An Experimental Study on Mechanical Properties of Concrete with GGBS and Quarry Dust Using Hybrid Steel Fibers

K. Anand, S. Manikandaprabhu, M. Vishnu Nishanth

Abstract**:** ***The Mechanical properties like Compression, Flexure and Split Tensile Strength of Steel fibre reinforced Concrete (SFRC) has investigated for M35 grade of Concrete with Ground granulated blast furnace slag (GGBS) and Quarry Dust. The objective is to understand the influence in mechanical properties of shape & types of Steel fibres in the concrete and increase strength behaviours. The Concrete mixes has propotioned as per IS 10262 : 2009, In which reference and all the mixes has partially replacing 20% of Cement with GGBS and 30% of River Sand with Quarry Dust. The Combinations of blending of Steel Fibre are as like 100% Crimp & 0% hooked, 25% Crimp &75% Hooked, 75% Crimp &25 Hooked, and 0% Crimp &100% Hooked end. Totally 13 Nos. of trials are carried out in different combinations including reference mix. The workability of Concrete in all the mixes are maintained 60 – 70 mm slump by addition of PCE based Chemical Admixture 0.25% to 0.4%. The dosage is incremented 0.05% while increasing 1% of Steel Fibre so as to manage equal workability. The result from experiments has been analysed and compared with conventional specimen without fibre. The influence of fibre volume over Compression, Flexure and Split Tensile are represented graphically. The result data are shows the percentage of increase in 28 days Mechanical properties like Compressive, Flexure and Split Tensile strengths for M35 grade Concrete.***

Index Terms**:** ***About four key words or phrases in alphabetical order, separated by commas.***

I. INTRODUCTION

Concrete is basically a brittle material good at compressive properties, but is weak in tension of less than 10% of its compressive behaviour, and it is mostly reinforced with strong tension materials. Steel fibers are added and dispersed uniformly in the concrete while the mixing of its raw materials. By adding steel fiber with hooked end there is a percentage of maximum increase in compressive strength, flexural strength, are achieved 6.15% and 7.94% respectively at 3%, 4% of fiber volume fractions.

The optimum fiber content for maximum gain of various strengths is varies with compressive, flexural and split tensile strengths. Ductility of concrete is found increased by the inclusion of fibers at higher fiber content. In the addition of fibers (crimped steel% – poly propylene %) in concrete minimizes the formation of internal micro cracks. The compressive, flexural and split tensile strength between (0.6%-0.4%), (0.7%-0.3%) is increases high, compared to other intervals. The high strength of hybrid fiber reinforced concrete is (0.8%-0.2%) of compressive strength 59.55 MPa as compared with other proportions. Compressive strength is increased from 11% to 24% with addition of steel fibers, there is a increase of 12% to 49% in flexure and 3% to 41% increment in split tensile strength while adding 3% of hooked end type steel fibers with aspect Ratio of 50. The hooked end steel fibers has enhanced in all the properties of concrete compared to normal like compressive strength by 20.42% for 2% of steel fiber and split tensile strength by 32.2% for 2% of steel fiber. The simultaneous replacement of cement and fine aggregate by GGBS and quarry dust respectively results betterment in enhancing the properties, the ideal usage of these materials in the concrete mix is of essential importance. The main objective of this study is to evaluate the behaviors and mechanical properties of steel fiber reinforced concrete with GGBS and quarry dust and to determine the optimum percentage of fiber required, influence of shape of steel fiber in strength behaviors, optimum percentages of mixing two fibers, and to increase the mechanical properties in GGBS & quarry dust mixed concrete. The mechanical properties of steel fiber reinforced concrete has evaluated with incrementing dosages of steel fibers from 1% to 3% by incrementing steps of 1% against the conventional concrete and the optimum percentage of steel fibers required to enhance the mechanical properties of concrete with GGBS and quarry dust has determined. The influence of shape of steel fibers by adding those in various ratios of combinations in to the concrete is compared.

II. MATERIALS AND PROPORTIONING

This experimental study deals with an investigation of M35 grade concrete with GGBS and quarry dust to study the mechanical properties behaviours like flexural, compressive and split tensile strength of steel fibre reinforced

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K. Anand, Post Graduate Student, Department of Civil Engineering, SRM Institute of Science and Technology, Ramapuram, Chennai, India

S. Manikandaprabhu, Assistant Professor(Sr.G), Department of Civil Engineering, SRM Institute of Science and Technology, Kattankulathur, Chennai, India

M. Vishnu Nishanth, Post Graduate Student, Department of Civil Engineering, SRM Institute of Science and Technology, Kattankulathur, Chennai, India

concrete (SFRC) containing hybrids steel fibres of type hooked end and crimped with same aspect ratio 50 in the volume fractions of 1%, 2% and 3%. The combinations of blending of steel fibre are as like 100% crimped: 0% hooked end, 25% crimped: 75% hooked end, 75% crimped: 25 hooked end, and 0% crimped: 100% hooked end. Totally 13 Nos. of trials are carried out in different combinations including reference mix. The workability of concrete in all the mixes are maintained 60 – 70 mm slump by addition of chemical admixture 0.25% to 0.4%. The dosage is incremented 0.05% while increasing 1% of steel fibre so as to manage equal workability. Steel fibers made from cold drawn type from mild steel wire for general engineering purpose conforming to ASTM A-820 M is used in this study. The steel fibers are added after dry mix of the materials for three minutes before adding water. In all the mixes of this program M35 grade concrete is commonly designed as 20 % partial replacement of GGBS in cement and 30% partial replacement of quarry dust in river sand. The strength comparison also made between controlled concrete and steel fiber reinforced concrete by addition of steel fibers in the volume fractions of 1%, 2% and 3%. Within the volume fractions of 1%, 2% and 3%, the mixing percentages of hooked end and crimped fibers are designated in the ratios of 0:100, 25:75, 75:25 and 100:0 (Hooked end %: Crimped %). The experimental concrete specimens were casted with four combinations as above in the percentages of 1%, 2%, and 3% along with a conventional concrete without fiber content as reference. The coarse aggregates 20 mm and 12.5 mm are used in the ratio of 60:40, the fine aggregates of river sand and quarry dust are used in 70:30 ratio to get better gradation. The trail mixes are planned to cast the following specimens as per the Indian Standard. The quantities and specimen details for the testing is shown in Table 1.

Table 1 Specimen details for various strength parameter tests of concrete

Size of specimen	No's of specimen per trial	Tests conducted
Cube 150 X 150 X 150 mm	9 no's 3 no's for 7 days strength 3 no's for 14 days strength 3 no's for 28 days strength	Compressive strength
Prism 150 X 150 X 700 mm	3 no's for 28 days strength	Flexural strength
Cylinder 150 mm Dia. X 300 mm height	3 no's for 28 days strength	Split tensile strength

The mix design calculation was done for M35 grade for different trails, as per the guidelines given in IS 10262:2009. The design mix working is given in the appendix. The various design mix proportion quantity was given in Table 2.

A. Mixing and Casting of Concrete

The required quantities of cement, GGBS, river sand, quarry dust, and coarse aggregates for required specimens were weighed. The above raw materials are placed in the pan mixer. The concrete ingredients were like cement, GGBS, steel fibers, coarse and fine aggregates were mixed dry in the mixer for two minutes. Then required quantity of water measured by measuring jar and added in to the pan mixer gradually. After two minutes of wet mixing, required quantity of chemical admixture, here it is Chryso optima S682, is added in to the concrete. After proper mixing, the cubes, prisms & cylinder moulds were packed by homogeneous concrete in 3 different layers, each and every layer was compacted well by rodding 35 blows with slump rod of standard size, to remove entrapped air and avoid any honey combs. After 24 hours of casting of cubes, prisms and cylinders in room temperature, the specimens were removed from their moulds and immersed in the curing tank. The water temperature in curing tank water was maintained at 27 ºC ± 2 ºC by means of cooling & heating arrangements.

Table 2 Proportions of ingredients used for controlled concrete (CC) and modified concrete

Trial Mix No	Steel fiber %	Ratio (Hook: Crimp)	% of Hooked end fiber in concrete	% of Crimped fiber in concrete
01 (CC)	0%	Nil	Nil	Nil
02	1%	0:100	0%	1%
03	1%	25:75	0.25%	0.75%
04	1%	75: 25	0.75%	0.25%
05	1%	100:0	1%	0%
06	2%	0:100	0%	2%
07	2%	25:75	0.5%	1.5%
08	2%	75: 25	1.5%	0.5%
09	2%	100:0	2%	0%
10	3%	0:100	0%	3%
11	3%	25:75	0.75%	2.25%
12	3%	75: 25	2.25%	0.75%
13	3%	100:0	3%	0%

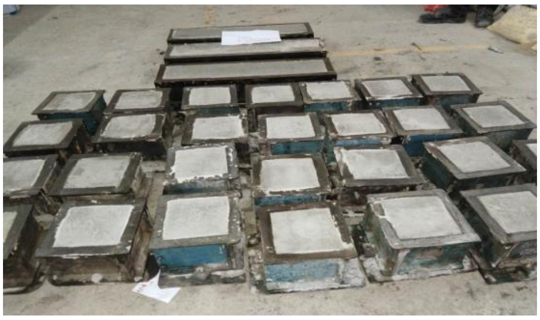

Fig. 1 Hardened Concrete in Cube & Prism Specimens

B. Testing setup for the properties of concrete

The compressive strength test was done on 150 mm size cubes as prescribed in IS 516 using 2000 KN capacity compression testing machine. A gradual moving load was given at the loading rate of 140 kg/cm2 per min until the load failure on cubes is registered and the load at failure of cube specimens was recorded. The mixed fresh concrete was placed in prism of size 150 mm X 150 mm X 700 mm specimens are casted for flexural testing. The specimen was placed above two rollers on the bed of the testing machine. The diameter of steel rollers is 38 mm. These rollers were mounted 600 mm distance apart. The load was applied through two rollers spaced at 200 mm center to center from top. The load was equally divided between the two loading rollers such that the application of load was in axial direction without any torsion stresses or restraints.In the testing setup the prism specimen was placed and the axis of the specimen and axis of the loading device was in same line. The load was applied in the manner of extreme fiber stress are increased at 7 kg/sq.cm/min i.e. the loading rate was 400 kg/min till failure occur in the specimen, and the failure load was recorded.

Flexural Strength (fb) = $p * l / b * d * d$

a= Distance between the nearest support and line of fracture, in cm

b = Width of the specimen in 'cm'

d = Depth of the specimen in 'cm'

l = Length of the span in 'cm'

p = Load at failure in 'kg'

The split tensile strength test was done on 150 mm diameter X 300 mm height cylinders as prescribed in IS 516:1999 using 2000 KN capacity compression testing machine.

The load is applied gradually without any vibrations at a linear range of 1.2 to 2.4 N/(mm^2/min). Once adjusted, maintain this rate until the failure. In each trial mix, three cylinder specimens were tested and their average value was calculated. Split tensile strength of concrete specimen was calculated as follows:

Split tensile strength (MPa) = $2P / \pi DL$

Where, P = Load of failure (N)

D = Specimen diameter in (mm)

L = Length of specimen (mm)

III. RESULTS AND DISCUSSION

Compression test of concrete cube specimens of conventional and various combinations of steel fiber concrete were tested at 7, 14 and 28 days are tabulated here as shown in Tables 3 and better understanding these are graphically represented in Figures 2.

Concrete prism specimens of various trails of design mixes were tested at the age of 28 days. The obtained flexural and split tensile strength results were tabulated in Table 4, their graphical representation is presented in Figure 3 and Figure 4.

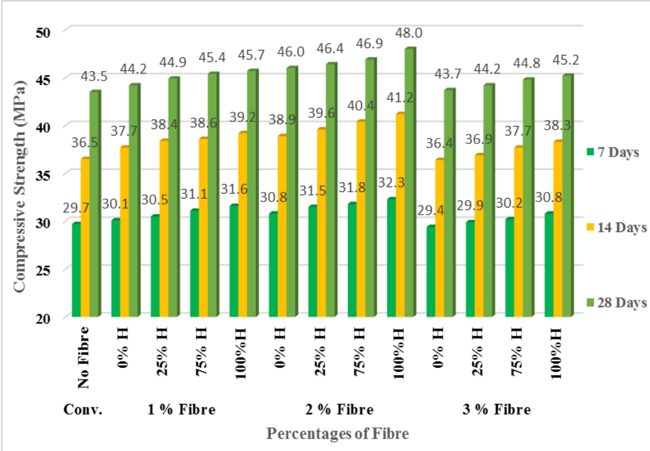

Fig. 2 Compressive strength results of concrete specimens at 28 days

Table 3 Compressive strength results of concrete specimens at 7th, 14th & 28th days

		Compressive strength (N/mm2)		
Sl.no	Description	7th day	14th day	28th day
1.	Conventional Concrete (0% Fiber)	29.7	36.5	43.5
2.	1% Fiber (0%H : 100%C)	30.1	37.7	44.2
3.	1% Fiber (25%H : 75%C)	30.5	38.4	44.9
4.	1% Fiber (75%H : 25%C)	31.1	38.5	45.4
5.	1% Fiber (100%H : 0%C)	31.5	39.2	45.7
6.	2% Fiber (0%H : 100%C)	30.8	38.9	46.0
7.	2% Fiber (25%H : 75%C)	31.5	39.5	46.4
8.	2% Fiber (75%H : 25%C)	31.8	40.4	46.9
9.	2% Fiber (100%H : 0%C)	32.3	41.2	48.0
10.	3% Fiber (0%H : 100%C)	29.4	36.4	43.7
11.	3% Fiber (25%H : 75%C)	29.9	36.9	44.2
12.	3% Fiber (75%H : 25%C)	30.2	37.7	44.8
13.	3% Fiber (100%H : 0%C)	30.8	38.3	45.2

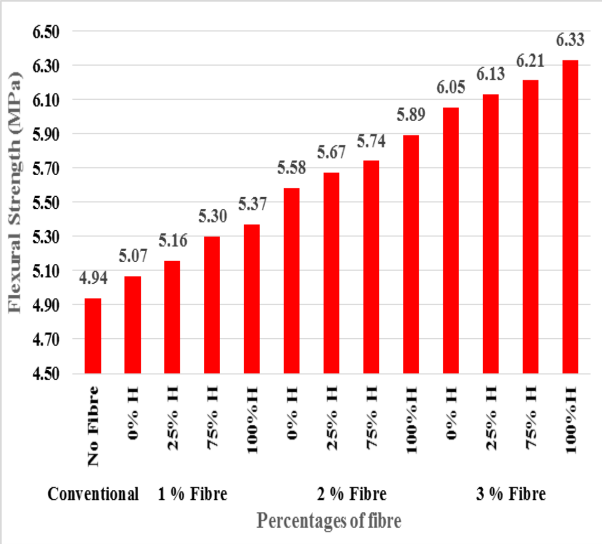

Figure 3 Flexural strength results of different concrete specimens at 28 days

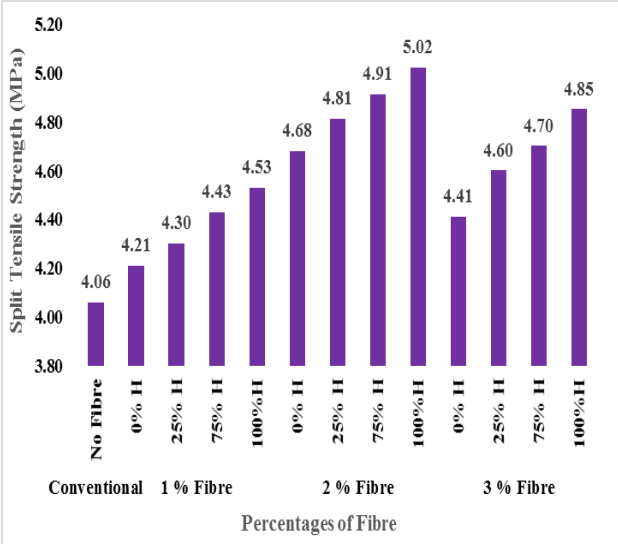

Figure 4 Split tensile strength results of concrete specimens at 28 days

Table 4 Flexural and split tensile strength of concrete specimens

S. No	Description	Flexural strength (N/mm2)	Split tensile strength (N/mm2)
1.	Conventional concrete (0% Fiber)	4.94	4.06
2.	1% Fiber – Hook : Crimp % Ratio – (0:100)	5.07	4.21
3.	1% Fiber – Hook : Crimp % Ratio - (25:75)	5.16	4.30
4.	1% Fiber – Hook : Crimp % Ratio - (75:25)	5.30	4.43
5.	1% Fiber – Hook : Crimp % Ratio - (100:0)	5.37	4.53
6.	2% Fiber – Hook : Crimp % Ratio - (0:100)	5.58	4.68
7.	2% Fiber – Hook : Crimp % Ratio - (25:75)	5.67	4.81
8.	2% Fiber – Hook : Crimp % Ratio - (75:25)	5.74	4.91
9.	2% Fiber – Hook : Crimp % Ratio - (100:0)	5.89	5.02
10.	3% Fiber – Hook : Crimp % Ratio - (0:100)	6.05	4/41
11.	3% Fiber – Hook : Crimp % Ratio - (25:75)	6.13	4.60
12.	3% Fiber – Hook : Crimp % Ratio - (75:25)	6.21	4.70
13.	3% Fiber – Hook : Crimp % Ratio - (100:0)	6.33	4.85

IV. CONCLUSION

The following conclusions are derived based on the results of the experimental investigation,

i. The workability of concrete mix is reducing by increasing percentage of steel fibers compared to conventional concrete. It is necessary to increase the admixture dosage while increasing the percentage of fibers in concrete to avoid slump loss in the concrete.

ii. The maximum percentage of increase in compressive and split tensile strength of concrete at 28 days is found 10.34% and 23.65% in 2% fiber addition of 100% hooked end fibers compared to conventional concrete.

iii. The maximum increase in flexural strength percentage of concrete at 28 days is 28.14% in 3% fiber addition of 100% hooked end fibers compared to conventional concrete.

iv. In addition of steel fibers in concrete flexural strength is got highest increase of 28.14% compared to compressive and split tensile strengths. It has got increasing curve of flexure strength in 28 days up to 3% addition of fibers concrete.

v. The optimum percentage to increase compressive and split tensile strength of concrete at 28 days is found by addition of 2% hooked end type steel fibers and the flexure strength of concrete is found by addition of 3% hooked end type steel fibers.

vi. While mixing two types of fibers like hooked end and crimped type, hooked end type steel fibers are shown better in compressive, flexure & split tensile strengths at 28 days compared to crimped type steel fibers. Those strengths are increased by increasing the percentages of hooked end type in combinations.

vii. As the hook edges of hooked end type steel fibers are helping for better performance to improve compressive, flexural and split tensile strengths, it is understood that mechanical properties of concrete are increased significantly by using 100% hooked end fiber than crimped fiber having same aspect ratio & diameter.

viii. The hooked end shape fibers are increase compressive, flexural and split tensile strength of concrete at 28 days by 3.72%, 5.37 & 8.28% respectively in average, compared to crimped shape steel fibers.

ix. There is a drop in compressive and split tensile strengths are found beyond the addition of 2 % steel fibers which concludes their optimum dosage is 2%. The flexure strength is increasing curve up to 3 % addition of steel fibers the optimum dosage may vary if further higher percentage of steel fibers are added in concrete.

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AUTHORS PROFILE

K. Anand, M.Tech (Structural Engineering) from SRM Institute of Science and Technology, MBA (Marketing) from Mononmaniam Sundaranar University, B.Tech (Civil Engineering) from SRM Institute of Science and Technology, B.Sc Chemistry from University of Madras.

S. Manikandaprabhu, Assistant Professor(Sr.G), Department of Civil Engineering, SRM Institute of Science and Technology, Kattankulathur, Chennai, India. Completed M.Sc (Construction Project Management) from University of Central Lancashire, England, UK and B.E (Civil Engineering) from Periyar Maniammai University, Thanjavur, Tamil Nadu, India

M. Vishnu Nishanth, Post Graduate Student, Department of Civil Engineering, SRM Institute of Science and Technology, Kattankulathur, Chennai. Completed B.E (Civil Engineering) from Sri Krishna College of Engineering and Technology, Coimbatore, Tamil Nadu, India.

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