BEHAVIOR OF STEEL FIPRE REINFORED CONCRETE

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ABSTRACT
Concrete is inherently brittle material with relatively low tensile strength compared to compressive strength. The low tensile strength and limited ductility, the unavoidable deficiency, of concrete can be overcome by the addition of fibres. The experimental study focuses on the effect of fibres on reinforced concrete in terms of strength, deformation and ductility by testing control specimens and standard grade of reinforced concrete with and without fibres. The concrete grade of M60 has been proposed in this investigation. Bundled hooked-end steel fibres with fibrillated polypropylene fibres are proposed in this study. For making concrete, the material properties of cement, fine aggregate and coarse aggregates were studied.
Keywords: Concrete mix, Steel fiber concrete, Strength, Workability.

1. INTRODUCTION

Concrete is the most widely used man made construction material in civil engineering practice. However, plain concrete possesses very low tensile strength, limited ductility and little resistance to cracking. The relatively low tensile strength of concrete is normally considered an unavoidable deficiency of the material. In recent years, high performance concrete is being used for high-rise buildings and long span bridges. To foster compressive strength without sacrificing the ductility, a strategy is to add discrete small fibres as reinforcement in concrete to improve the toughness of concrete by preventing or controlling initiation and propagation of cracks. Fibre reinforced concrete (FRC) is a composite material made of hydraulic cement, aggregates and small-diameter short-length randomly distributed fibres. When concrete cracks, the randomly distributed fibres arrest the micro cracking mechanism and limit the crack propagation thus improving the strength and ductility. The extent of improvement depends on the type, aspect ratio and volume fraction of fibres as well as the quality of concrete mix.

2. REVIEW OF LITERATURE

Yoo et al (2010) carried out a study on the fibre reinforced aerated lightweight concrete which was developed to reduce concretes density and to improve its fire resistance, thermal conductivity, and energy absorption. Compression tests were also performed to determine basic properties of fibre reinforced aerated lightweight concrete. The test variables of the study were the types and volume fraction of fibres and the amount of air in the concrete. Polypropylene and carbon fibres were used in the study. The properties investigated include the unit weight, uniaxial compressive strength, modulus of elasticity, and toughness index. The test results showed that the compressive strength and elastic modulus were strongly dependent on the amount of air in the concrete. Using steel fibres was found to be 31%, 21.74% using glass fibres with 1% fibre Content compared to that of plain concrete.

Nagar et al. (2011) Carried out the Steel fibres have been used in concrete since the early1900s.The early fibre sere round and smooth and the wire was cut or chopped to the required lengths. The use of straight, smooth fibres has largely disappeared and modern fibres have either rough surfaces, hooked ends or are crimped orundulated through their length. Modern commercially available steel fibres are manufactured from drawn steel wire, from slit sheet steel or by the melt-extraction process which produces fibres that have a crescent-shaped cross section.

Mohod (2015) Carried out theSteel Fibre reinforced concrete (SFRC) is defined as concrete made with hydraulic cement containing Fine and coarse aggregate and discontinuous discrete fibre. In SFRC, thousands of small fibres are dispersed and distributed randomly in the concrete during mixing, and thus improve concrete properties. SFRC is being increasingly used to improve static and dynamic tensile strength, energy absorbing capacity and better fatigue strength. **.** Japanesan, P. V. Indira and S. Rajendra Prasad **[1]** reported the effect of steel fibre on the strength and behaviour of reinforced concrete is two-way action. They concluded that the addition of steel fibre increases the ultimate strength and ductility. The plain structure cracks into two pieces when the structure is subjected to the peak tensile load and cannot withstand further load or deformation.

3. OBJECTIVES OF THE STUDY:

It is intended to study the following objectives:

1. To assess the enhancement in mechanical strength of concrete with hybrid fibres.
2. To examine the effects of hybrid fibres on the strength and deformation characteristics of hybrid fibre reinforced concrete.
3. To study the effects on ductility on the performance of hybrid fibre reinforced concrete.
4. To understand the associated cracking and failure mechanisms of tested specimen.

4. METHODOLOGY:

i. Testing of material properties on cement, coarse aggregate, and fineaggregate.

ii. Investigation on discrete fibres.

iii. Preparation of mix design for concrete.

iv. Evaluation of compressive strength of concrete with hybrid fibres.

v. Evaluation of flexural strength of concrete with hybrid fibres.

vi. Casting of concrete with and without hybrid fibres.

vii. Testing of concrete with and without hybrid fibres

viii. Compilation of extensive data on the strength, deformation and failure characteristics as well as ductility of the concrete with hybrid fibres.

ix. Analysis of test data of concrete with and without hybrid fibres.

x. Presentation of detailed summary of recommendations and guidelines for effective utilization of hybrid fibre reinforced concrete in construction industry.

5. MATERIALS:

Following materials were used for the study is described in the following sections**.**

- Ordinary Portland Cement (OPC)
- Aggregate
- Water
- Hooked End Steel Fibres

6. PRELIMINARY TESTS:

6.1 Fineness Modulus ofFine Aggregate andCoarse Aggregate:

The fineness modulus can be found by conducting sieve analysis test. The quantity of the aggregate was taken as 1000g.

Table 1: Grading Limits of Fine Aggregate As Per IS: 383-1970

I.S sieve designation	Percentage Passing by weight for			
	Grading zone I	Grading Zone II	Grading Zone III	Grading Zone IV
10mm	100	100	100	100
4.75mm	90-100	90-100	90-100	95-100
2.36mm	60-95	75-100	85-100	95-100
1.18mm	30-70	55-90	75-100	90-100
600micron	15-34	35-59	60-79	80-100
300micron	5-20	8-30	12-40	15-50
150micron	0-10	0-10	0-10	0-15

6.2 Fibres:

Hooked end steel fibres and polypropylene fibres were used in the study. The properties of fibres provided by the manufacturer are shown in Table 4.9 and Table 4.10 respectively for steel fibres and polypropylene fibres.

Table 2: Properties of Hooked End Steel Fibres

Property	Values
Length (mm)	60
Diameter (mm)	0.75
Aspect Ratio (l/d)	80

7. DESIGN OF CONCRETE MIX:

In this study, standard grade of concrete of M 60 was adopted. For designing the concrete mix, IS 10262-2009 was adopted. The following are the mix design for standard grade concrete.

Requirements for Mix

Specified 28-day works cube strength
= 60 N/mm^2

Very good degree of control; control factor
= 0.80

Degree of workability = Medium

Type of cement=OrdinaryPortland cement

Type of coarse aggregate= crushed granite (angular) of maximum size 20mm.

Type of fine aggregate = natural sand

Specific gravity of cement = 3.10

Specific gravity of fine aggregate = 2.60

Specific gravity of coarse aggregate = 2.50

7.1 DESIGN OF CONCRETE MIX - 0.1%STEEL FIBRE:

In this study, standard grade of concrete of M 60 was adopted. For designing the concrete mix, IS 10262-2009 was adopted. The following are the mix design for standard grade concrete.

Requirements for Mix

Specified 28-day works cube strength
= 60 N/mm^2

Very good degree of control; control factor
= 0.80

Degree of workability = Medium

Type of cement=Ordinary Portland cement

Type of coarse aggregate= crushed granite (angular) of maximum size 20mm.

Type of fine aggregate = natural sand

Specific gravity of cement = 3.10

Specific gravity of fine aggregate = 2.60

Specific gravity of coarse aggregate = 2.61

Steps for Mix Design

Step: 1 - Target Strength for mix proportioning

f'ck= *f'ck* +ks

From Table 1 standard deviation, *s* = 4 N/mm^2

Therefore target strength = 60+1.65 x4= 66.6 N/mm^2

Where

f'ck = Target average compressive strength at 28 days characteristics compressive strength at 28 days.

s = standard deviation.

Therefore, target strength = 60 + 1.65 x 5 = 68.25 N/mm^2

Step: 2 - Selection of water-cement ratio

From Table 5 of IS 456, maximum water-cement ratio = 0.55. Based on experience, adopt water-cement ratio as 0.50. 0.50 < 0.55, Hence O.K.

Step: 3 - Selection of water content

From table 2 of IS 10262-2009, the maximum water content for 20 mm aggregate = 186 litre .Assumed workability for 100 mm slump

Estimated water content for 100 mm slump = 186 + 0.056 x 186 = 197 litre

As super plasticizer is used, the water content can be reduced up to 30 percent. It is proposed to use Glenium B233, an admixture of modified polycarboxylic ether which has a specific gravity of 1.09 and solid contents not less than 30% by weight. Glenium B233 complies with ASTM C494 Type F. In this study, the dosage of hyper plasticizer adopted was 0.8% by weight of binder. Based on trials with chemical admixture, water content reduction of 30 percent has been achieved. Hence, the arrived water content =197 x 0.70 =137.9 litre = 140 litre (approx.)

Step: 4 - Calculation of cement content

Water-cement ratio = 0.50

Cement content =350kg/m^3

From Table 5 of IS 456,

Minimum cement content for 'severe' exposure condition = 320 kg/m^3 350 kg/m^3> 320 kg/m^3, hence, O.K.

Step: 5- Proportion of volume of coarse aggregate and fine aggregate content

From Table 3 of IS 10262-2009,volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II) for water-cement ratio of 0.50 =0.62. For this mix, the water-cement ratio is 0.40. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.10. The proportion of volume of coarse aggregate is increased by 0.02 (at the rate of -/+ 0.01 for every – 0.05 change in water-cement ratio). Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.40 = 0.62.

The mix may be used as a pump able concrete, these values should be reduced by 10 percent.

Therefore, volume of coarse aggregate = 0.62 x 0.9 = 0.56.

Volume of fine aggregate content =1 - 0.56 =0.44.

Step:6- Mix Calculations

Mix calculations per unit volume of concrete shall be as follows:

Volume of concrete= 1 m^3

Volume of cement= mass of cement/specific gravity of cement x 1/1000= [355.95/3.15] x [1/1000] = 0.113 m^3

Volume of water= [140/1] x [1/1000] = 0.140 m^3

Volume of all in aggregate =1-(0.113 +0.140+0.006) =0.741m^3

Mass of coarse aggregate= 0.741 x 0.56 x 2.50 x 1000 = 1037.40 kg

Mass of fine aggregate = 0.741 x 0.44 x 2.60 x 1000 = 848 kg

Mix proportions for trial:

Cement	= 350 kg/ m^3
Water	= 140 lit/ m^3
Fine aggregate	= 848 kg/ m^3
Coarse aggregate	= 1037.40 kg/ m3

By adding of steel fibre at 0.1% of cement =350 gm/m^3

Water-Cement ratio = 0.5

Based on the above mix proportions, a trial study has to be made in the field 1:2.5:3.

7.2 COMPRESSIVE STRENGTH TEST:

In the case of cubes, the specimen is placed in the machine in such a manner that the load is applied to opposite sides of the cubes as cast. The axis of the specimen is carefully aligned with the centre of thrust of the spherically seated plate. No packaging is used between the faces of the test specimen and the steel plate of the testing machine. A spherically seated block is brought to bear on the specimen; the movable portion is rotated gently by hand so that uniform seating may be obtained.

Fig 1: (i)Bundled Hooked-EndSteel Fibres, (ii)casting of concrete cube, (iii)Compression test, (iv) Specimen after testing

Table 4: Compressive Strength of SFRC of 0.1% Added

Type of specimen	Area (mm²)	Compressive StrengthN/mm²		
		7days	14days	28days
Cube 1	22500	34.0	49.5	69.6
Cube 2	22500	33.3	49.2	68.7
Cube 3	22500	34.2	48.6	69.2

The average compressive strength of steel fibre concrete of 0.05% of steel fibre. This strength is very well suited for M60 grade concrete. The average compressive strength of steel fibre concrete of 0.05% of steel fibre is N/ mm². This strength is very well suited for M60 grade concrete.

8. **RESULT AND DISCUSSION**

Static tests were conducted on all four cube and observations were made moment curvature, load Vs deflection, moment crack widths were plotted. The results obtained for steel fibre. Concrete M60 grade show the encouraging results.

8.1 STEEL FIBRE CONCRETE:

The concrete mix was kept as.The percentage of steel is kept as 0.05% and 0.1%. The compressive strength of SFC (N/mm²) – 0.05% of steel fibre, SFC (N/mm²) – 0.1% of steel fibre and PCC (N/mm²) are tabulated below:

Table 5: Compressive Strength of 0.05% Steel Fibre Concrete

Type of specimen	Percentage of Steel Fibre	Compressive Strength N/mm ²	Average Strength N/mm²
Cube 1	0.05%	66.3	66.3
Cube 2		66.7	
Cube 3		66.0	

Table 6: Compressive Strength of 0.1% Steel Fibre Concrete

Type of specimen	Percentage of Steel Fibre	Compressive Strength N/mm²	Average Strength N/mm²
Cube 1	0.1%	69.6	69.2
Cube 2		68.7	
Cube 3		69.2	

Table 7: Compressive Strength of PCC

Type of specimen	Compressive Strength N/mm²	Average Compressive Strength N/mm²
Cube 1	63.0	63.1
Cube 2	63.3	
Cube 3	62.8	

9. CONCLUSION

Based on the use of Bundled hooked-end steel fibres as a ingredient of steel fibre concrete was investigated. The following conclusions are drawn.

1. The slump value of the fresh concrete based steel fibre concrete increases without addition of extra water added to the mixture.
2. The static compressive strengthof cube specimen
   a. Conventional Cubes. 63.1N/mm^2
   b. SFC -0.05% of steel fibre. 66.3N/mm^2
   c. SFC -0.1% of steel fibre. 69.2N/mm^2
3. From the above result it is found that flexural strength of steel fibre concrete for 0.05% is = 5.1% higher compare to conventional Cubes.
4. From the above result it is found that flexural strength of steel fibre concrete for 0.1% is = 9.6% higher compare to conventional Cubes ref fig 2 and fig 3.

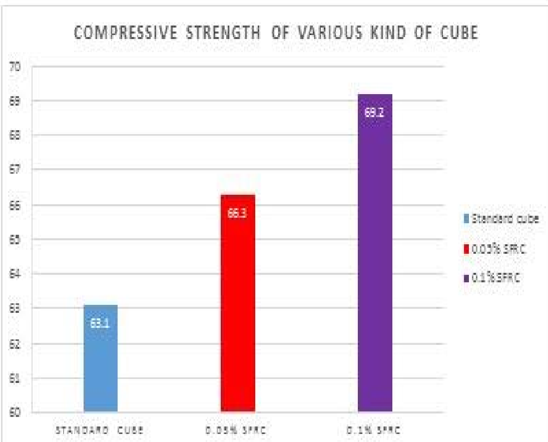

Fig 2: Compressive strength in Bar Chart

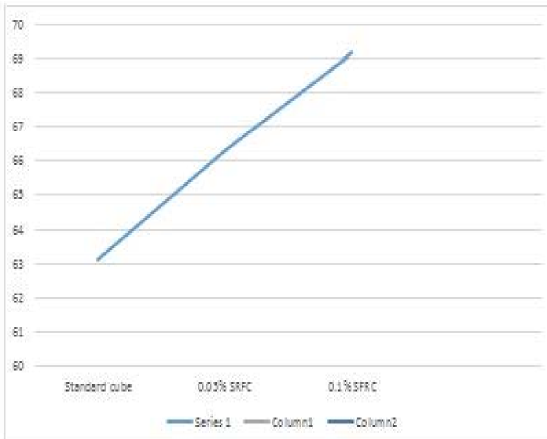

Fig 3: Compressive Strength in Line Chart

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