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Performance Evaluation of Fiber Reinforced Concrete at Different Temperatures

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Abstract

Concrete is a composite material whose constituents have different properties and also depends on moisture and porosity. Exposure of concrete to elevated temperature affects its mechanical and physical properties. An increase in temperature causes an increase in initial strength and reduces long-term strength. Fibers are added to the concrete in order to improve the characteristics. This study's scope is to evaluate the effect of varying percentages of steel fibers in the concrete mixture subjected to different temperatures and to determine the optimum usage of steel fiber reinforced concrete in the construction field and to prove certain advantages it can provide over conventional practiced.

Keywords*: - Fiber reinforced concrete, Cylinders and beams, Mechanical and physical properties, Coarse aggregates, Steel fibers*

INTRODUCTION

Concrete is a composite material containing hydraulic cement, water, coarse aggregate and fine aggregate. The resulting material is a stone-like structure, which is formed by the chemical reaction of the cement and water. This stone-like material is a brittle one, which is strong in Compression, favorable in Flexure, but very weak in Tension. Concrete structural members, when used in buildings, have to satisfy appropriate fire safety requirements specified in building codes. Fire represents one of the most severe environmental

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conditions to which structures may be subjected. Therefore, the provision of appropriate fire safety measures for structural members is an important aspect of building design.

Fire is one of the most severe risks to buildings and structures. Exposure to fire is undoubtedly the most destructive process that a concrete structure can be subjected to during its service life. Under high-temperature effect, chemical composition, physical structure and moisture content of concrete changes. These changes are primarily observed at the cement paste and then at the aggregates as well. Heating to high temperatures causes the dehydration of hardened cement paste and conversion of calcium hydroxide into calcium oxide in which chemically bound water is gradually released to become free water. As a result, the bond becomes weak and a sudden crack occurs and affects the concrete to fail.

FIBER REINFORCED CONCRETE:

Fiber-reinforced concrete (FRC) is defined as a composite material of cement concrete or mortar along with certain discontinuous discrete and uniformly dispersed fiber. Fiber is a small piece of reinforcing material possessing certain characteristic properties. They can be circular, triangular, rectangular or flat. The fibers are often described by a convenient parameter called the aspect ratio. The aspect ratio of the fiber is the ratio of the length to its diameter. The typical aspect ratio ranges from 30 to 150. Fiber-reinforced concrete (FRC) is a building material whose utilization in the concrete industry has been rapidly increasing. Recently, many comprehensive studies have been undertaken with the aim to observe the mechanical behaviour of FRC exposed to elevated temperature. These fibers act as crack arrestors and increase the structural integrity of the concrete. By their incorporation, there will be a shift from the usual limitation of concrete restricted to pre-cracking behaviour to a definite and measurable post-cracking behaviour. This forms an interface between the first cracks of concrete – stress transfer on the reinforcing steel and visibly extends the duration between the same, giving sufficient warning and breathing time, as well as reducing the ill-effects on the RC structure due to sudden release of energy at the first crack level. This also results in optimizing the load-carrying/moment capacities of the entire RC structure when properly modelled, analyzed and designed.

2. Materials

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Ordinary Portland Cement [53 Grades]:

Table 1: Test results of Ordinary Portland cement (OPC)

Particulars	Results	References
Normal consistency %	29	IS:12269-2008
Specific gravity	3.15	IS: 12269-2008
Setting time(minutes)		IS: 12269-2008
a)Initial setting time	80	Should not be less than 30 min
b) Final setting time	170	Should not be less than 600 min

Coarse Aggregates:

Coarse aggregate used is graded aggregate of nominal size 20mm and they confirm to Table 2 of IS: 383-1970.

Table 2: Physical properties of coarse aggregate

IS SIEVE	Weight retained	Cumulative weight retained	Cumulative percentage retained	Percentage passing
40	0	0	0	100
20	0.135	0.135	2.7	97.3
10	2.59	2.725	54.5	45.5
4.75	1.94	4.665	93.3	6.7

Fine Aggregates:

Fine aggregates used confirms to Zone II (Table 4) of IS: 383-1970. Fine aggregate used is M-sand.

Table 3: Physical properties of fine aggregates

IS SIEVE (mm)	Weight retained (g)	Cumulative weight retained (g)	Cumulative % retained	% passing
10	0	0	0	100
4.75	26	26	5.2	94.8
2.36	74	100	20	80
1.18	85	185	37	63
600µ	66	251	50.2	49.8
300µ	113	364	72.8	27.2
150µ	89.5	453.5	90.7	9.3
PAN	46.5	500	100	-

Water:

Table 4: Properties of water

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Sl no	Properties	Readings
1	pH	7.72
2	Acidity	Nil
3	Specific conductance	835 micro/mhos
4	Total hardness	274 mg/litre
5	Chloride	105 mg/litre
6	Turbidity	1NTU
7	Sulphate	63 mg/litre
8	Calcium	109 mg/litre
9	Magnesium	17 mg/litre
10	Na	10 mg/litre
11	K	2 mg/litre
12	Alkalinity	260 mg/litre
13	TDS	500 mg/litre
14	Iron	0.04 mg/litre
15	Fluoride	0.7 mg/litre
16	Nitrate	7 mg/litre

Fibers (Steel):

Hooked end steel fibres are filaments of wire, deformed and cut to lengths, for reinforcement of concrete, mortar and other composite materials. Dramix® RC-80/60-BN is a cold drawn wire fibre, with hooked ends and glued in bundles. Geometry: 60 mm Length (l) Diameter (d) 0.75 mm Performance class: 80 Aspect ratio (l/d): 80.

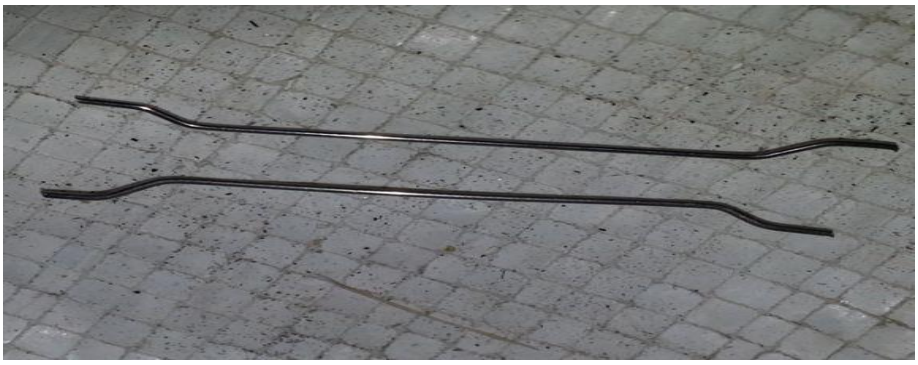


Figure 1: Hooked End Steel Fiber

3. METHODOLOGY

Mix design has been carried out for M35 grade of concrete, as per relevant Indian standard Code. Mix designing is carried out to arrive at the quantities required for a 1-meter cube of concrete.

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Details of specimen: To study the effect of elevated temperature, concrete cubes, Cylinders and Beams are to be tested in order to determine the strength characteristics of the concrete. Three different temperatures, 50° C, 100 °C and 150°C, are chosen. Specimen with fiber percentage 0%, 1%, 2%, 3% are cast.

Relevant tests are conducted on fresh and hardened concrete and the results are finally analysed.

The various tests that were conducted are;

1. Compressive strength test
2. Split-tensile strength test
3. Flexural strength test

Result and Discussion:

Compressive strength test:

Table 5: Compressive strength at different temperatures for addition of 1% steel fiber

Temperature	**Compressive strength(N/mm^2)**	**Percentage Variation in Strength**
Room temperature	54.27	100
At 50^{o}C	59.13	108.9
At 100^{o}C	64.52	118.8
At 150^{o}C	70.98	130.7

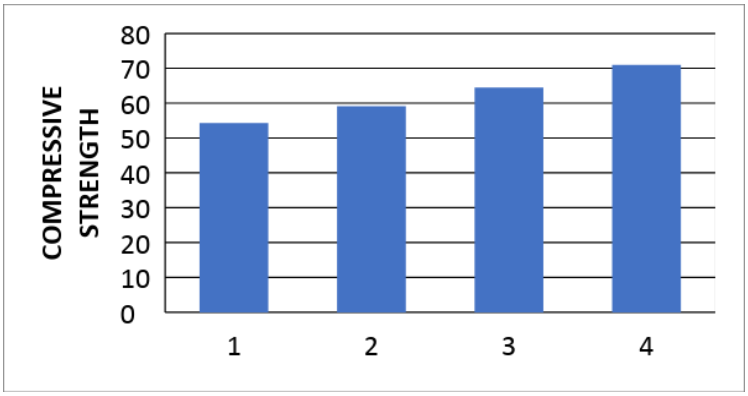


Fig 2: Variation of compressive strength at different temperatures for addition of 1% Steel fiber

Table 6: Compressive strength at different temperatures for addition of 2% steel fiber

Temperature	**Compressive strength (N/mm^2)**	**Percentage Variation in Strength**

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Room temperature	47.60	100
At 50^{o}C	49.35	103.6
At 100^{o}C	54.19	113.8
At 150^{o}C	59.87	125.7

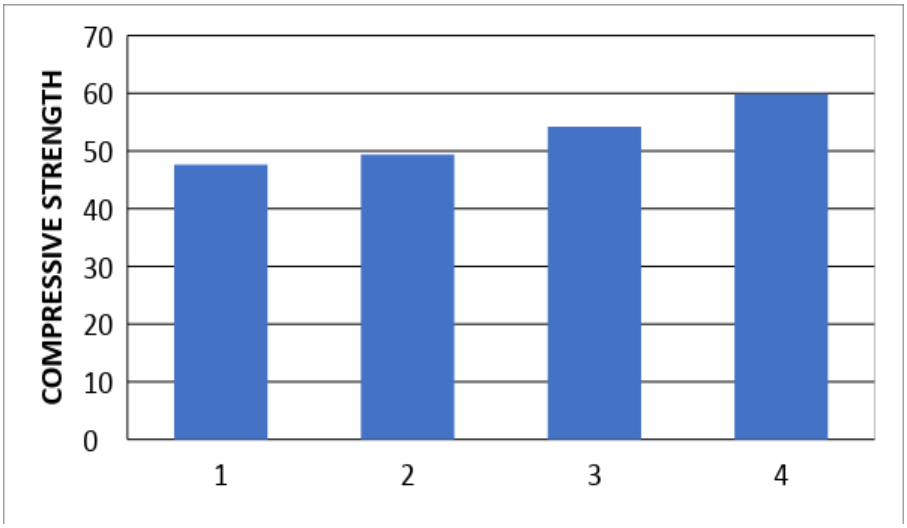


Fig 3: Variation of compressive strength at different temperatures for addition of 2% Steel fiber

Table 7: Compressive strength at different temperatures for addition of 3% steel fiber

Temperature	Compressive strength(N/mm^2)	Percentage Variation In Strength
Room temperature	46.29	100
At 50^{o}C	47.80	103.3
At 100^{o}C	52.65	113.7
At 150^{o}C	57.3	123.8

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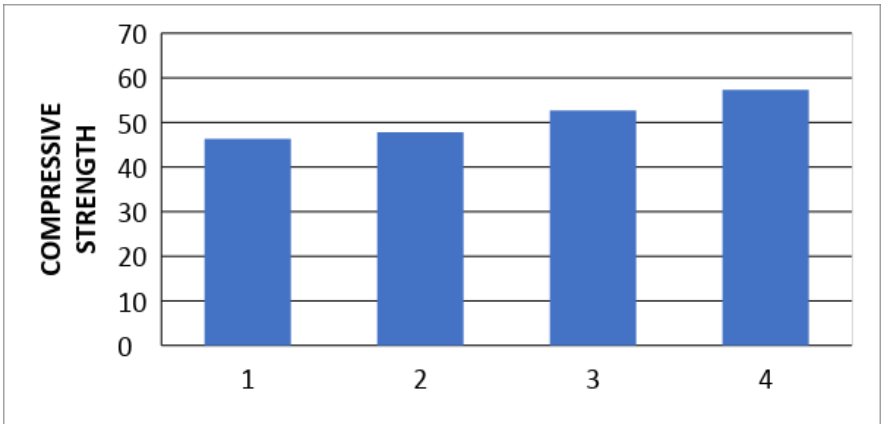


Fig 4: Variation of compressive strength at different temperatures for addition of 3% steel fiber

Split Tensile Strength:

Table 8: Split tensile strength at different temperatures for addition of 1% steel fiber

Temperature	TENSILE STRENGTH (N/mm^2)	Percentage e Variation In Strength
Room temperature	4.804	100
At 50^oC	5.056	105.2
At 100^oC	5.316	100.6
At 150^oC	5.647	117.5

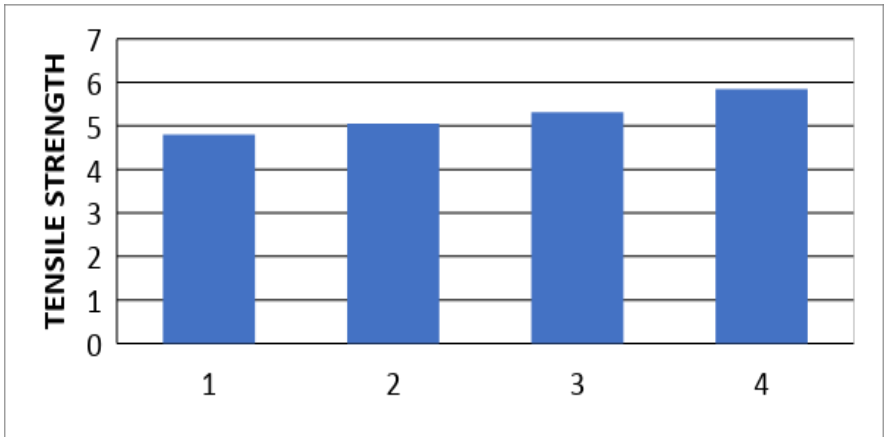


Fig 5: Variation of tensile strength at different temperatures for addition of 1% Steel fibers

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Table 9: Split tensile strength at different temperatures for addition of 2% steel fiber

Temperature	**TENSILE STRENGTH (N/mm^2)**	**Percentage Variation In Strength**
Room temperature	4.972	100
At 50^oC	5.289	106.4
At 100^oC	5.534	111.3
At 150^oC	5.978	120.2

Table 10: Split tensile strength at different temperatures for addition of 3% steel fiber

Temperature	TENSILE STRENGTH (N/mm^2)	Percentage Variation In Strength
Room temperature	5.312	100
At 50^oC	5.700	107.3
At 100^oC	5.970	112.4
At 150^oC	6.485	122.0

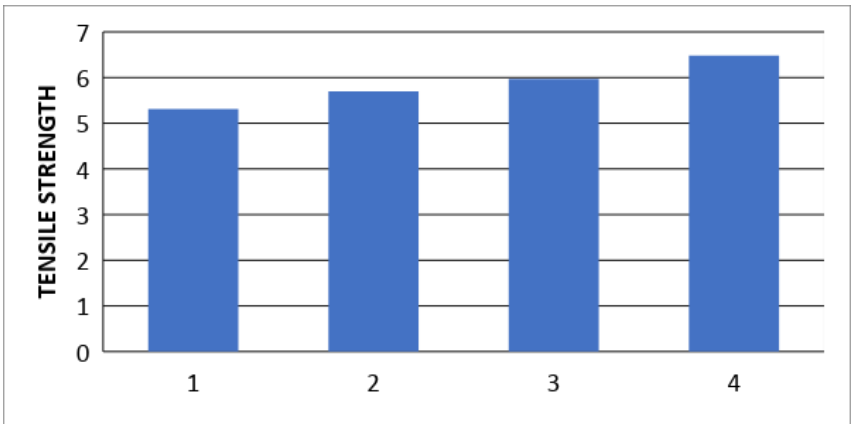


Fig 7: Variation of tensile strength at different temperatures for addition of 3% Steel fibers

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Flexure Strength

The results of the flexure strength of specimens with various percentages of STEEL Fiber is tabulated below:

Table 11: Flexure Strength at Different Temperatures for Normal Mix Concrete

Temperature	**Flexure Strength (N/mm2)**	**Percentage Variation in Strength**
Room temperature	4.780	100
At 50oC	5.262	110.0
At 100oC	5.873	122.8
At 150oC	6.47	135.4

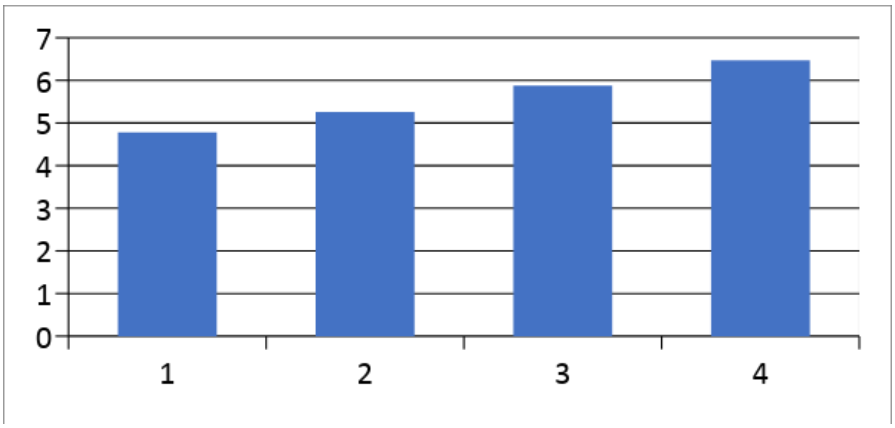


Fig 8: Variation of flexure strength at different temperatures for 0% of steel fiber.

Table 12: flexure strength at different temperatures for addition of 1% steel fiber

Temperature	**Flexure Strength (N/mm2)**	**Percentage Variation In Strength**
Room temperature	5.312	100
At 50oC	5.700	107.3
At 100oC	5.970	112.4
At 150oC	6.485	122.0

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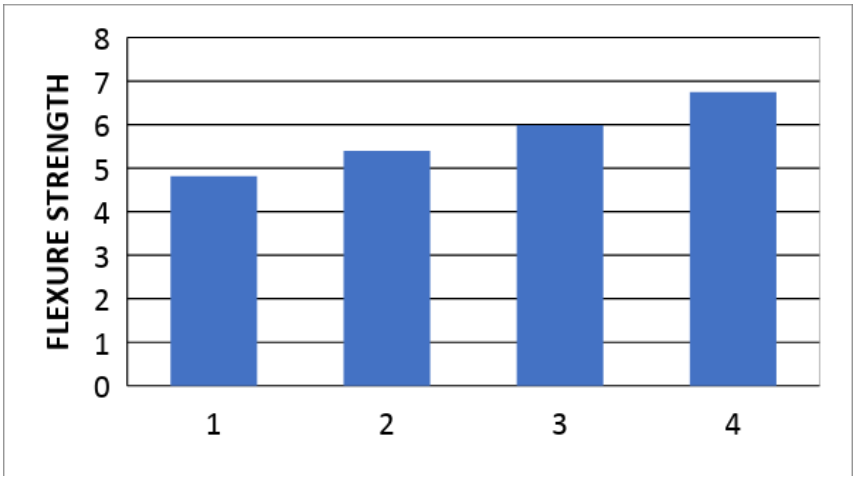


Fig 9: Variation of flexure strength at different temperatures for addition of 1% of steel fiber.

Table 13: flexure strength at different temperatures for addition of 2% steel fiber

Temperature	**FLEXURE STRENGTH (N/mm2)**	**Percentage Variation In Strength**
Room temperature	4.976	100
At 50oC	5.674	114.0
At 100oC	6.498	130.5
At 150oC	7.517	151.0

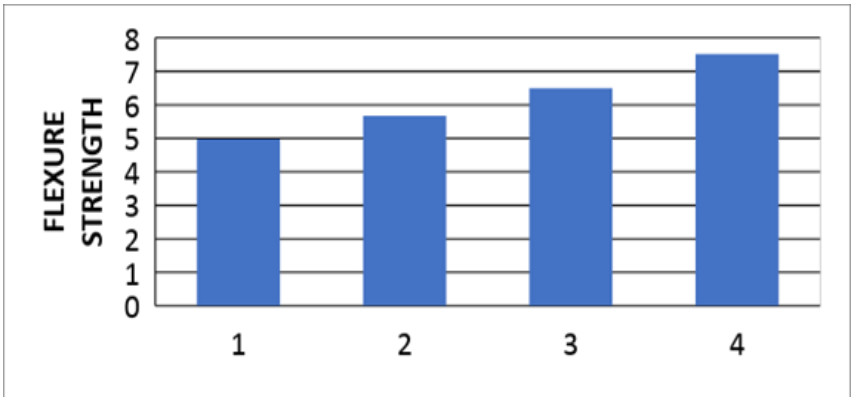


Fig 10: Variation of flexure strength at different temperatures for addition of 2% of steel fiber.

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Table 14: flexure strength at different temperatures for addition of 3% steel fiber

Temperature	**Flexure strength(N/mm2)**	**Percentage Variation in Strength**
Room temperature	5.350	100
At 50oC	6.247	116.8
At 100oC	7.430	138.8
At 150oC	8.939	167.0

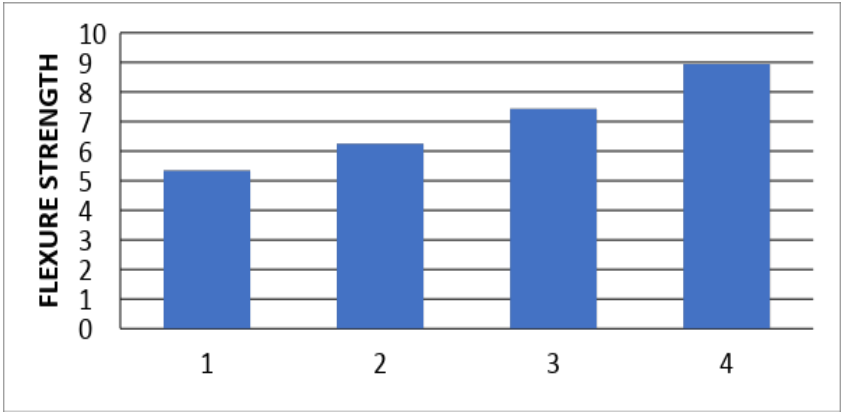


Fig 11: Variation of flexure strength at different temperatures for addition of 3% of steel fiber

CONCLUSIONS

Based on the experiment conducted on steel fiber reinforced concrete using the local materials, we have arrived at the following conclusions:

a) As the fiber volume increases, the tensile and flexural strength increases. But the incorporation of steel fibers in concrete had a small effect on the compressive strength. Overall from the observations, it can be said that an increase in strength is directly proportional to the fiber content in the specimen.

b) The flexural toughness results show that the specimen with a higher dosage of steel fibers is capable of withstanding more loads even after the failure.

c) The fresh density of concrete increases gradually by increasing the dosage of steel fibers.

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The residual strength increases with an increase in the dosage of steel fibers.

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