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ANALYZING FLEXURAL STRENGTH IN STEEL-FIBER-REINFORCED CONCRETE BEAMS THROUGH EXPERIMENTAL TESTING

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ABSTRACT
Despite being the most widely used building material in the world, traditional reinforced concrete has to be updated due to its brittle failure mechanism under stress. Concrete is combined with short steel fibres to bring back its brittleness. This study examines the flexural behaviour of RC beams and determines the optimal ratio of steel fibre insertion. Hooked end steel fibres with a diameter of 0.75 mm and a length of 50 mm are included into reinforced concrete beams to achieve the required concrete compressive strength of 30 MPa (M30). Steel fibres added to the concrete mix at the following percentages: zero, seventy-five hundredths of a percent, one percent, one and a quarter of a percent, and one and a half of a percent were tested on fifteen cubes, fifteen cylinders, and fifteen beams. 700 mm is the length, 150 mm is the width, and 150 mm is the depth of the beam. The flexural behaviour of reinforced concrete beams with steel fibre additions was compared to ordinary (or conventional) reinforced beams without steel fibres using a third-point loading test apparatus made for M30 concrete.
The ideal ratio of steel fibres, hooked-end steel fibres, and flexural behavior/flexural strength are all important.

.I.INTRODUCTION

Structural concrete is the most extensively used construction material in the world. Concrete is a brittle nature with resist the little capacity of tensile stress without cracking. It requires reinforcement, in the form of continuous reinforcing bars are placed in the structure at the suitable locations to withstand the tensile and shear stresses.

Steel fibers are most commercial type of fiber uses in fiber reinforced concrete. Steel fibers are short, discontinuous, and randomly placed throughout the concrete. This type of concrete is known as fiber reinforced concrete. The steel fibers are used to prevent the plastic and shrinkage in concrete. The steel fibers are increase the flexural toughness, ductility and energy absorption capacity, then reduces the cracking and improving durability of the concrete. Steel fiber reinforced concrete also known as steel-fiber-added concrete.

This steel fiber reinforced concrete is used in dam constructions, large slabs and floors with heavy load, tunnel linings, marine structures, dynamic loading conditions. The additional steel fibers has more effect on the flexural strength of concrete compared to tensile and compressive strength. Steel fiber reinforced concrete is superior resistance to cracking. The hooked end steel fibers density is 7.85g/cm^3 and tensile strength is 1100Mpa.

The steel fibers are ability to arrest cracks. The fibers are able to hold the matrix together and extensive cracking. The fiber reinforcement is short, discrete fibers, they act effectively in the concrete matrix. Fiber reinforced concrete improve the resistance of cracking, deflection and other serviceability conditions.

Definition

It is defined as short, discrete lengths of steel fibers with a dia of 1mm and length 50mm with different cross-sections. The certain amount of steel fiber in concrete's physical property, greatly increasing resistance to cracking, fatigue, bending, impact, durability and other properties. It can be categorize into five groups, it's depending on the manufacturing process and its section: mill cut, cold-drawn wire, cut sheet, modified cold-drawn wire.

Advantages

Steel fibers resist to withstand heavy loads, and dynamic or static. Steel fibers resist to minimize cracks in hardened concrete. Steel fibers increase load bearing capacity, durability, impact, abrasion. Steel fibers improve flexural properties. Even distribution of fibers throughout the concrete. It reduce the absorption of water.

Objectives

To see the optimum percentage of the precise variety of SFs utilized in this study for M30 and C50 of concrete supported the cube compressive strength and flexural strength tests with five different SF dosages of 0%v/v, 0.75%v/v, 1%v/v, 1.25%v/v and 1.5%v/v. To work out the structural flexural behaviour of steel-fiber- added concrete (SFARC) beams of M30 of concrete, containing the optimum percentage of the SFs as determined within the previous step, compared against the standard RC beams of the identical concrete grades.

Fig. 1.1 Steel fiber

II.METHODOLOGY

2.1. General

In this experiment, a study made by casting of concrete mix cubes and beams with water-cement from 0.3 to 0.5 and addition of steel fibers with the quantity of 0%, 0.75%, 1%, 1.25% and 1.5%. Then tested for 7days, 14days, 28days compressive strength and flexural strength. By using these experimental values compressive strength and flexural strength found out.

Materials

The following materials are used in this project and each material explained indetail.

Cement

1. Fine aggregate
2. Coarse aggregate
3. Steel fiber
4. Water

2.1.1 Cement and their properties

Cement is a preferred binding material, is a important civil engineering material. A cement is a substance used for construction that sets, hardens, and bond to other materials to bind them together. Cement is infrequently used on its own, but rather to bind sand and gravel (aggregate) together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. In this project investigation OPC 53 grade cement is used. By the adding of water in cement is called hydration. The extreme heat generated when water reacts in cement. The released heat is depend on the cement composition, curing temperature, water cement ratio and fineness.

Fig. 2.1.Ordinary Portland cement

2.2. Physical properties of cement

1. Fineness of cement
2. Soundness
3. Consistency
4. Strength
5. Setting time
6. Heat of hydration
7. Specific gravity
8. Fineness of cement:

The fineness of cement has a vital relating the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offers a greater expanse for hydration and hence faster the event of strength. The fineness of grinding has increased over the years. The greater surface area the hydration rate will be grater. The rapid strength depends on the fineness of cement. Strength of concrete or cement will depend on fineness of cement.

Fig. 2.2: Fineness of cement

Trial	Weight of Cement	Weight of residue	%of fineness
1.	100g	4.9	4.9%
2.	100g	4.85	4.85%
3.	100g	5.15	5.15%

Table 2.1 Observations of fineness of cement

Fineness of cement is 4.96

Standard Consistency of cement:

The Standard Consistency Test is performed to estimate the quantity of water to shape a standard consistency paste. it's determined through the use of 10 mm plunger vicat apparatus. The range of consistency by weight of Ordinary Portland Cement usually varies between 25 and 35%.

Table 2.2 Observations for consistency of cement

S No.	Weight of cement (W1) (g)	Weight of water (W2) (g)	Penetration Readings (mm)	W2/ W1	Standard consistency
1	400	104	33	0.26	26
2	400	112	24	0.28	28
3	400	120	9	0.3	30
4	400	128	5	0.32	32

From the above observations the standard consistency of cement paste is 32%

Initial and final setting time

The initial setting time is that the amount between adding water to cement and also the point at which the 1 mm square section needle doesn't penetrate the cement paste, positioned from the bottom of the mould within the Vicat's 5 mm to 7 mm mould.

The final setting time is that the fundamental measure between the time water is applied to cement and therefore the point at which 1 mm needle creates an impression on the paste within the mould but no impression is formed by the 5 mm attachment.

Fig. 2.3 Vicat apparatus

Table 2.3: observations of initial setting time

S No	Time (Mins)	Vicat apparatus Readings
1	5	0
2	10	0
3	15	0
4	25	0
5	35	0
6	45	6
7	55	8

Initial and final setting time of cement is 45 minutes and 310 minutes respectively.

Soundness of cement

Soundness is ability of the hardened cement paste to keep up its volume after setting destructive expansion directly (PCA 1988). Excessive quantities of free lime (CaO) or magnesia (MgO) are accountable for this harmful growth. Le-Chatelier apparatus is used to see the soundness of cement.

Soundness of cement is 1mm

Specific gravity of cement

Cement's specific gravity is that the ratio of the weight of any given volume of matter to the weight of the same volume of standard liquid. it's a mere number, which refers to how many times a material is heavy as standard liquid. Density bottle is used to find to relative density of cement. Kerosene is used during this test because it's a non-polar.

Fig. 2.4: Specific gravity of cement

Specific Gravity of Kerosene (k) = (W4-W1)/ (W5-W1)

Specific Gravity of cement (c) = [(W2-W1)/ ((W4-W1)-(W3-W2))] *k

Trial No.	W1	W2	W3	W4	W5
1.	30.465	41.70	78.68	70.05	80.76
2.	30.465	42.50	79.32	70.05	80.76
3.	30.465	41.80	78.28	70.05	80.76

Table 2.4 Observations for Specific Gravity of Cement.

Specific gravity of cement is 3.15

Physical properties of cement	Results
Standard consistency (%)	32
Initial setting time (minutes)	45

Final setting time(minutes)	310
Fineness modulus (%)	7.5
Soundness(mm)	1
Specific gravity	3.15

Table 2.5. Physical properties of cement.

Chemical properties of cement:

Compositions	**% Content**
Lime (CaO)	60 – 67%
Silica (SiO2)	17- 25%
Alumina (Al2O3)	03 – 08%
Iron oxide (Fe2O3)	0.5 – 06%
Magnesium oxide (MgO)	0.5 – 04%
Alkalies (K2O, Na2O)	0.3 - 1.3%

Table 2.6 Chemical properties of cement.
Bogue's Compounds

Name of compound	**Formula**	**Abbreviation**	**Percentage by mass in cement**
Tricalcium silicate	3CaOSiO2	C3S	30 - 50%
Dicalcium silicate	2CaOSiO2	C2S	20 – 45%
Tricalcium aluminate	3CaOAl2O3	C3A	08 – 12%
Tetracalcium aluminoferrite	4CaO, Al2O3, Fe2O3	C4AF	06 – 10%

Fine aggregate

In this experimental investigation present river sand is used. The sand which is passing through the 4.75mm sieve and retained on 75µ sieve is used. Sand is of zone-II as per IS 383-1970. within the mortar 70%to80% of volume occupies by the fine aggregate.

Fig. 2.5.Fine aggregate

Sieve analysis of fine aggregate:

The sieve analysis is determine the size of particle distribution of the fine aggregates and also determine suitable to ue in concrete mixing. This analysis determine the zone of the sand and fineness modulus. This analysis utilize to draw the particle size distribution curve for fine aggregate.

Table 2.7.: Grading of fine aggregate (∑Cumulative percentage of weight retained)/100

Sieve size (mm)	**Weight Retained on Sieve (g)**	**Percentage weight retained (%)**	**Cumulative percentage (%)**	**Percentage of finer (%)**
10	0	0	0	100
4.75	25	1.25	1.25	98.75
2.36	108	5.4	6.65	93.35
1.18	200	10	16.65	83.35
0.6	285	14.25	30.9	69.1
0.3	1108	55.4	86.3	13.7
0.15	225	11.25	97.55	2.45
Pan	49	2.45	100	0

= (0+1.25+6.5+16.65+30.9+86.3+97.7)/100

Fineness modulus = 2.39

Specific gravity of fine aggregate:

Specific gravity is thought because the ratio of Aggregate weight to weight of equal water volume. the specific gravity of an aggregate is viewed as a measure of the material 's strength or consistency. In general, aggregates that have low relative density (or) specific gravity are under those with high relative density (or). This property assists within the detection of aggregates generally.

Fig. 2.6: Specific gravity of fine aggregate

Description of test	results
Specific gravity	2.7
Water absorption	2%
Fineness modulus	2.39
Zone	ii

Coarse aggregate

The aggregate retained on the 4.75mm sieve is called as a coarse aggregate. Gravel, cobble and boulders return underneath this class. Then 40mm size aggregate using for mean strength and 20mm size used for higher strength.

Fig.2.7. Coarse aggregate

Coarse aggregate size variation

Particular	Results
Aspect ratio	20-100
Length	6.5-80mm
Dia	0.25-10mm
Tensile strength	275-2760mpa
Young's modules	$200*10^3$ Mpa
Ultimate elongation	0.5-35%

Coarse aggregate	Size
Fine gravel	4mm – 8mm
Medium gravel	8mm – 16mm
Coarse gravel	16mm – 64mm
Cobbles	64mm – 256mm
Boulders	>256mm

Properties of coarse aggregate

Coarse aggregate	Result obtained
Specific gravity	2.8
Impact value	9.2
Crushing value	0.82
Water absorption	0.2%

Water

As per IS 456 : 2000 the portable water should be used in concrete mixing. The water is free from organics material and clean, odourless, colourless. The pH value range from 6.5 to 8.5 for concrete mixing.

Steel fiber

Steel fibers are available only in European market within the 1980's. steel fibers are new technology to adopt now a days. Generally the steel fibers are increase the flexural toughness, ductility and energy absorption capacity, then reduces the cracking and improving durability of the concrete. the quantity of fibers added within the concrete mix is expressed because the proportion of the total volume of the concrete. Some recent study indicate that using fibers in concrete has inadequate effect on the impact resistance of the material. during this project 50mm length and 0.75mm dia hooked steel fibers are used. Steel fibers are gives high tensile strength. the typical tensile strength of steel fibers is > 1100Mpa.

Chemical Composition in Steel Fibers

Oxides	Volume
Carbon	0.05-0.15%
Manganese	0.45-0.6%
Phosphorus	0.05-0.6%
Sulphur	0.040%
Nitrogen	0.010-0.14%

Physical Properties of Steel fibers:

III.MIX DESIGN

3.1MIX DESIGN PROCEDURE FOR M30 OPC

Mix design procedure

Mix design is the process of defining the essential and specified characteristics of a concrete mixture. The quantified concrete characteristics can be fresh concrete properties, mechanical properties of the hardened concrete for example strength and durability requirements and the addition or exclusion of specific ingredients. Mix proportioning on the other hand is the process of determining the quantities of concrete ingredients using local materials to achieve the specified characteristics of the concrete

Table 3.1 Material properties

Cement grade	53 OPC
Cement specific gravity	3.15
Coarse aggregate (20mm)	2.8
Fine aggregate	2.7
Zone corresponding to fine aggregate	Zone II
Slump	100mm
Exposure Conditions	Severe
Target strength	38.25MPa
w/c ratio	0.45
Minimum cement content	320 kg/m^3
Maximum cement content	450 kg/m^3

IV.EXPERIMENTAL INVESSTIGATION

4.1.TESTING OF SPECIMENS

Cubes, beams and cylinders are tested for the compressive strength, flexural strength, and spilt tensile strength severally for 7days, 14days, 28days. three kinds of specimens are employed in these research speciffically the cubes, beams, and cylinders.
TEST PROCEDURES

4.2.SLUMP CONE TEST

Objective

The slump cone test is that the foremost typically used methodology of measure the workability of concrete which could use either with within the laboratory or at the field. it is not associate applicable methodology for more wet or dry concrete. It doesn't quantify all elements adding to the functionally, nor it's consistently delegate of the placeability of the concrete.
It shows the concrete characteristics are additional to the slump value. If the concrete equally slumps it's called as true slump. On the off chance that cone slides down the portion, it's referred to as shear slump**.**
Apparatus Required

A metallic shape cone of a dimensions is top Dia 10 cm, bottom Dia 20 cm, height 30 cm and thickness of metallic sheet not more slender than 1.6 mm.
Tamper rod dimensions is length 600 mm and 16mm Dia
Ruler.

4.3.PROCEDURE

If this test is being exhausted the field, the instance blended concrete are going to be gotten. within the case of concrete containing aggregate of size in way over 38 mm, the concrete are going to be wet seived through one and half inch screen to prohibit aggregate particles greater than 38 mm.

The mould are placed on a smooth, horizontal, inflexible and non -absorbent surface, for instance, flat metal plate, the mould being held founded while it's being filled.

The mould should be filled in four layers, every roughly twenty - five percent of the height of the mould. each layer shall be tamped with 25 blows by tamping rod.

The concrete are affected off level by using trowel, in order that the mould is exactly filled.
After the tamping of top layer, take out the top of the concrete by ways for screeding and resonant movement by using tamping rod.

The mould should be lift up gradually and thoroughly in vertical direction.

This permits the concrete to subside and so known the slump shall be straightway by measuring the excellence between the height of the mould and tested specimen highest point. the above activities are done at place free form vibration, and within two minutes following testing

Fig. 4.1 Slump cone test

4.4.COMPACTION FACTOR TEST

Objective

It is more exact and sensitive than the slump test and particularly valuable for concrete mixes of very low workability and ordinarily utilized when concrete is to be compacted by vibration. the strategy applies to plain and air entrained concrete, made with lightweight, ordinary weight or substantial aggregate shaving a nominal extreme size of 38 mm or less however to not circulated air through concrete or no - fines concrete
Apparatus Required

- Balance
- Scoop
- Trowel
- Tamper
- Ruler
- Procedure

The sample of concrete to be tested shall be placed softly within the upper container, utilizing the hand scoop. fill the container and level with its edge and therefore the entryway are opened then the concrete falls into lower container.

Certain blends tend to stay in either of the

containers. on the off chance that this happens, the concrete is also helped through by pushing the bar gently into the concrete at the top. during this procedure, the trowels are covered the cylinder.
Immediately when the concrete had stopped, the cylinders are revealed, the lower container trap-door is opened and so the concrete fall to shoe the cylinder.

The surface of the cylinder should be cleaned. the highest process shall be allotted at free from vibration. the cylinder with concrete weight shall then be determined to the closest 10g.
The surplus of concrete remaining staying above the cylinder can at that point be removing by trowel.

This weight are going to be called because the weight of partially compacted concrete. the cylinder is full of concrete by layers approximately 5cm deep, and rammed or vibrated to accumulate full compaction.
The cylinder surface will at that time be cleaned off.

Fig. 4.2 Compaction factor test

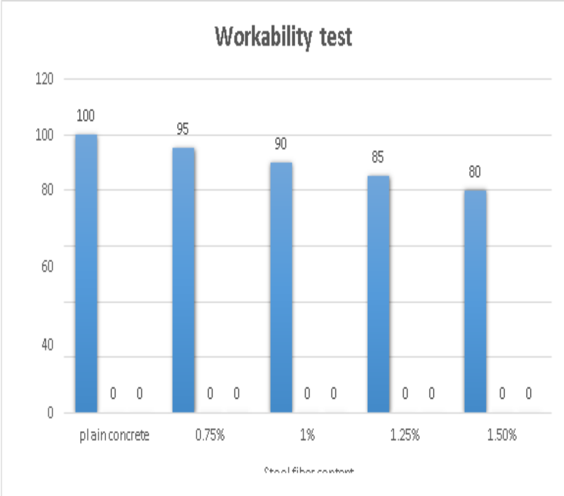
V.TEST DATA AND RESULTS

5.1. TEST RESULTS FOR VARYING STEEL FIBER CONTENT

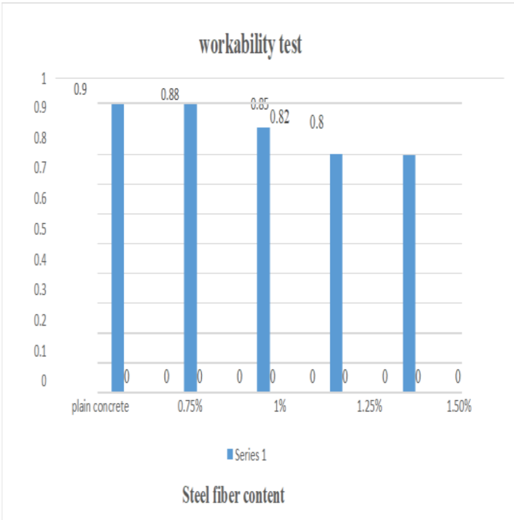
WORKABILITY OF CONCRETE TEST RESULTS FOR VARYINGSTEEL CONTENT

Table 5.1 Workability of concrete tests results for varying steel fibercontent

Steel fiber content	**Slump cone**	**Compaction factor**
Plain concrete (0%)	100	0.90
0.75%	95	0.88
1%	90	0.85
1.25%	85	0.82
1.5%	80	0.80



Graph 5.1. Slump cone test result for varying steel content

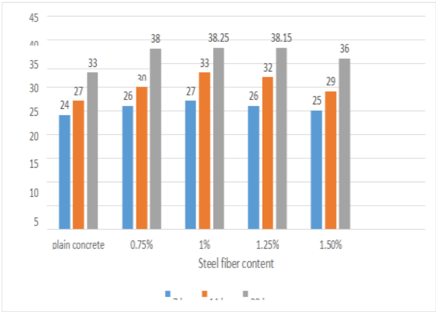


Graph 5.2. Compaction factor test result for varying steel fiber content

5.2 COMPRESSIVE STRENGTH TEST RESULT FOR VARYING STEEL FIBER CONTENT

Table 5.2 Compressive strength test results for varying steel fiber content

	7 Days	**14 Days**	**28 Days**
Steel fib ercontent	**Compressiv estrength (N/MM^2)**	**Compressiv e strength (N/MM^2)**	**Compressiv e strength (N/MM^2)**
0%	24	27	33
0.75%	26	30	38
1%	27	33	38.25
1.25%	26	32	38.15
1.5%	25	29	36

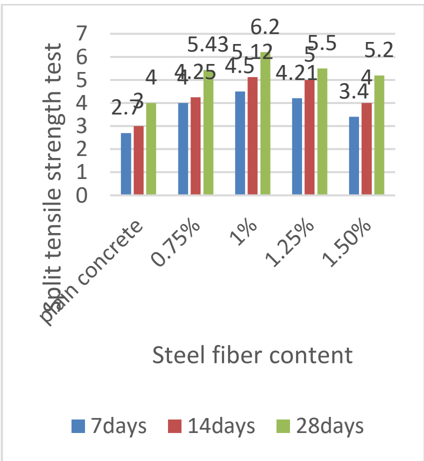


Graph 5.3. Compressive strength test for varying steel content

5.3 SPLIT TENSILE STRENGTH RESULTS FOR VARYING STEEL FIBER CONTENT

Table 5.3 Split tensile strength test results for varying steel fibers

	7 Days	14 Days	28 Days
Steel fiber content	**Split tensile strength (N/MM^2)**	**Split tensile strength (N/MM^2)**	**Split tensile strength (N/MM^2)**
0%	2.7	3	4
0.75%	4	4.25	5.43
1%	4.5	5.12	6.2
1.25%	4.21	5	5.5
1.50%	3.4	4	5.2

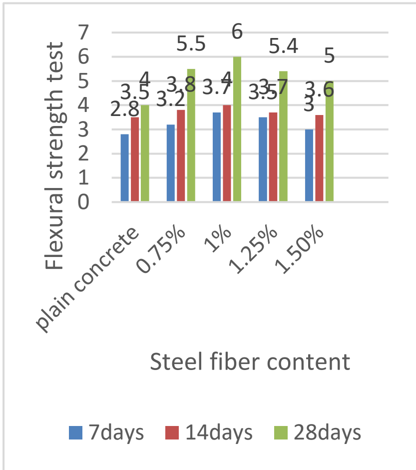


Graph 5.4. Split tensile strength test for varying steel content

5.4 FLEXURAL STRENGTH TEST RESULTS FOR VARYING STEEL FIBER CONTENT

Table 5.4 Flexural strength test results for varying steel fiber content

	7 Days	14 Days	28 Days
Steel fiber content	**Flexural strength (N/MM^2)**	**Flexural strength (N/MM^2)**	**Flexural strength (N/MM^2)**
0%	2.8	3.5	4
0.75%	3.2	3.8	5.5
1%	3.7	4	6
1.25%	3.5	3.7	5.4
1.50%	3	3.6	5



Graph 5.5. flexural strength test result for varying steel fiber content

VI.CONCLUSION

According to the results of the different proportion of the steel fiber contents, it's strengths are observed for M30 grade of concrete. In this experiment the steel fiber contents are varying (0%, 0.75%, 1%, 1.25%, 1.5%) by concrete volume. In this percentages 1% is the optimum for the flexural strength, compressive strength and split tensile strength test.

The results of the three-point loading test on the steel fiber reinforced concrete beam made from M30 grade of concrete.

Compressive strength of cube the highest strength is observed at 1% of steel fiber content. In M30 grade of concrete at adding 1% of steel fiber resulted 16% increase in compressive strength.

split tensile strength of cylinder in M30 grade of concrete adding 1% of steel fiber resulted 55% increases in split tensile strength.

flexural strength of beam in M30 grade of concrete adding 1% of steel fiber resulted 50% increase in flexural strength.

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