International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 05 | May 2019 www.irjet.net p-ISSN: 2395-0072

Study on Mechanical Properties of Steel Fibre Reinforced Concrete

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Abstract - *The objective of this research investigation was to study mechanical properties of Steel Fibre Reinforced Concrete using straight fibres with hooked ends and aspect ratio 50. Slump Test, compressive strength test and splitting tensile strength test were conducted for varying percentage of steel fibres and a comparison has been made between the concrete with steel fibres and without the presence of steel fibres.*

Key Words: *FRC, SFRC, Optimum steel fibre percentage.*

1. INTRODUCTION

Fibre reinforced concrete(FRC) is a fairly new concrete type being used in construction, presently under the purview of extensive experimental works trying to study various mechanical and thermal behavior of such concrete and its viability on large scale construction project. Fibre reinforced concrete (FRC) is Portland cement concrete reinforced with more or less randomly distributed fibres. Incorporation of fibre in concrete has found to improve several qualities like tensile strength, cracking resistance, wear resistance, ductility and fatigue resistance. Several fibres like asbestos, nylon, glass, carbon, poly propene etc. have been used so far. Steel Fibre Reinforced Concrete (SFRC) is a type of FRC extensively drawing attention towards its usage due to reasonable pricing and enhanced concrete properties on its usage. It has a huge untapped potential of use in pavement and tunnelling due to increased strength and building frames due to its high seismic energy absorption and relatively simple construction technique. However, corrosive damage and increased density are the drawbacks of SFRC. The aim of the paper is to study through experimental investigation, a comparison between ordinary concrete and steel fibre reinforced concrete at varying percentages by performing test on steel fibre incorporated cubes and cylinders. Thus, drawing a trend of workability, compressive and split tensile behavior of SFRC.

2. MATERIALS AND METODOLOGY

2.1 Steel Fibres

The diameter of 1mm with hook end steel fibres are being used in this project. Length of these fibres is 50 mm and the aspect ratio of 50. Density of steel fibre is 7850 kg/m^3.

2.2 Aggregates

Coarse Aggregate: It should be hard, strong, dense, durable and clean. It must be free from 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 should be avoided. It should confirm to IS 2838(I). Of Nominal size 20mm has been used for the study. Testing for Specific Gravity and Water Absorption are done as per the guidelines pertaining to IS:2386 (Part III)-1963.

Fine Aggregates: It passed through IS Sieve 4.75 mm. It should have fineness modulus of 2.50-3.50 and silt contents should not be more than 4%. Coarse sand should be either river sand or pit sad; or combination of the two. Grading Zone II (as per IS 383-1970) has been used for the study Testing for specific gravity and water absorption is done as per guidelines pertaining to IS:2386 (Part III)-1963.

2.3 Cement

OPC Grade 43 Cement has been used for the study.

2.4 Chemical Admixture

Superplasticizer MasterGlenium 51 was used which have properties of water reduction and increased strength. It imparts early and high initial and final strengths.

3. EXPERIMENTAL PROGRAM

The objective of this research investigation was to study the effect of steel fibres on the mechanical properties of Steel Fibre Reinforced Concrete (SFRC). Straight steel fibres with hooked ends and aspect ratio of 50 were used. The steel fibres used had a diameter of 1mm and length 5cm.Specimen were cast without fibres and with fibres of 0.15%, 0.3%, 0.45% and 0.6%. Tests were conducted for determining workability, compressive strength and split tensile strength. Slump Test was conducted for workability. Cubes of dimension 150*150*150 mm were cast and tested using Compression Testing Machine (C.T.M) for Compressive Strength and Cylinders of dimension 150mm(diameter) and 320mm (height) were cast and tested for Split Tensile Strength.

Five type of specimens were prepared and designed as S-0, S-1, S-2, S-3 and S-4.

S-0: Control Concrete containing no fibres.

S-1: Concrete containing 0.15% steel fibres by volume of concrete.

S-2: Concrete containing 0.3% steel fibres by volume of concrete.

S-3: Concrete containing 0.45% steel fibres by volume of concrete.

S-4: Concrete containing 0.6% steel fibres by volume of concrete.

A.MIX DESIGN FOR M30 GRADE OF CONCRETE

TEST DATA FOR MATERIALS

Proper design of concrete mixture is crucial for appropriate proportioning of ingredients that will produce concrete of high durability and performance during the designed life of a structure.

- DESIGN STIPULATIONS

  i. Grade designation: M30

  ii. Type of cement: OPC 53 grade confirming to IS 8112

  iii. Maximum nominal size of aggregates: 20 mm

  iv Maximum water cement ratio: 0.5

  v. Workability: 100 mm (slump)

  vi. Exposure condition: Mild

  vii. Degree of supervision: Good

  viii. Type of aggregate: Crushed angular aggregate

  ix. Chemical admixture: Super Plasticizer (MasterGlenium 51)

- TEST DATA FOR MATERIALS

a) Cement used: OPC 53 grade confirming to IS 8112

b) Specific gravity of cement: 3.12

c) Specific gravity

Coarse aggregate: 2.89

Fine aggregate: 2.59

d) Water absorption

Coarse aggregate: 0.86 percent

Fine aggregate: 1.72 percent

e) Free (surface) moisture

Coarse aggregate: Nil (absorbed moisture full)

Fine aggregate: Nil

f) Sieve analysis

Coarse aggregate: Conforming to Table 2 of IS: 383

Fine aggregate: Conforming to Zone II of IS: 383

- MIX CALCULATIONS

  For 1m3 of concrete,

  1. Cement=335kg/m^3

  2.Water=140kg/m^3

  3.Coarse Aggregate= 1230.5 kg/m^3

  4.Fine Aggregate= 832kg/m^3

  5. Chemical Admixture (MasterGlenium 51) = 6.7kg/m^3

  6. Water-Cement Ratio= 0.42

B. CASTING OF SPECIMEN

The materials were weighed accurately using a digital weighing instrument. For plain concrete, coarse aggregates, fine aggregate, cement, water and chemical admixture were added to the mixture machine and mixed thoroughly for three minutes. Steel fibres were sprinkled in a random fashion inside the mixture during mixing of the ingredients so as to obtain a homogenous mixture. Each batch was tested for workability using Slump Test. For preparing the specimen for compressive and split tensile strength permanent steel moulds and cylinders were used. Before mixing, the moulds were kept ready for filling. The sides and the bottom of the all the mould were properly oiled for easy opening after drying. Mixing Methodology, moulds specification and related processes are followed as per IS 516:1959

C. CURING

The test specimen were stored in a place, free from vibration, in moist air of at least 90 percent relative humidity and at a temperature of 27° ± 2°c for 24 hours ± l hour from the time of addition of water to the dry ingredients, After this period, the specimens were be marked and removed from the moulds and, unless required for test within 24 hours, immediately submerged in clean, fresh water or saturated lime solution and kept there until taken out just prior to test. The water in which the specimens are submerged were maintained at a temperature of 27° ± 2°C.

Curing Methodology followed as per IS 516:1959

D. SLUMP TEST

It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows. Procedure followed as per IS 1199 (1959)

This cone is filled with fresh concrete in four stages. Each time, each layer is tamped 25 times with a tamping rod. At the end of the fourth stage, the concrete is struck off flush with the top of the mould. The mould is carefully lifted vertically upwards, so as not to disturb the concrete cone. The concrete then slumps (subsides). The slump of the concrete is measured by measuring the distance from the top of the slumped concrete to the level of the top of the slump cone.

E. COMPRESSIVE STRENGTH TEST

The load, applied without shock and increased continuously at a rate of approximately 140 kg/cm^2/min until the resistance of the specimen to the Increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen then recorded and the appearance of the concrete and any unusual features.

Age at Test - We conducted test for 7-day strength. Three specimens, tested at each selected age.

Specimens stored in water was tested immediately on removal from the water and while they were still in the wet condition.

Calculation - The measured compressive strength of the specimen is calculated by dividing the maximum load applied to the specimen during the test by the cross-sectional area. Average of three values was taken as the representative of the batch Reference for Compressive Strength Test is taken from IS 516(1959)

F. SPLITTING TENSILE TEST

Methodology followed as per IS 5816 (1999)

Age at Test-. We performed for 7-day age. Three specimens, tested at each selected age. Rate of Loading -The load is applied without shock and increased continuously at a nominal rate within the range 1.2 N/mm^2/min to 2.4 N/mm^2/min. The maximum load applied then recorded.

Calculation- The measured splitting tensile strength, of the specimen shall is calculated to the nearest 0.05 N/mm2 using the following formula:

$f(ct)=2P/(\pi)ld$

where

P = maximum load in Newtons applied to the specimen,

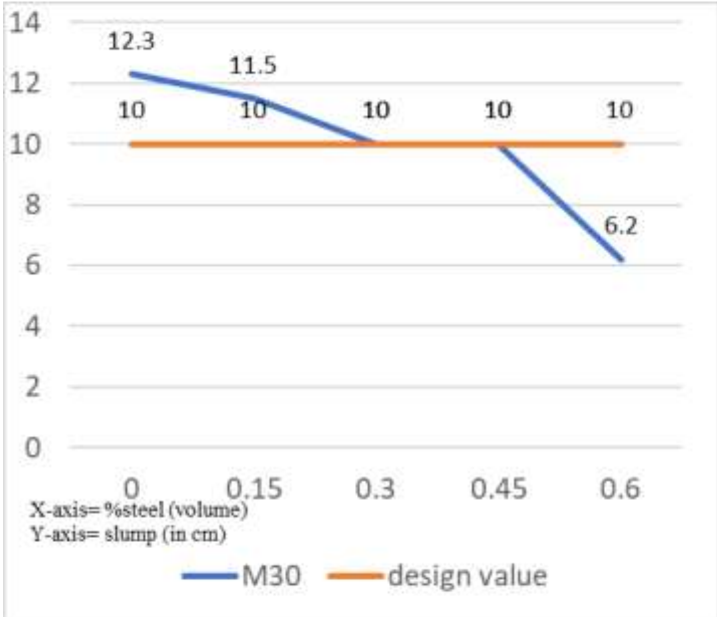
l = length of the specimen in mm and

d = cross sectional dimension of the specimen in mm

4. RESULT AND DISCUSSION

A. Slump Test

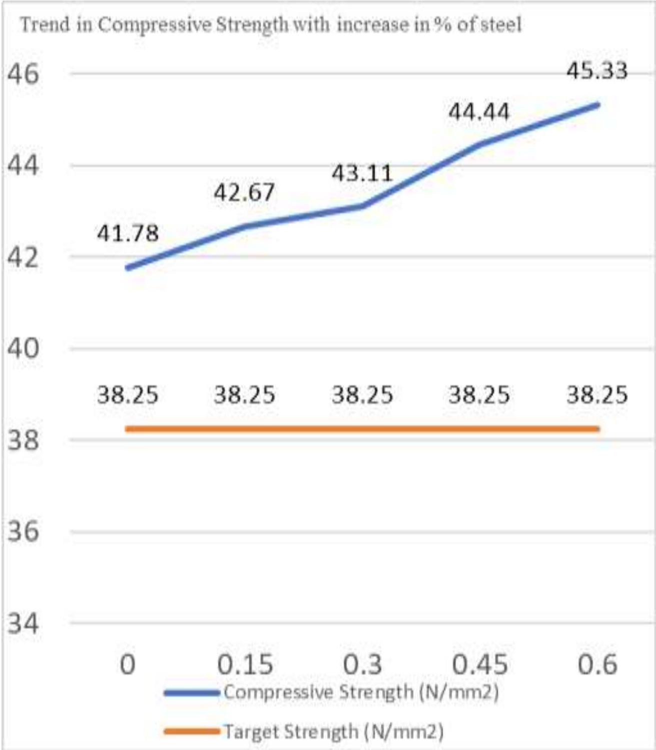
Result for Slump Test have been done for two samples of concrete and the values have been presented in tabular as well as graphical form.



Observation

- For initial increase in 0.15% there is a decrease in slump by 0.8cm.
- Further, 0.15% increase in steel- decrease in slump by 1.5cm.
- In range of 0.3 to 0.45% no decrease in slump.
- Further, increase by 0.15%- significant decrease in slump by 3.8 cm.

B. Compressive Strength Test



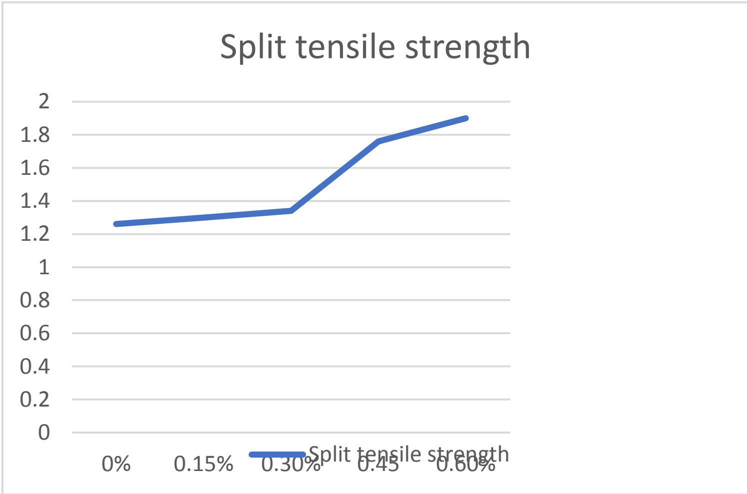
X-axis- % of steel (by volume)

Y-axis- Compressive Strength (N/mm²)

Observation:

- For initial increase in 0.15% there is an increase in compressive strength by 0.89 N/mm².
- Further, 0.15% increase in steel-increase in compressive strength by 0.44N/mm².
- In range of 0.3 to 0.45% steel-increase in compressive strength by1.33N/mm².
- Further, increase by 0.15%- steel-increase in compressive strength by 0.89N/mm².

C. Splitting-tensile Strength Test



X-axis- % of steel (by volume)

Y-axis- Split Tensile Strength (N/mm²)

Observation:

- For initial increase. In 0.15% there is an increase. in splitting tensile strength by 0.04N/mm².
- Further, in range of 0.15 to 0.30 % steel increase. in splitting tensile strength by 0.04N/mm² , there is no drastically change in comparison of initial percentage.
- In range of 0.30 to 0.45% steel increase. in splitting tensile strength by 0.42N/mm².
- Further, increase by 0.15% , steel increase. in splitting tensile strength by 0.14N/mm².

D. Figures and Tables

TABLE I. SLUMP VALUES

% steel	0	0.15	0.3	0.45	0.6
Sample 1	12.5	11.7	10	10	6.3
Sample 2	12.1	11.3	10.1	10	6.1
Average	12.3	11.5	10	10	6.2

TABLE II. COMPRESSIVE STRENGTH RESULT

% steel	0	0.15	0.3	0.45	0.6
Compressive Strength(N/mm²)	41.78	42.67	43.11	44.44	45.33

TABLE III. SPLITTING TENSILE STRENGTH RESULT

% steel	0	0.15	0.3	0.45	0.6
Splitting Tensile Strength(N/mm²)	1.26	1.30	1.34	1.76	1.90

CONCLUSIONS

1. Workability of Concrete decreases with increase in steel fibres.
2. Optimum range for steel fibres is 0.3%to 0.45% since no change in slump is observed and obtained slump is 10cm which is in consonance with design.
3. Compressive Strength increase with increase in steel fibres.
4. Optimum range for steel fibres is 0.3% to 0.45% as compressive strength increases maximum in this range.
5. At present market range of steel (Rs 80/kg)-for 1m3 of concrete-additional average cost of Rs220,000-for an addition of steel fibres in the percentage range of 0.3 to 0.45.
6. For larger construction projects this amount seems to be reasonable considering the additional benefits that are obtained.

ACKNOWLEDGEMENT

With profound respect and gratitude, we take the opportunity to convey my thanks to our Honorable HOD & Respected faculty teachers, of Civil Engineering Department, ADGITM for their effort of constant co-operation which have been significant factor in the accomplishment of my in-house training. We are greatly thankful to the sincere efforts made by Ms. Shikha Sachan (Guide) & Mr. Sunil Sharma (Guide) to teach us and share their experience with us, without them this project would be abstract. We would also thank to our Lab Technitians of Environment Department as well as the Applied Science Department.

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