Experimental Investigation on Steel fiber Chip as Partial Replacement of Coarse Aggregate in High Performance Concrete

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Abstract The present work describes the experimental investigation of steel fiber chip reinforced concrete with M-30 and M-35 grade of concrete in addition of steel fiber chips with different percentages. To over-come the difficulties due to optimum percentage of steel fiber chip for maximum strength in concrete & high performance concrete. The objective of this investigation work is to investigate the optimum percentage of steel fiber chip on M-30 and M-35 grade concrete and develop a high performance concrete. It is proposed to determine and compare compressive strength, split tensile strength, flexural strength & slump test of concrete grade M-30 and M-35 having different percentage of steel fiber chip (0%, 3%, 6% and 9%). Compressive strength, split tensile strength, flexural strength increases up to 9 % steel fiber chip for M-30, M-35 grade of concrete. The experimental investigation is carried out on a total no of 108 specimens for compressive strength, split tensile strength & flexural strength each**.**

Key words- steel fiber chip, compressive strength. Split tensile strength. Slump value

I. INTRODUCTION

The Plain concrete has a very low tensile strength, limited ductility, and little resistance to cracking. Internal micro cracks are inherently present in the concrete and its poor tensile strength is due to the propagation of such micro cracks, eventually leading to brittle failure of the concrete. The most widely accepted remedy to this flexural weakness of concrete is the conventional reinforcement with high strength steel. Although these methods provide tensile strength to members, they however do not increase the inherent tensile strength of concrete itself. Also the reinforcement placing and efficient compaction of RCC is very difficult if the concrete is of low workability especially in the case of heavy concrete (M-30 & M-35). In plain concrete and similar brittle materials, structural cracks (micro-cracks) develop even before loading, particularly due to drying shrinkage or other causes of volume change. The width of these cracks seldom exceeds a few microns, but their two dimensions may be of higher magnitude. When loaded, the micro cracks propagate and open up, and owing to the effects of stress concentration, additional cracks form in places of minor defects. The structural cracks proceed slowly. The development of such micro crack is the main cause of inelastic deformation in concrete. It has been recognized that the addition of small, closely spaced and uniformly dispersed fibres to concrete would act as crack arrester and would substantially improve its static and dynamic properties. This type of concrete is known as fibre reinforces concrete.

II. OBJECTIVE

The aim of in this project is to use the Steel Fibres chips as reinforcement to concrete and study various strength parameters with the variation in fibre content.(i.e., to study the strength properties of concrete (M-30 & M-35 Grade) for fibre content of 3%, 6% & % at 7, 14 & 28 days. The strength properties being studied in our thesis are as follows:

1. Slump test
2. Compressive strength
3. Split tensile Strength
4. Flexural strength

These properties are then compared to the conventional M30 & M-35 grade cement concrete.

II. LITRATURE REVIEW

Doo Yeol Yoo, Goangseup Zi, Su-Tae Kang (2015) This study investigates the effects of fiber length and placement method on the biaxial flexural behavior and fiber distribution characteristics of ultra-high-performance fiber-reinforced concrete (UHPFRC). A number of UHPFRC panels including three different fiber lengths were fabricated using two different placement methods, and an image analysis was performed to quantitatively evaluate the fiber distribution characteristics such as fiber orientation, fiber dispersion, and number of fibers per unit area. The biaxial flexural performances including load carrying capacity, energy absorption capacity, and cracking behavior were found to be improved with the increase in fiber length up to 19.5mm. The biaxial flexural performances were also influenced by the placement method; the specimens with concrete placed at the center (maximum moment region) showed better flexural performances than those with concrete placed at the corner. These observations were confirmed by the image analysis results, which showed poorer fiber orientation and fewer fibers across the crack surfaces at the maximum moment region for the specimens with concrete placed in the corner, compared with their counterparts. The present study, the effects of fiber length and placement method on the biaxial flexural behaviors and fiber distribution characteristics of UHPFRC panels were investigated. From the above discussions, the Following conclusions can be obtained:

1. All test panels exhibited deflection-hardening behavior with multiple micro-cracks. The first cracking strength and corresponding deflection showed no noticeable difference with fiber length and placement method, whereas the load carrying capacity and deflection capacity (deflection at the peak)increased with increasing fiber length up to 19.5 mm In addition, the panels with concrete placed at the center (maximum moment region) provided a higher load carrying capacity than those with concrete placed at the corner.
2. The S19.5 specimen exhibited the toughest response, whereas the S13 specimen showed the lowest toughness, and the S16.3 specimen had values in between. The S16.3 specimen placed at the center showed higher toughness at deflection points up to $d10$ compared to the S19.5 mm specimen placed at the corner, indicating that the energy absorption capacity is influenced by the fiber length as well as the placement method. [19].
3. The panels with concrete placed at the center failed by two different failure modes (flexural failure and punching failure), whereas the specimens with concrete placed at the corner only failed by the flexural failure mode. The panels with concrete placed at the center and higher fiber lengths showed more cracks and smaller crack spacing than their counterparts.
4. Based on the image analysis results, the panels with concrete placed at the center had better fiber orientation and more fibers in the area of the maximum moment region than those with concrete placed at the corner. This mainly caused the specimens with concrete placed at the center to show higher load carrying capacities than their counterparts.

Athira Omanakuttan (2017) Hybrid Fiber-reinforced concrete is a composite material consisting of mixtures of cement, fine aggregate, coarse aggregate, steel fiber and glass fiber. The hybrid fiber reinforced concrete exhibits better fatigue strength and increased static and dynamic tensile strength. In this project, the strength of fiber reinforced concrete was investigated with partial replacement of cement with rice husk ash and fly ash. Steel fiber and glass fiber was added in the order of 0.25%, 0.5% and 0.75% by volume of concrete and 0.25%, 0.5% and 0.75% by weight of cement. Rice Husk Ash was used to replace ordinary Portland cement by 20% and fly ash 20% by weight of cement proportion

IV. MATERIALS USED

The materials used in this investigation were: Portland cement, coarse aggregate of crushed rock with a maximum size of 20 mm, fine aggregate of clean river sand and portable water & Steel chip-Fibres is used. The detailed properties are given in subsequent contents.

A. CEMENT

Portland cement of 43 grades conforming to IS 8112-1989 was used. Tests were carried out on various physical properties of cement and the results are shown in Table -1

Image 1 Cement

B. FINE AGGREGATE

Natural river sand was used as fine aggregate. The properties of sand were determined by conducting tests as per IS: 2386 (Part- I). The results are shown in Table 3.2. The results obtained from sieve analysis are furnished in Table 3.3. The results indicate that the sand conforms to Zone II of IS: 383 – 1970

C. COURSE AGGREGATE

Crushed granite stones obtained from local quarries were used as coarse aggregate. The maximum size of coarse aggregate used was 20 mm. The properties of coarse aggregate were determined by conducting tests as per IS: 2386 (Part – III). The results are tabulated in Table 3

Image 2 coarse & fine aggregate

D. WATER

Water plays an important role in the formation of concrete as it participates in chemical reaction with cement. Potable water is generally considered satisfactory for mixing. Potable water free from salts was used for casting and curing of concrete as per IS: 456 – 2000 recommendations.

E. STEEL FIBRE CHIP

Stainless steel chips were taken as steel fibres for this study. These are industrial waste of high-grade stainless steel to handle toughest jobs. Since each chip is made of a single strand of stainless steel, they will not tear or splinter. Also, they will not corrode. It has a good tensile strength and the fibre strips length vary by 25 to 50 mm. These fibers will improve toughness, durability and tensile strength of concrete.

Image 3 Sample of steel fibre chip

TABLE.1 PHYSICAL PROPERTIES OF 43 GRADE PORTLAND CEMENT

S.No.	Physical Properties	Values of Portland Cement used	Requirements as per IS 8112-1989
1	Standard Consistency	29.2 %	-
2	Initial Setting Time	45 Minutes	Minimum of 30 minutes
3	Final Setting Time	265 Minutes	Maximum of 600 minutes
4	Specific gravity	3.15	-
5	Compressive strength in N/mm2 at 3 days	29	Not less than
6	Compressive strength in N/mm2 at 7 days	38.5	Not less than
7	Compressive strength in N/mm2 at 28 days	48	Not less than

TABLE.2 SIEVE ANALYSIS OF FINE AGGREGATE

I.S. Sieve Size	Weight Retained (gm)	Cumulative Weight Retained (gm)	Cumulative Percentage Weight Retained	Cumulative Percentage Weight Passing
10 mm	2	2	0.4	99.6
4.75 mm	6	8	1.6	98.4
2 mm	20	28	5.6	94.4
1.18 mm	76	104	20.8	79.2
850 microns	224	328	65.6	34.4
425 microns	114	442	88.4	11.6
150 microns	54	496	99.2	0.8
<150 microns	4	500	100	0.0

TABLE.3 PHYSICAL PROPERTIES OF FINE AGGREGATE

(TESTS AS PER IS: 2386 – 1968: PART III)

S. no	Physical properties	Values
1	Specific gravity	2.65
2	Fineness Modulus	2.83
3	Water Absorption	0.84%
4	Bulk density (kg/m3)	1654

TABLE. 4 PHYSICAL PROPERTIES OF COURSE AGGREGATE

(TESTS AS PER IS: 2386 – 1968 PART III)

S. No	Physical properties	Values
1	Specific gravity	2.65
2	Fineness Modulus	2.73
3	Water Absorption	0.68%
4	Bulk density (kg/m3)	1590
5	Aggregate Impact value (%)	11.2
6	Aggregate Crushing value (%)	25.12

COMPRESSIVE STRENGTH

According to Indian Standard specifications (IS: 516–1959) The compressive strength on each 150×150×150 Cubic specimen was determined in accordance with Compression testing machine. The testing was hydraulic controlled with a maximum capacity of 2000 KN. Load was applied to the specimen at a constant loading rate of 0.5 N until complete failure occurred. The maximum load is recorded and the compressive stress computed by dividing the maximum load by the cross sectional area of the specimen. The type of fracture was also recorded. Figure shows a cube in the testing machine before test.

Image 4. Compression test machine

FLEXURAL STRENGTH TEST

Flexural strength test was conducted as per recommendations IS: 516 – 1959, The flexural strength test was done in Universal testing machine (UTN) on 150×150×700mm beam specimen at each age and the average strength was computed. Before testing, the two loading surfaces were ground evenly by using a grinding stone to ensure that the applied load was uniform. The flexural strength was calculated according to the type of fracture in the beam as follows:

Figure 5. Flexural test setup

Figure shows a typical setup of the beam during testing. If the fracture initiates in the tension surface within the middle third of the span length, then modulus of rupture is calculated as follows:

$$R = \frac{PL}{bd^2}$$

Where R = modulus of rupture (mm^3);
P = maximum applied load indicated by the testing machine (N);
L = span length (mm);
b = average width of specimen (mm) at the fracture; and
d = average depth of specimen (mm) at the fracture.

If the fracture occurs in the tension surface outside of the middle third of the span length by not more than 5% of the span length, then modulus of rupture is calculated as follows:

$$R = \frac{3Pa}{bd^2}$$

Where R = modulus of rupture (mm^3);
P = maximum applied load indicated by the testing machine (N);
a = average distance between line of fracture and the nearest support measured on the tension surface of the beam (mm);
b = average width of specimen (mm) at the fracture; and
d = average depth of specimen (mm) at the fracture.

If the fracture occurs in the tension surface outside of the middle third span length by more than 5% of the span length, discard the results of the test. Figure shows a typical failed beam specimen after the flexural test.

SPLITTING TENSILE STRENGTH TEST

The Split tensile strength test was carried out on the compression testing machine. The casting and testing of the specimens were done as per IS 5816: 1999. The splitting tensile strength of concrete was done in accordance with Indian Standard on cylindrical specimens (150×300mm). Four lines were drawn along the centre of the cylinder to mark the edges of the loaded plane and to help align the test specimen before the application of load. Figure shows a typical setup of the cylinder during testing. A strip of wood, 3-mm thick and 25-mm wide, was inserted between the cylinder and the platens; this helped the applied force to be uniformly distributed. Load was applied and increased under a controlled rate until failure by indirect tension in the form of splitting along vertical diameter took place.

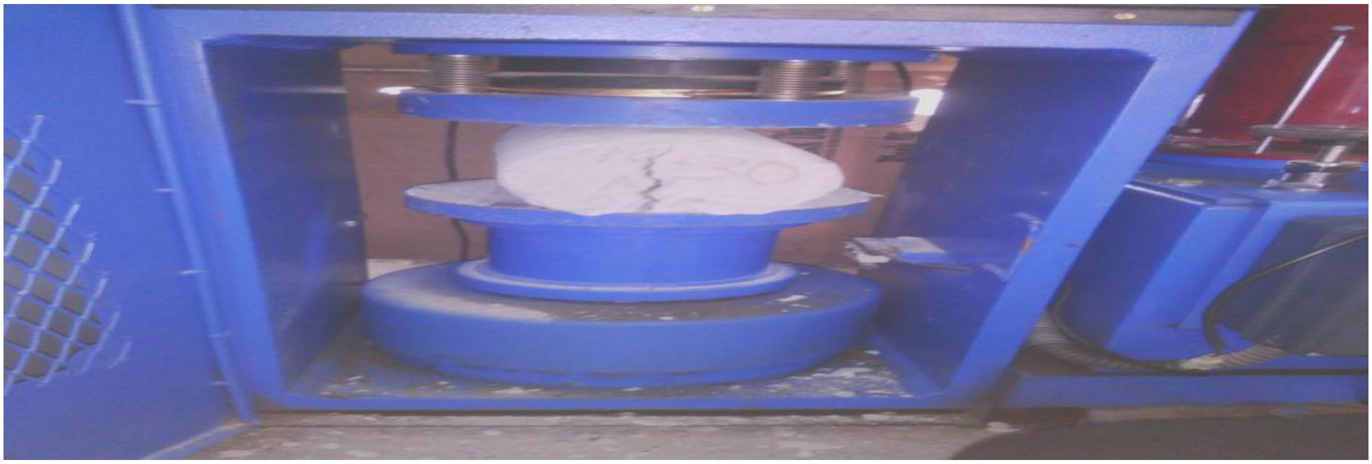


Image 7. Splitting tensile setup

Figure shows a typical failed sample. The splitting tensile strength of a cylinder specimen was calculated using the following equation:

$$T = \frac{2P}{\pi LD}$$

Where T = splitting tensile strength of cylinder (mm^3);
P = maximum applied load (N);
L = average length of cylinder (mm); and
D = average diameter of cylinder (mm).

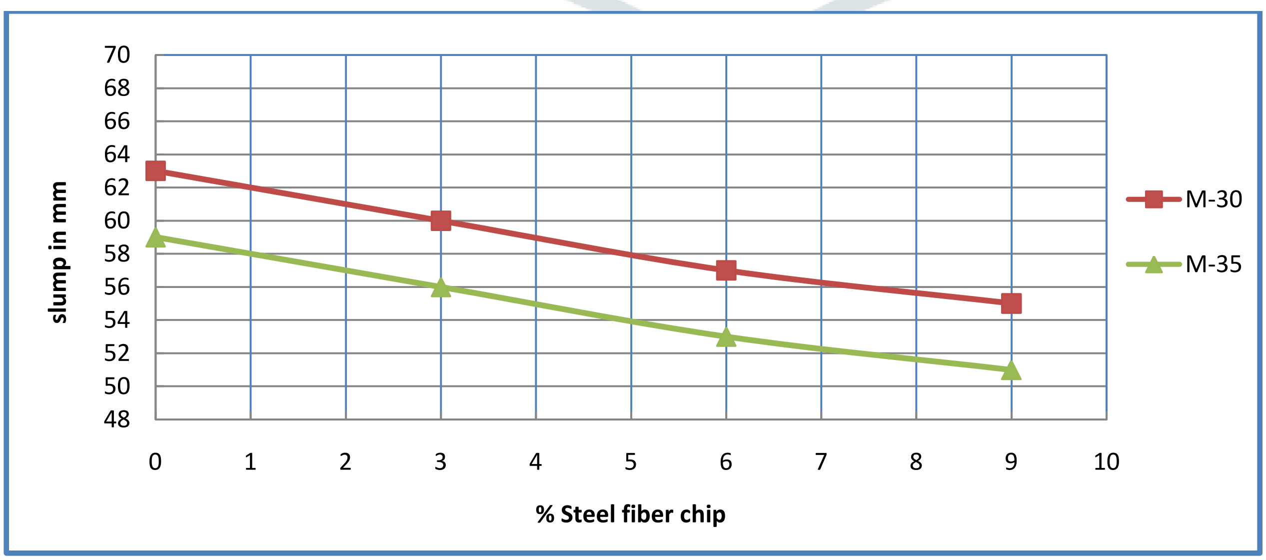
IV. RESULTS AND DISCUSSION

Fresh mix characteristics are more emphasized in fibre concrete compared to the plain concrete. Generally increasing weight fraction of fibres results in further reduction of fresh concrete workability, in this study, fibres as steel fibre chips of different volume fractions like 3 %, 6 %, and 9 % and length of fibre lengths is 25mm to 40 mm.

SLUMP TEST

TABLE 5 SLUMP TEST RESULTS

S. No.	% Replacement of Steel fibre chip	Slump for M30	Slump for M35
1	0 %	63	59
2	3 %	60	56
3	6 %	57	53
4	9 %	55	51



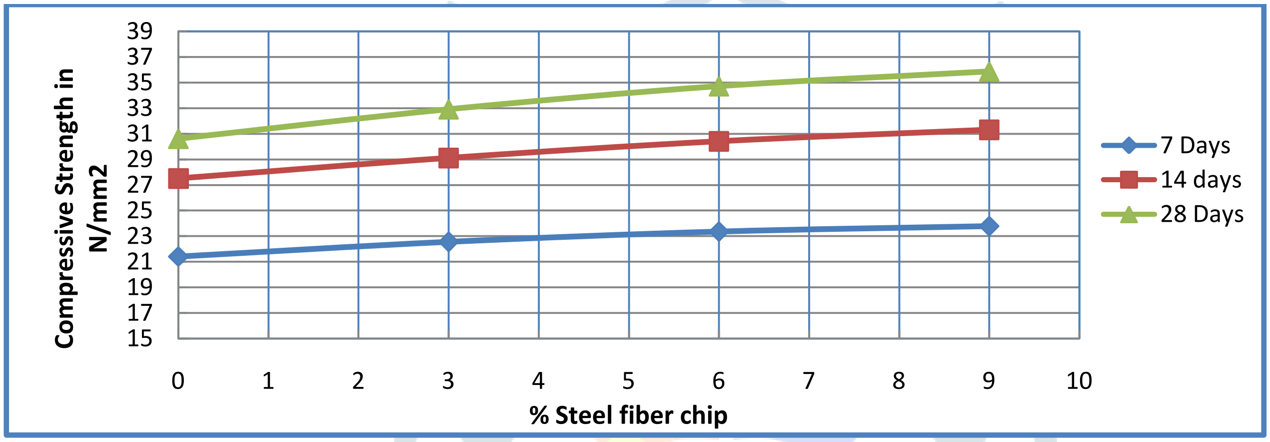
Graph -1 slump value with steel fiber (Grade M-30 & M-35)

CUBE COMPRESSIVE STRENGTH

Totally 72 cube specimens of size 150 mm x150 mm x 150 mm with 3 mixes were casted and tested. Three volume fractions were considered for steel fibre chips (3%, 6% and 9% of steel fibres chip). Results for compressive strength based on the average values of three test data are shown in Table-6, 7 and 8. A sample comparisons graph for steel fibres chip concrete is plotted to study the effect of fibre reinforcement on conventional concrete strength which is shown in Graph..2, and 3

Table 6 – Compressive Strength of M30 Grade concrete in N/mm^2

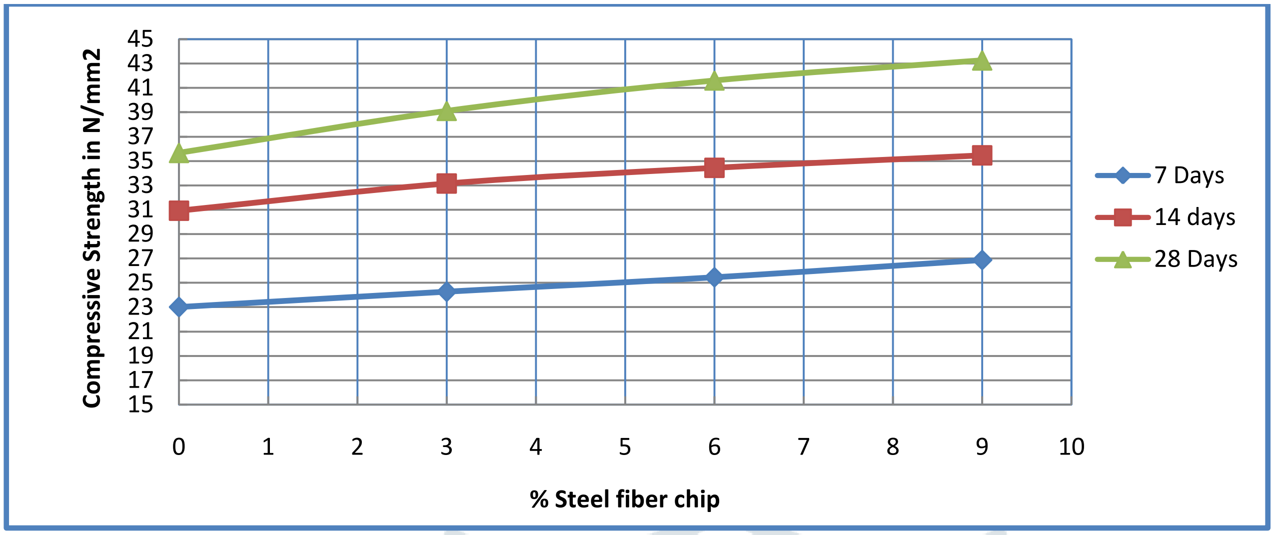
S. No.	% of Steel fibre chip	Grade of Concrete		
		7 Days	14 Days	28 Days
1	0 %	21.40	27.50	30.60
2	3 %	22.54	29.10	32.90
3	6 %	23.35	30.40	34.70
4	9 %	23.78	31.30	35.86



Graph 2 – Compressive Strength of M30 Grade concrete

Table 7 – Compressive Strength of M35 Grade concrete in N/mm^2

S. No.	% of Steel fibre chip	Grade of Concrete		
		7 Days	14 Days	28 Days
1	0 %	23.00	30.92	35.66
2	3 %	24.26	33.16	39.12
3	6 %	25.45	34.44	41.62
4	9 %	26.88	35.47	43.25



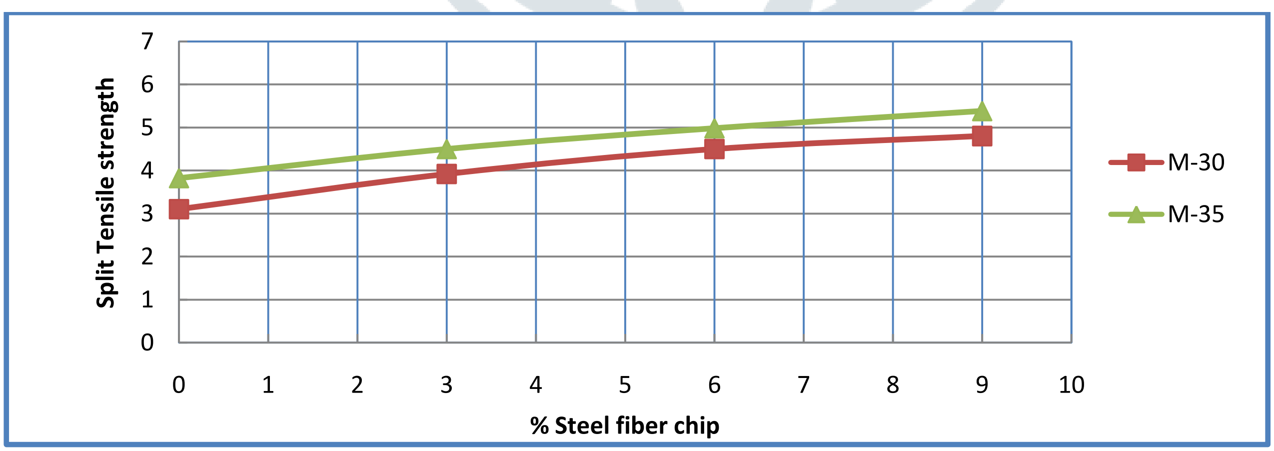
Graph 3 – Compressive Strength of M35 Grade concrete

SPLIT TENSILE STRENGTH

Totally 72 cylinder specimens of size 100 mm diameter and 300 mm height with 3 different % mixes were casted and tested. Three weight fractions were considered for steel chip fibres of constant length. Results for split tensile strength based on the values of test data. A sample comparison graph for steel fibres chip concrete is plotted to study conventional concrete strength which is shown in Graph..The values of the split tensile strength of different mixes are shown in Table

Table 8 – 28 days Split tensile strength of Cylinder in N/mm^2

S. No.	% of Steel fibre chip	Grade of Concrete	
		M30	M35
1	0 %	3.10	3.82
2	3 %	4.22	4.50
3	6 %	4.50	4.92
4	9 %	4.80	5.38



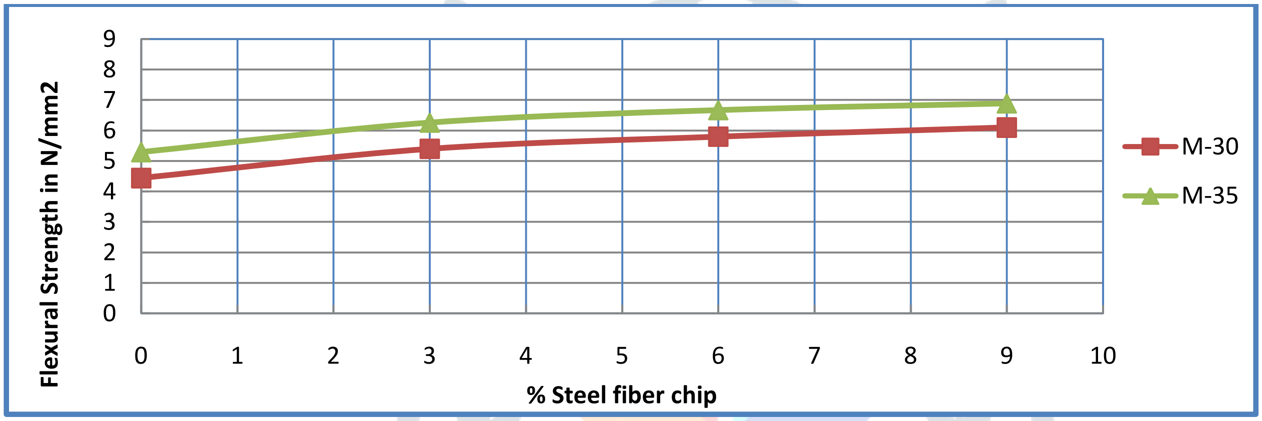
Graph 4 – 28 days Split tensile strength of Cylinder

4.3.3 FLEXURAL STRENGTH OF CONCRETE:

The determination of flexural strength of the prepared samples is carried out as per IS code. The following table shows the flexural strength of various samples using different percentage of steel fibre chips.

Table 9 – Flexural Strength of concrete Beam in N/mm²

S. No.	% of Steel fibre chip	Grade of Concrete	
		M30	M35
1	0 %	4.90	5.29
2	3 %	5.40	6.26
3	6 %	5.70	6.67
4	9 %	6.10	6.89



Graph 5 – Flexural Strength of concrete Beam

V. CONCLUSION

Based on the experimental investigation the following conclusion is given within the limitation of the test result.

- Addition of steel fiber chip resulted in significant improvement on the strength properties of concrete (M-30 and M-35) grade.
- Compared to plane concrete the steel fiber chip addition resulted in better strengthening (compressive, tensile and flexural) properties of concrete.
- The optimum percentage of steel fiber chip added was 9 % since increased fiber addition resulted in loss of workability.
- The Slump of the concrete mix reduces from 63mm to 55mmon increasing the percentage of steel fiber (from 0% to 9%) for M-30 Concrete mix
- The Slump of the concrete mix reduces from 59 mm to 51mm on increasing the percentage of steel fiber (from 0% to 9%) for M-35 Concrete mix
- The Compressive strength of M30 concrete mix increases from 30.60N/mm^2 to 35.86N/mm^2 on increasing the percentage of steel fiber (from 0% to 9%).
- The Compressive strength of M35 concrete mix increases from 35.66N/mm^2 to 43.25N/mm^2 on increasing the percentage of steel fiber (from 0% to 9%).
- The Tensile strength of M30 concrete mix increases from 3.1N/mm^2 to 4.8N/mm^2 on increasing the percentage of steel fiber (from 0% to 9%).
- The Tensile strength of M35 concrete mix increases from 3.82 to 5.38 N/mm^2 on increasing the percentage of steel fiber (from 0% to 9%).
- The Flexural strength of M30 concrete mix increases from 4.9N/mm^2 to 6.1N/mm^2 on increasing the percentage of steel fiber (from 0% to 9%).
- The Flexural strength of M35 concrete mix increases from 5.29N/mm^2 to 6.89N/mm^2 on increasing the percentage of steel fiber (from 0% to 9%).
- Compressive, Tensile and flexural strength is increasing on increasing the percentage of steel fiber chip and maximum strength was achieved in the case of 9% steel fiber chip for grade of concrete M-30 and &M-35.

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