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Study of the Compressive Strength Behaviour of Steel Fibre Reinforced Concrete Using Various Percentage of Steel Fibre

*Tarun Gehlot [1], Divanshu Seervi [2], Dr. Peeyush Chowdhary [3]
[1](*M.E Scholar, Structural Engineering Department MBM engineering college JNV university Jodhpur, Rajasthan India)*
[2](*M.E Scholar, Structural Engineering Department MBM engineering college JNV university Jodhpur, Rajasthan India)*
[3] (*Associate Professor, Structural Engineering Department MBM engineering college JNV university Jodhpur, Rajasthan India)*
Corresponding Author: Tarun Gehlot

Abstract : *The objective of this Research investigation was to study the compressive strength behavior of Steel Fibre Reinforced Concrete (SFRC) using Round straight fibres with aspect ratio of 75 .Specimens were cast without fibres and with fibres of 0.5%, 1%, 1.5% and 2 %. Compressive strength test were conducted on cube. A total of 24 cubes of dimension 150x150x150 mm were casted. The steel fibres used in the experiment were obtained from binding steel wires used in tying reinforcement bars. These wires were properly cut to obtain a length of 6 cm and diameter of steel fibre was 0.8 mm with aspect ratio of 75.*

Keywords**:** *FRC, SFRC, UTM, OPC, PCC, ASTM*

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I. INTRODUCTION

It is now well established that steel fibre reinforcement offers a solution to the problem of cracking by making concrete tougher and more ductile. It has also been proved by extensive research and field trials carried out over the past three decades, that addition of steel fibres to conventional plain or reinforced and pre stressed concrete members at the time of mixing/production imparts improvements to several properties of concrete, particularly those related to strength, performance and durability. Many types of steel fibres are used for concrete reinforcement. Steel fibres greatly increase toughness of concrete, which primarily is used for crack and shrinkage controls, to serves as secondary reinforcement for pavements, slabs, pipes, channel and tunnels. Its potential improvement to increase toughness, minimize cracking due to temperature changes and resistance due to extreme loading and environment such as impact, abrasion, blasting and fatigue. Furthermore, steel fibre-reinforced concrete greatly reduces the potential for fractures and spalling.. The steel fibres used in the experiment were obtained from binding steel wires used in tying reinforcement bars. Aspect ratio of the steel fibres was 75. These wires were properly cut to obtain a length of 6 cm. The diameter of steel fibre was 0.8 mm and tensile strength of steel fibre is 1500 N/mm^{2}. The necessity for the addition of fibers in structural material is to increase the strength of the concrete and mortar and also to reduce the crack propagation that mainly depends on parameters like Strength characteristics of fiber, Bond at fiber matrix interface ,Ductility of fibers ,Volume of fiber reinforcement and shape and aspect ratio of fiber.

II. RESEARCH METHODOLOGY

The aim of this research is to use the Steel Fibres as Fibre reinforcement to concrete. Our objective is to add the Steel fibres to the concrete and to study the compressive strength properties of concrete (M20 Grade) for fibre content of 0.5%, 1%, 1.5 % and 2% at 28 days. The main properties of Steel Fibre Reinforced concrete are discussed below.

2.1 TOUGHNESS

The main reason for incorporating steel fibres in concrete is to impart ductility and otherwise brittle material. Steel fibre reinforcement improves the energy absorption, impact resistance and crack resistance of concrete. Steel fibre reinforcement enables the concrete to continuously carry load after cracking ,called post crack behavior variety of tests have been developed to measure and quantify the improvements achievable in steel fibre reinforced concrete.

2.2 DURABLITY

The corrosion resistance of Steel Fibre Reinforced Shotcrete (SFRS) is governed by the same factors that influence the corrosion resistance of conventionally reinforced concrete. As long as the matrix retains inherent alkalinity and remains un cracked, deterioration of SFRC is not likely to occur. It has been found that good quality SFRC when exposed to atmospheric pollution, chemicals or a marine environment, will only carbonate to a depth of a couple of millimeters over a period of many years.

2.3 SEISMIC RESISTANCE

By using SFRC in a beam-column joint, some of the difficulties associated with joint construction can be overcome and a greater seismic strength can be provided. One joint was built according to ACI 318-71. The other joint was reduced steel congestion common in seismic resistant joints by replacing hoops with steel fibre concrete. Brass plated steel fibres with a length of 1.5-in (38 -mm) and an aspect ratio of 75 were added to the concrete mix at a volume fraction of 1.67%. An earthquake loading was simulated using a quasi-static loading rate utilizing an applied double acting hydraulic actuator.It was found that the steel fibre reinforced concrete joint had a higher ultimate moment capacity, had better ductility, was stiffer, and was more damage tolerant.

2.4 SHEAR RESISTANCE

Large earthquakes result in high shear forces within the beam-column joint. To withstand such forces, hoop spacing is decreased within the joint region. This can sometimes result in congestion problems that can result in construction difficulty. SFRC can be used with increased hoop spacing to provide higher shear resistance.

2.6 COMPRESSIVE SRENGTH BEHAVIOUR WITH STEEL FIBRE REINFORCED CONCRETE

Compressive strength is little influenced by steel fibre addition. High compressive this can be achieved using silica fume or fly ash. However, the use of steel fibres the mode of failure of high strength concrete from an explosive brittle one to a more ductile one, again showing the increased toughness of SFRC and its ability to absorb energy under dynamic loading. The fibre type, volume fraction and aspect ratio play important roles in determining the compressive ductility and energy absorption capacity of fibre reinforced concrete. The material behaviour is generally enhanced as the volume fraction and aspect ratio of fibres increase up to limits after which the problems with fresh mix workability and fibre disperse ability start to damage the hardened material properties.. Due to their material properties, steel fibres do not at all influence the strength parameters of concrete. Under compressive loading, when micro cracking occurs because of transverse tension forces, steel fibres cause crack-closing forces, on the one hand. This leads to an increase of compressive strength. On the other hand, porosity increases when steel fibres are mixed in with the fresh concrete. This effect decreases the compressive Strength of steel fibre reinforced concrete. Both effects in combination have the tendency to cancel each other out. The influence of fibres in improving the compressive strength of the matrix depends on whether mortar or concrete (having coarse aggregates) is used and on the magnitude of compressive strength.

III. EXPERIMENTAL PROGRAM

The objective of this research investigation was to study the behavior of Steel Fibre Reinforced Concrete (SFRC). Straight rounded steel fibres with aspect ratio of 75 were used. Specimens were casted without fibres and with fibres of 0.5%, 1%, 1.5 % and 2% .Tests were conducted for studying the compressive property and Compressive strength tests were conducted on cube . A total of 24 cubes of dimension 150X150X150 mm were casted. The steel fibres used in the experiment were obtained from binding steel wires used in tying reinforcement bars. These wires were properly cut to obtain a length of 6 cm. The diameter of steel fibre was 0.8 mm.

Five types of specimens were prepared and designated as S-0, S-1, S-2, S-3 and S-4.
S-0: Control Concrete containing no fibres (PCC).
S-1: Concrete containing 0.5% steel fibres by volume of concrete.
S-2: Concrete containing 1% steel fibres by volume of concrete.
S-3: Concrete containing 1.5% steel fibres by volume of concrete.
S-4: Concrete containing 2% steel fibres by volume of concrete.

3.1 **MIX DESIGN FOR M20 GRADE CONCRETE (IS 10262:2009)**

Proper design of concrete mixture is intended to obtain such proportioning of ingredients which will produce concrete of high durability performance during the designed life of a structure, usually 50 years.

STEP 1 DESIGN STIPULATIONS FOR PROPORTIONING
i. Grade designation: M20
ii. Type of cement: OPC 43 grade confirming to IS 8112
iii. Maximum nominal size of aggregates: 20 mm

iv Maximum water cement ratio: 0.55
v. Workability: 75 mm (slump)
vi. Exposure condition: Mild
vii. Degree of supervision: Good
viii. Type of aggregate: Crushed angular aggregate
ix. Chemical admixture: not used
STEP 2 TEST DATA FOR MATERIALS
p) Cement used: OPC 43 grade confirming to IS 8112
q) Specific gravity of cement: 3.15
r) Specific gravity of
Coarse aggregate: 2.68
Fine aggregate: 2.65
s) Water absorption
Coarse aggregate: 0.6 percent
Fine aggregate: 1.0 percent
t) Free (surface) moisture
Coarse aggregate: Nil (absorbed moisture full)
Fine aggregate: Nil
u) Sieve analysis
Coarse aggregate: Conforming to Table 2 of IS: 383
Fine aggregate: Conforming to Zone II of IS: 383
STEP 3TARGET STRENGTH FOR MIX PROPORTIONING
fck = fck + 1.65 s Where fck = Target average compressive strength at 28 days,
fck = Characteristic compressive strength at 28 days,
s= Standard deviation
From Table 1 standard deviation, s = 4 N/mm2
Therefore target strength = 20 + 1.65 x 4 = 26.60 N/mm2
STEP 4 SELECTION OF WATER CEMENT RATIO
From Table 5 of IS: 456-2000, maximum water cement ratio = 0.55 (Mild exposure)
Based on experience adopt water cement ratio as 0.50
0.5 < 0.55, hence ok

STEP 5 SELECTION OF WATER CONTENT
From Table-2, maximum water content = 186 liters
Estimated water content for 75 mm slump = 186 + 3/100 x186 = 191.6 liters

STEP 6 CALCULATION OF CEMENT CONTENT
Water cement ratio = 0.50
Cement content = 191.6/0.5 = 383 kg/m3
From Table 5 of IS: 456, minimum cement content for mild exposure condition = 300 kg/m3
Hence OK

STEP 7 PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT
From Table 3, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II) for water-cement ratio of 0.50 =0.62. Aggregates are assumed to be in SSD.

STEP 8 MIX CALCULATIONS
The mix calculations per unit volume of concrete shall be as follows
a) Volume of concrete = 1 m3
b) Volume of cement = Mass of cement/specific gravity of cement *1000
= [383.16/3.15] x [1/1000] = 0.122 m3
c) Volume of water = [192/1] x [1/1000] = 0.192 m3
d) Volume of all in aggregates (e) =a – (b + c)
= 1 – (0.122 + 0.192) = 0.686 m3
e) Volume of coarse aggregates = e x Volume of CA x specific gravity of CA
= 0.686 x 0.6 x 2.68 x 1000 = 1103 kg
f) Volume of fine aggregates= e x Volume of FA x specific gravity of FA
= 0.686 x 0.4 x 2.65 x 1000 = 727 kg

Table 1: MIX PROPORTION:

Cement	Water	Fine Aggregate	Coarse Aggregate
383	191.6	727	1103
1	0.50	1.89	2.88

3.1.1 Materials Required For A Batch Of M20 Grade Concrete:
STEP 1 VOLUME CALCULATIONS:
Volume of 1 cube = 3.375 x 10-3 m3
Volume of 1 cylinder = 5.30 x 10-3 m3
Volume of 1 beam = 50 x 10-3 m3
Total volume to be filled with concrete = 958.20 x 10-3 m3

STEP 2 QUANTITY CALCULATIONS:
Cement required = 958.20 x 10-3 x 383
= 366.99 kg
Fine Aggregate = 958.20 x 10-3 x 727
= 696.61 kg
Coarse Aggregate = 958.20 x 10-3 x 1103
= 1056.9 kg
Water required = 0.50 x cement content
= 0.50 x 383
= 183.49 liter

3.2 CASTING OF SPECIMENS:

The materials were weighed accurately using a digital weighing instrument. For plain concrete, fine aggregates, coarse aggregate, cement, water were added to the mixture machine and mixed thoroughly for three minutes. Steel fibres were sprinkled randomly inside the mixture after thorough mixing of the ingredients of concrete so that homogenous mix is formed. For preparing the specimen for compressive, tensile, and flexure strength permanent steel moulds were used. Before mixing the concrete the moulds were kept ready. The sides and the bottom of the all the mould were properly oiled for easy demoulding
.

Table 2 : Different types of Specimen

Specimen Mould		Dimension
1	Cube	150X150X150 mm

3.3 CURING:

Curing is the process of preventing the loss of moisture from concrete while maintaining a satisfactory temperature. More elaborately curing is defined as process of maintaining satisfactory moisture content and favorable temperature in concrete during the period immediately following placement, so that hydration of cement may continue until the desired properties are developed to a sufficient degree to meet the requirement at service. After casting the moulded specimens are stored in the laboratory and at a room temperature for 24 hours from the time at addition of water to dry ingredients. After this period the specimens are removed from the moulds immediately submerged in clean and fresh water. The specimens are cured for 28days in the present work.

3.4 TESTS ON HARDENED CONCRETE: COMPRESSIVE STRENGTH TEST

This test was conducted as per IS 516-1959. The cubes of standard size150x150x150mm were used to find the compressive strength of concrete. Specimens were placed on the bearing surface of UTM, of capacity 300 tones without eccentricity and a uniform rate of loading of 140 Kg/cm was applied till the failure of the cube. The maximum load was noted and the compressive strength was calculated.
Cube compressive strength = $(\sigma_{cc}) = P_f / A_b$ in N/mm^2
Strength of concrete is its resistance to rupture. It may be measured in a number of ways, such as, strength in compression, in tension, in shear or in flexure In order to determine the compressive strength, a total number of 24 cubes were casted. After 24 hours of casting, the specimens were demolded and cured under water in a curing pond. At the end of curing period, the above specimens were tested in a compressive testing machine as per: IS: 516-1989

IV. RESULT

The results obtained during the experiment are provided in terms of charts and tables .7 & 28 days compressive strength of steel fibre reinforced concrete are compared with each other for a clearer representation of how percentage of steel fibres added affects the strength of concrete.

4.1: 7 Days Compressive Strength

Design Mix: 1:1.89:2.88 & w/c ratio = 0.50

Table 3: Result of 7 days Compressive strength

Sample	1st Reading	2nd Reading	3rd Reading	Average Reading	Compressive Strength (N/mm^2)
S-0	310	330	320	320	14.22
S-1	360	355	341	352	15.644
S-2	385	365	360	370	16.44
S-3	342	345	333	340	15.11

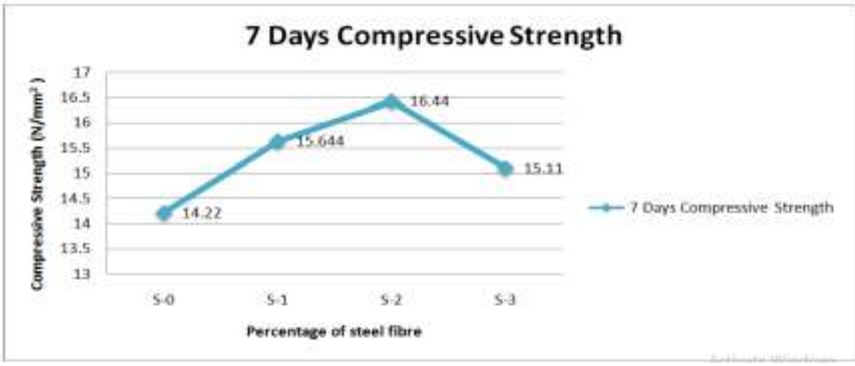

Figure 1: Compressive Strength for 7 days with different % of steel fibre

4.2: **28 Days Compressive Strength**

Design Mix: 1:1.89:2.88 & w/c ratio = 0.50

Table 4: Result of 28 days Compressive strength

Sample	1st Reading	2nd reading	3rd Reading	Average Reading	Compressive Strength (N/mm^2)
S-0	545	550	545	546	24.26
S-1	595	600	590	598	26.55
S-2	610	615	620	615	27.33
S-3	525	538	527	530	23.55

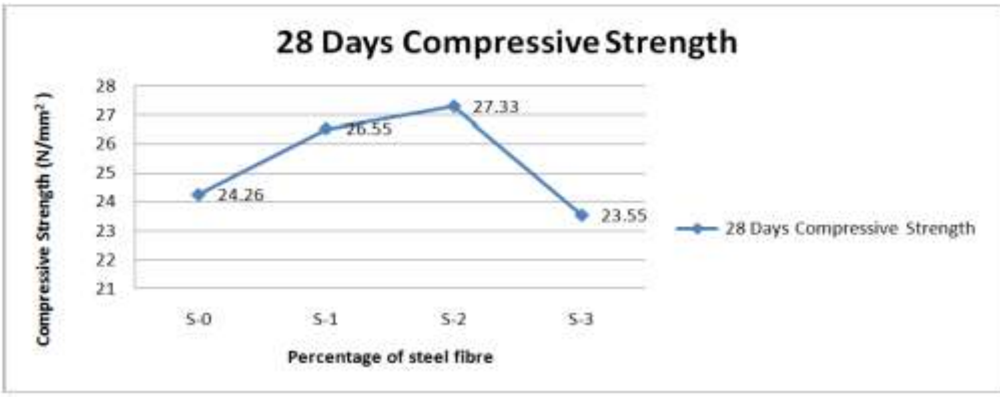

Figure 2: Compressive Strength for 28 days with different % of steel fibre

4.3: **7 Days vs. 28 Days Compressive Strength Comparison**

Design mix: 1: 1.89:2.88 & w/c :0.50

Table 5: 7 days Vs 28 days compressive strength comparisons

Sample	7 Days Compressive Strength (N/mm^2)	28 Days Compressive Strength (N/mm^2)
S-0	14.22	24.26
S-1	15.644	26.55
S-2	16.44	27.33
S-3	15.11	23.55

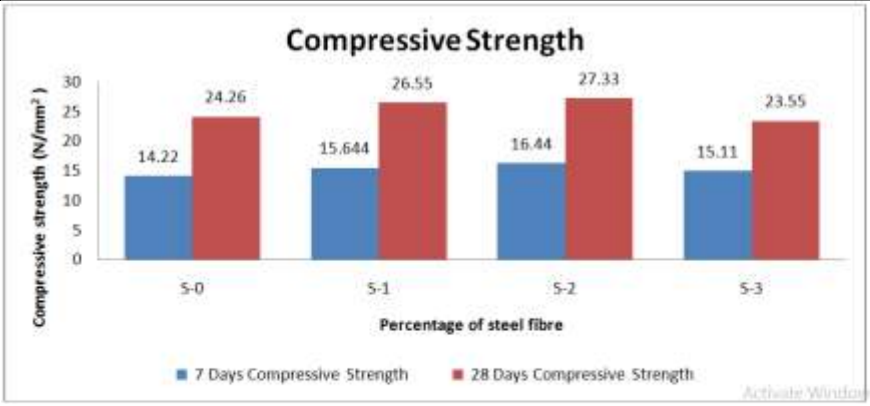

Figure 3: Bar chart of Variation of compressive strength for 7 days and 28 days with different % of steel fibre

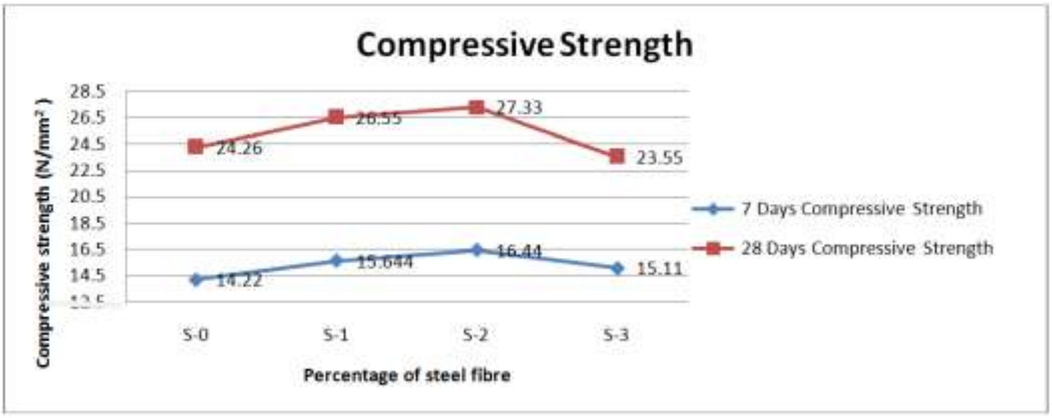

Figure 4: Comparison of 7 days and 28 days Compressive Strength with different % steel fibre

V. CONCLUSION

1. The strength of the steel fibre reinforced concrete depends largely on the quantity of fibres added to it. The increase in the volume of fibres, increase approximately linearly.
2. Use of higher percentage of fibre is likely to cause segregation and hardness of concrete and mortar and also the workability of concrete is greatly reduced.
3. The 7 & 28 days compressive strength of the concrete increases linearly with the increase in amount of steel added to it, but to a maximum of 1% steel fibre inclusion. After that the compressive strength decreases. So the optimum percentage of steel fibre inclusion is 1% by volume of the concrete mix

Parameter (28 Days-N/mm^2)	PCC	Optimum % Of Steel fibre inclusion	Steel Fibre Reinforced Concrete (SFRC)	% increase in Strength
Compressive strength	24.26	1%	27.33	12.65%

Table 6 : Variation of different parameters of steel fibre reinforced concrete

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