fibers, crimped-steel fibers and Straight-steel fibers) on Cube specimens & Cylinder Specimens. To determine the percentage of fibers to be added to improve Strength of concrete. This project deals with M40 Grade of Concrete

4. MATERIALS AND METHODS

Properties of Materials

4.1 Cement

In this study, UltraTech Cement of 53 grade Ordinary Portland Cement conforming to IS: 12269–1987 was used for the entire work. The cement was purchased from single source and was used for casting of all specimens. The properties are shown in Table 1.

S. No	Characteristics	Test results	Requirements as per IS 12269 – 1987
1	Fineness (retained on 90-μm sieve)	5%	<10%
2	Normal Consistency	33%	--
3	Initial setting time of cement	63 min's	30 minutes (minimum)
4	Final setting time of cement	450 min's	600 minutes (maximum)
5	Expansion in Le-chatelier's method	2 mm	10 mm (maximum)
6	Relative Density	3.15	3.10 – 3.25

4.2 Fine Aggregate

Locally available natural (river) sand confirming to IS specifications was used as a fine aggregate in the concrete mix. The properties are shown in Table.2.

S.No	Test conducted	Results obtained	Permissible Limits as per IS 383 -1970
1	Relative Density	2.67	2.5 to 3.0
2	Fineness modulus	2.77	--
4	Water absorption(%)	1.09	Max 3%
5	Sieve Analysis	Zone – II	--

4.3 Coarse Aggregate

Locally available Crushed granite metal of nominal size 20 mm and 10 mm and confirming to IS specifications were used. The properties are shown in Table.3. The coarse aggregate was used for the concrete mix is a combination of 20 mm and 10 mm size aggregates in ratio 1.5: 1.0.

S. No	Test conducted	Results obtained	Permissible Limits as per IS 383 – 1970
1	Relative Density	2.78	2.5 to 3.0
2	Fineness modulus	7.1	--
3	Water absorption (%)	1.20	Max 3%
4	Sieve Analysis	Zone – II	--

4.4 Steel Fibres

S. No	Properties	Straight Fibre	Crimpt Fibre	Hooked Fibre
1	Length of Fibre	45 mm	36 mm	35 mm
2	Diameter of fibre	0.45 mm	0.45 mm	0.55 mm
3	Aspect ratio of Fibre	100	100	64
4	Ultimate Tensile strength of Fibre	500-600 N/mm^2	600-700 N/mm^2	1100 N/mm^2
5	Density	7850 Kg/m^3	7850 Kg/m^3	7850 Kg/m^3

4.5 Water

Water used for casting and curing of concrete test specimens is free from impurities which when present can adversely influence the various properties of concrete.

5. Concrete Mix Proportion

In the present experimental investigation, the influence of individual application of various types (straight, hooked and crimped) of steel fibers on M40 grade concrete is studied.

M40 grade of concrete were designed as per the Indian Standard code of practice. The various ingredients for one cubic meter of M40 grade concrete are shown in Table 5.

Table -5: Quantities of Ingredients per cum of M40 Grade Concrete

S. No	Mix Identification	Cement (kg's)	Fine Aggregate		Water (lit)	Steel Fibers (kg's)
			Sand (kg's)	Coarse Aggregate (kg's)		
1	C.C	360	704	1302	164	0
2	1% SF (Straight)	360	704	1302	164	78.50
3	2% SF (Straight)	360	704	1302	164	157
4	3% SF (Straight)	360	704	1302	164	235.5
5	1% SF (Hooked)	360	704	1302	164	78.50
6	2% SF (Hooked)	360	704	1302	164	157
7	3% SF (Hooked)	360	704	1302	164	235.5
8	1% SF (Crimped)	360	704	1302	164	78.50
9	2% SF (Crimped)	360	704	1302	164	157
10	3% SF (Crimped)	360	704	1302	164	235.5

6. Test Specimens

Concrete test specimens consist of 150 mm × 150 mm × 150 mm cubes, cylinders of 150 mm diameter and 300 mm height and 100 mm × 100 mm × 500 mm prisms. Concrete cube specimens were tested at 3, 7 & 28 days of curing to obtain the compressive strength of concrete. Cylindrical and prism samples were tested at the age of 28 days curing to

Obtain the split tensile strength and flexural strength of concrete respectively. The rate of loading is as per the Indian Standard code specifications.

Fig-1 Testing of specimens

5. RESULTS AND DISCUSSIONS

5.1 Compressive Strength Results

The variation of the cube compressive strength with the age of M40 grade concrete prepared using the various proportions of (1%, 2% & 3%) of Straight Steel Fibers, (1%, 2% & 3%) of Hooked Steel Fibers and (1%, 2% & 3%) of Crimped Steel Fibers is shown in Figure 1. Each value of the cube compressive strength indicates the average of three test results. It can be observed that all the Steel Fiber (Straight, Hooked & Crimped) Reinforced Concrete exhibits improved Compressive strength compared to Control Concrete up to 2% of Weight of Concrete. But, The compressive strength of concrete with 2% Crimped steel Fibers exhibits 16.92 % more Strength than the control concrete and other Fiber proportions.

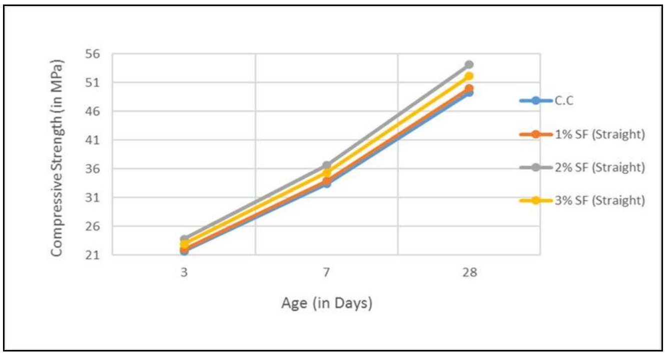

Fig -2.a: Straight Steel Fibre

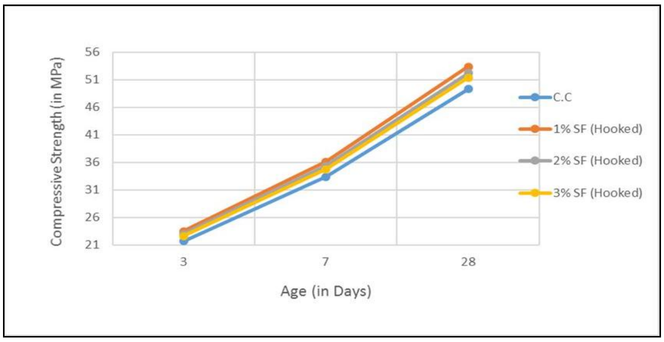

Fig -2.b: Hooked Steel Fibre

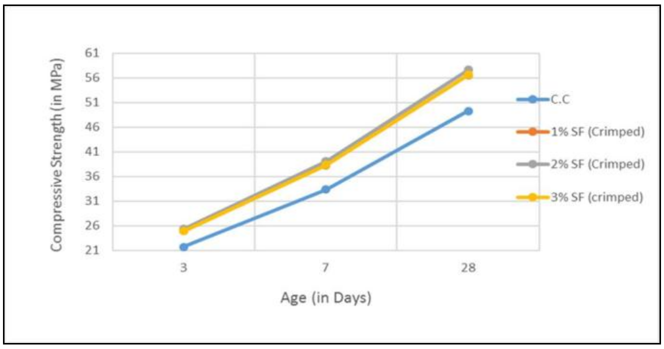

Fig -2.c: Crimped Steel Fibre

Figure 1 shows the Variation of the cube compressive strength with the age of M40 grade concrete prepared using the various proportions of (1%, 2% & 3%) of Straight Steel Fibers, (1%, 2% & 3%) of Hooked Steel Fibers and (1%, 2% & 3%) of Crimped Steel Fibers.

The variation of 7 days and 28 days cube compressive strength of M40 grades of concrete prepared with various proportions of (1%, 2% & 3%) of Straight Steel Fibers, (1%, 2% & 3%) of Hooked Steel Fibers and (1%, 2% & 3%) of Crimped Steel Fibers shown in Figure 2.

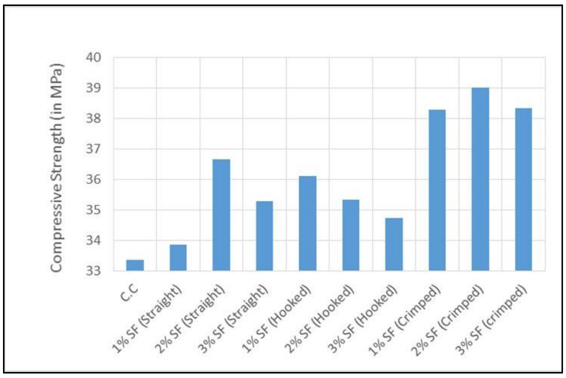

Fig -3.a: 7 days Cube Compressive Strength

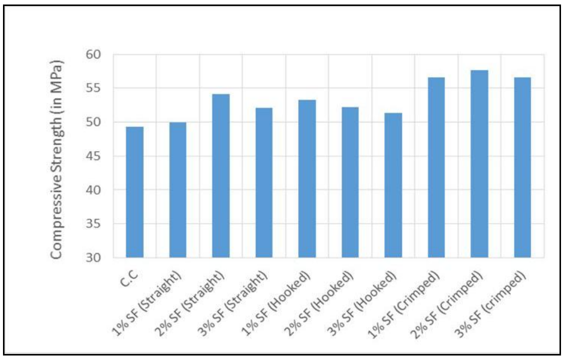

Fig -3.b: 28 days Cube Compressive Strength

Figure 2 Variation of 7 days and 28 days Cube Compressive Strength of M40 grades of concrete prepared with various proportions of (1%, 2% & 3%) of Straight Steel Fibers, (1%, 2% & 3%) of Hooked Steel Fibers and (1%, 2% & 3%) of Crimped Steel Fibers

5.2 Split Tensile Strength Results

The variation of split tensile strength of M40 grade of concrete Steel Fibers (Straight, Hooked & Crimped) is shown in Figure .

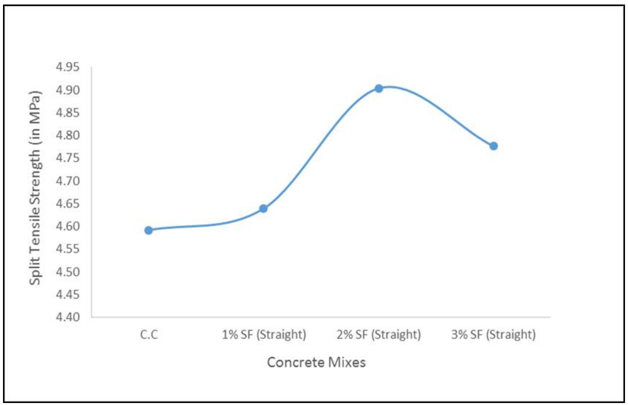

Fig -4.a: Straight Steel Fibre

The split tensile strength of M40 grade of control concrete is 4.59 MPa. The split tensile strength of Steel Fiber (Straight, Hooked & Crimped) Reinforced Concrete exhibits improved strength compared to Control Concrete up to 2% of Volume of Concrete, The Concrete with 2% of Crimped Steel Fiber possesses higher Split Tensile Strength when compared to all other proportions and with further increase in the content of Steel Fiber.

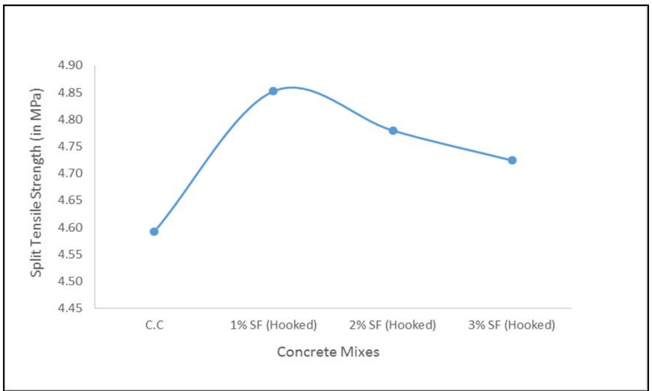

Fig -4.b: Hooked Steel Fibre

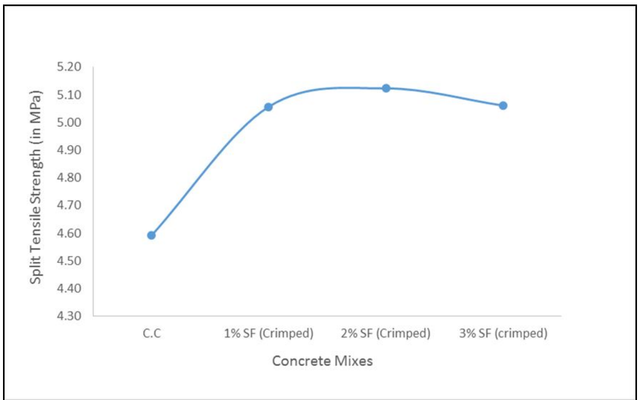

Fig -4.c: Crimped Steel Fibre

Figure 4 Variation of Split Tensile Strength of M40 grade of concrete Steel Fibers (Straight, Hooked and Crimped).

5.3 Flexural Strength Results

The variation of Flexural strength of M40 grade of concrete Steel Fibers (Straight, Hooked and Crimped) is shown in Figure 4. The Flexural strength of M40 grade of control concrete is 7.12 MPa. The Flexural strength of all the Steel Fiber (Straight, Hooked & Crimped) Reinforced Concrete exhibits improved strength compared to Control Concrete up to 2% of Weight of Concrete, The Concrete with 2% of Crimped Steel Fiber possesses higher Flexural Strength when compared to all other proportions and with further increase in the content of Steel Fiber.

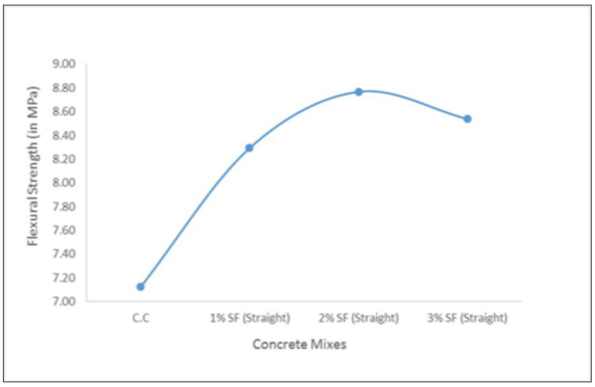

Fig -5.a: Straight Steel Fibre

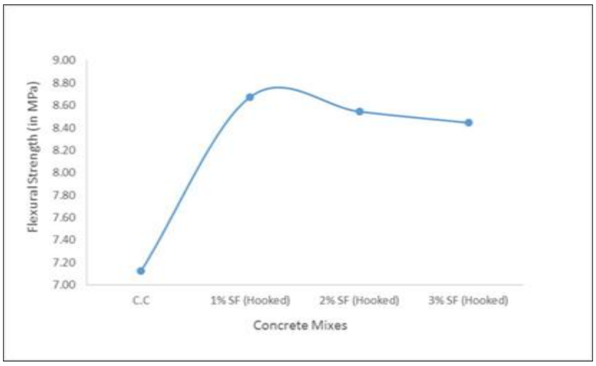

Fig -5.b: Hooked Steel Fibre

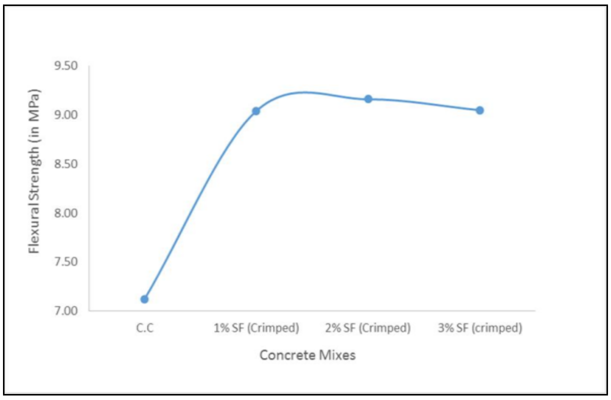

Fig -5.c: Crimped Steel Fibre

Figure 5 Variation of Flexural Strength of M40 grade of concrete Steel Fibers (Straight, Hooked and Crimped).

6. CONCLUSIONS

Plain cement concrete is a brittle material and fails suddenly. Addition of steel fibers to concrete changes its brittle mode of failure into a more ductile one and improves the post cracking behavior of concrete. Fibers are addition to concrete results in more closely spaced reducing the crack width and improved resistance to the cracks. There is a significant increase in Compressive Strength of concrete with addition of Crimped Steel Fiber when compared to Straight and Hooked Steel Fiber. The percentage increase in Compressive Strengths of Straight Steel Fiber (2%), Hooked Steel Fiber (2%) and Crimped Steel Fiber (2%) are 9.84%, 5.9% & 16.92% respectively. The percentage increase in Split Tensile Strengths of Straight Steel Fiber (2%), Hooked Steel Fiber (2%) and Crimped Steel Fiber (2%) are 6.75%, 4.13% and 11.5% respectively. Ductility is increased due to the addition of crimped steel fibers to OPC. The presence of steel fibers with higher content reduced the crack propagation in OPC. The percentage increase in Flexural Strength of Straight Steel Fiber (2%), Hooked Steel Fiber (2%) and Crimped Steel Fiber (2%) are 23.17%, 19.95% and 28.66% respectively.

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