



# An Experimental Investigation on Mechanical Properties of High Strength Fiber Reinforced Concrete

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**ABSTRACT:** Concrete is the most widely used construction material. It is prepared together mixing cementing materials, aggregates, water in required proportions. Admixtures are ingredients other than water, aggregate and cement that are added to a concrete mixture prior to or during mixing.

At present a large scale production of cement is useful for construction which causes global warming on one side and depletion of natural resources on other side. So that different pozzolanic materials like silica fume, Fly ash, are used in concrete as admixtures. The present study was to evaluate the mechanical properties of M50 grade concrete by replacing 10%, 15% of silica fume and 10%, 20% of fly ash to cement, 0.5% steel hook fibers are used by volume fraction as admixture for all proportions of HSFRC. The main objective of the present work is to develop M50 grade concrete and to find the effective dosage of silica fume and fly ash. This paper presents the detailed experimental study on compressive strength at different ages i.e. 3 days, 7 days, 28 days, 56 days, 90 days and split tensile test and flexural strength at the age of 28 days.

**KEYWORDS:** Silica Fume (SF), Fly Ash (FA), Steel Hook Fibers (SHF), High Strength Concrete (HSC), High Strength Fiber Reinforced Concrete (HSFRC), Compressive Strength, Split Tensile Strength, Flexural Strength.

## I. INTRODUCTION

The history of high strength concrete (HSC) is about 35 years old, in late 1960s the invention of water reducing admixtures lead to the high strength precast products and structural elements were cast in situ using high strength concrete (HSC). The primary difference between high-strength concrete (HSC) and normal-strength concrete (NSC) relates to the compressive strength that shows the maximum resistance to concrete sample to applied pressure.

This study describes the development of high strength fiber reinforced concrete (HSFRC) with  $f_{ck}$  in the range of 40-100 N/mm<sup>2</sup>. The objective of present study was mainly to increase the compressive strength, split tensile strength and flexural strength, with the aim of producing a concrete requiring less steel for use in the construction of pre-stressed concrete bridge superstructures. In addition to increasing compressive strength of the concrete and using fiber reinforcement to improve compressive strength, another development objective was to increase versatility by producing HSFRC that does not requiring special materials or special curing methods. The addition of high strength steel fibers to the concrete increases flexural strength and ductility. This residual strength also tends to reduce crack sizes and spacing's. The use of steel fibers is particularly attractive for high-strength concrete, which can be relatively brittle without fibers.

In the present study, the different admixtures were used to study their combined effect on the resistance of concrete in addition to their effects on compressive strength, split tensile strength and flexural strength by partial replacement of mineral admixtures by 10%, 15% of silica fume & 10% and 20% of fly ash by the weight of cement with a constant amount of 0.5% steel hook fibers are added by volume fraction of concrete, throughout the study.

## II. MATERIALS

### 2.1 CEMENT

Ordinary Portland cement of (Zuari brand) 53 grades was selected for the experimental investigation. The characteristics of cement were tested as per IS: 4031-1988 and IS: 12269-1987(9). The experiments such as fineness, standard consistency, initial setting time, final setting time and specific gravity of cement are 6%, 33%, 40 minutes, 350 minutes, 3.14 respectively.

## 2.2 FINE AGGREGATES

Sand is a naturally occurring material from Rock and Minerals by weathering and is composed of majorly  $\text{SiO}_2$ , and Calcium carbonate. The specific particle size composition of the sand as per the **IS 650:1966 and IS 383:1970** was used. River sand was used for the experimental work. The properties of fine aggregate such as specific gravity, water absorption and fineness modulus of fine aggregates are 2.583, 1% and 2.8 respectively.

## 2.3 COARSE AGGREGATE

Gravels are popularly used as Coarse aggregates, which are free from organic impurities and silt. Locally available aggregates of passing through 20 mm sieve and retained on 10 mm sieve are taken. As per **Indian standard specifications IS 383-1987** the coarse aggregates were tested. The aggregates are angular in shape and free from dust. The specific gravity, water absorption and fineness modulus are 2.68, 0.5% and 6.26 respectively.

## 2.4 SILICA FUME

Silica fume is a waste by-product of the production of silicon and silicon alloys. It is available in different forms, of which the most commonly used is in a dandified form. Silica fume used was conforming to IS: 1331(PART-1) 1992 and also ASTM C (1240-2000). Silica fume was also referred as micro silica or condensed silica fume, is a byproduct material that is used as a pozzolanic. This by product is a result of the reduction of high-purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloy. In this project silica fume is used as partial replacement to cement and its properties are mentioned in table 2.1.



Fig- 2.1: sample of silica fume used in concrete

TABLE2.1:- PROPERTIES OF SILICA FUME

Property	Results
Color	Dark grey
Practical size	<1 $\mu\text{m}$
Specific surface	15,000 to 30,000 $\text{m}^2/\text{kg}$
Bulk density	695 $\text{g}/\text{cm}^3$
Specific gravity	2.2
Moisture content	0.78%
$\text{SiO}_2$	92.83%
$\text{Al}_2\text{O}_3$	0.69%

\*As per manufacturers manual

## 2.5 FLY ASH

For this project Fly ash is taken from Rayalaseema thermal power plant (RTPP), Kadapa. Fly ash conforms to the requirements of **IS: 3812 part-I and also ASTMC-618 type-F** were used.

TABLE 2.2 PROPERTIES OF FLY ASH

Characteristics	Percentage
Silica, $\text{SiO}_2$	49-67
Alumina, $\text{Al}_2\text{O}_3$	16-28
Iron oxide, $\text{Fe}_2\text{O}_3$	4-10
Lime, CaO	0.7-3.6
Magnesia, MgO	0.3-2.6
Sulphur trioxide, $\text{SO}_3$	0.1-2.1
Loss of ignition	0.4-0.9
Surface area, ( $\text{m}^2/\text{kg}$ )	230-600
Specific gravity	2.3

## 2.6 STEEL HOOK FIBERS

Steel fibres make significant improvements in flexure, impact and fatigue strength of concrete. These fibres are used in concrete as crack arrester and would substantially improve its static and dynamic properties. Compressive strength of fibre reinforced concrete increased with increase in steel fibre content. The additions of steel fibres shear strength increases significantly. Steel hook fibers compliance to the requirements of **ASTM A 820** (type-1 cold drawn wire).



Fig- 2.2: sample of steel hook fibres used in concrete

TABLE-2.3: PROPERTIES OF STEEL HOOK FIBRES

Type	Hooked end
Diameter of fibers	0.60 mm
Length of fibers	30 mm
Aspect ratio (L/D)	50

As per ASTM Yield Strength of Wire : > 1000 MPa

### Wire Mechanical Properties

Tensile strength of the wire : 1450 MPa

Strain at failure : < 4 %

### **Shape**

The ending shapes of Hooked End Steel Fiber are very important to grant adhesion between fiber and concrete.

## **III. MIX-PROPORTIONS**

### **3.1 Mix Proportions:**

	Water	Cement	F.A	C.A
Proportion by Weight (kg/m <sup>3</sup> )	140	400	660	1196
Proportion by Ratio	0.35	1	1.65	2.99

### **3.2 Experimental Procedure**

The specimen of standard cube of (150mm x 150mm x 150mm) and standard cylinders of (300mm x 150mm) and Prisms of (100mm x 100mm x 500mm) were used to determine the compressive strength, split Tensile strength and flexural strength of concrete. For each proportion of silica fume replacement, 10% and 20% fly ash is replaced to cement and a constant amount of 0.5% steel hook fibers are added for all proportions HSFRC. The constituents were weighed and the materials were mixed by hand mixing. The water binder ratio (W/B) (Binder = Cement + Partial replacement with silica fume and fly ash) adopted was 0.35. The casted specimens were cured in water at room temperature and then tested for its compressive strength, split tensile and flexural strength as per Indian Standards.

### **3.3 TEST METHODS**

#### **3.3.1 Mechanical Properties**

Mechanical properties such as compressive strength and split tensile strength are evaluated.

#### **3.3.2 Compressive Strength Test**

Compressive strength test usually gives an overall picture of the quality of concrete because strength is directly related to the structure of the hydrated cement paste. The compression test is an important concrete test to determine the strength development of the concrete specimens. Compressive strength tests were performed on the cube specimens at the ages of 7, 28 and 90 days.

#### **3.3.3 Splitting Tensile Strength**

The indirect method of applying tension in the form of splitting was conducted to evaluate the effect of MSP and CRD on tensile properties of concrete. The split tensile strength is a more reliable technique to evaluate tensile strength of concrete (lower coefficient of variation) compared to other methods. The split tensile strength of 150 mm diameter and 300 mm high concrete cylindrical specimens was determined.

#### **3.3.4 Rapid Chloride Permeability Test**

The RCPT method is the fastest method and is often used for specification and quality control purposes. The digital LED display indicates the voltage available across the concrete specimen under test as shown in Figure. The procedure of this test method for measuring the resistance of concrete to chloride ion penetration has no bias because the value of this resistance can be defined only in terms of a test method. The method relies on the results from a test in which electrical current passes through a concrete sample during a six-hour exposure period. The interpretation is that the larger the Coulomb number or the charge transferred during the test, the greater the permeability of the sample the more permeable the concrete, the higher the coulombs, the less permeable the concrete, the lower the coulombs. The method has shown good correlation with chloride tests. The following formula, based on the trapezoidal rule can be used to calculate the average current flowing through one cell.

$$Q=900(I_0+2I_{30}+2I_{60}+2I_{90}+2I_{120}+2I_{150}+2I_{180}+2I_{210}+2I_{240}+2I_{270}+2I_{300}+2I_{330}+I_{360})$$

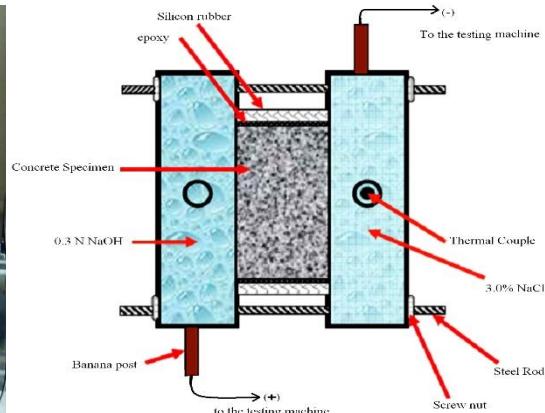
Where,

Q = current flowing through one cell (coulombs)

I<sub>0</sub> = Current reading in amperes immediately after voltage is applied, and

I<sub>t</sub> = Current reading in amperes at t minutes after voltage is applied

The table 3-2 shows the rating of chloride permeability according to ASTM C 1202-97[10].



#### IV. RESULTS AND DISCUSSION

Results of hardened concrete with partial replacement of silica fume and fly ash with 0.5% steel hook fibers are discussed in Comparison with normal concrete.

The cube compressive strength results of high strength fiber reinforced concrete mixes at the ages of 3, 7, 28, 56 and 90 days are presented in table 4.1. The development of compressive strength of M<sub>60</sub> grade HSFRC mixes containing 10% and 15% of silica fume, 10% and 20% of fly ash at various ages are plotted in graphs as shown in fig. According to results the combination of silica fume and fly ash shows considerable improvement in compressive strength when compared with controlled concrete. Results shows that at 10% silica fume and 20% fly ash replacement to cement (S10F20) with 0.5% steel hook fibers shows higher compressive strength, split tensile strength and flexural strength of HSFRC compared with all other proportions.

**TABLE-4.1: COPRESSIVE STRENGTH OF HSFRC CONCRETE WITH 0.5% STEEL HOOK FIBRES AS ADMIHTURE:**  
**4.1.1 MIX PROPORTION-1**

S.NO	SAMPLES	AVERAGE COMPRESSIVE STRENGTH (N/mm <sup>2</sup> )				
		3 days	7 days	28 days	56 days	90 days
1	<b>Controlled mix</b>	<b>22.66</b>	<b>30.81</b>	<b>58.22</b>	<b>64.14</b>	<b>67.11</b>
2	<b>10%SF +0.5%SHF</b>	<b>24.96</b>	34.85	<b>67.25</b>	<b>70.22</b>	<b>79.35</b>
3	<b>10%FA+0.5%SHF</b>	<b>24.37</b>	<b>32.81</b>	<b>62.92</b>	<b>68.14</b>	<b>75.77</b>
4	<b>10%SF+10%FA+0.5%SHF</b>	<b>28.78</b>	39.48	<b>68.88</b>	<b>70.51</b>	<b>79.55</b>

**4.1.2 MIX PROPORTION-2**

S.NO	SAMPLES	AVERAGE COMPRESSIVE STRENGTH (N/mm <sup>2</sup> )				
		3 days	7 days	28 days	56 days	90 days
1	<b>Controlled mix</b>	<b>22.66</b>	<b>30.81</b>	<b>58.22</b>	<b>64.14</b>	<b>67.11</b>
2	<b>15%SF +0.5%SHF</b>	<b>24.66</b>	33.70	<b>65.33</b>	<b>69.11</b>	<b>78.14</b>
3	<b>20%FA+0.5%SHF</b>	<b>24.49</b>	<b>33.86</b>	<b>63.66</b>	<b>68.19</b>	<b>76.18</b>
4	<b>15%SF+20%FA+0.5%SHF</b>	<b>26.96</b>	39.4.	<b>67.18</b>	<b>69.77</b>	<b>80.11</b>

## 4.1.3 MIX PROPORTION-3

S.NO	SAMPLES	AVERAGE COMPRESSIVE STRENGTH (N/mm <sup>2</sup> )				
		3 days	7 days	28 days	56 days	90 days
1	Controlled mix	22.66	30.81	58.22	64.14	67.11
2	10%SF+10%FA+0.5%SHF	28.78	39.48	68.88	70.51	79.55
3	10%SF+20%FA+0.5%SHF	30.98	41.23	72.06	72.68	81.40
4	15%SF+10%FA+0.5%SHF	30.18	40.07	71.92	72.67	80.46
5	15%SF+20%FA+0.5%SHF	26.96	39.4.	67.18	69.77	80.11

TABLE-4.2: SPLIT TENSILE AND FLEXURAL TEST RESULTS

Days	Samples	Average Split Tensile Strength (MPa)	Average Flexural Strength (MPa)	Ultra sonic pulse velocity (km/sec)
28 days	Controlled mix	5.34	9.86	4.33
	10% SF+0.5% SHF	5.36	10.65	4.19
	10% FA+ 0.5% SHF	5.55	10.43	4.99
	10% SF+10% FA+ 0.5% SHF	5.80	13.25	4.28
	15% SF + 0.5% SHF	5.65	11.45	3.87
	20% FA+ 0.5% SHF	5.58	10.89	4.21
	15% SF+20% FA+ 0.5% SHF	5.73	12.46	3.77
	10% SF+20% FA+ 0.5% SHF	6.05	15.44	4.18
	15% SF+10% FA+ 0.5% SHF	5.70	13.88	4.15

## V.GRAPHS

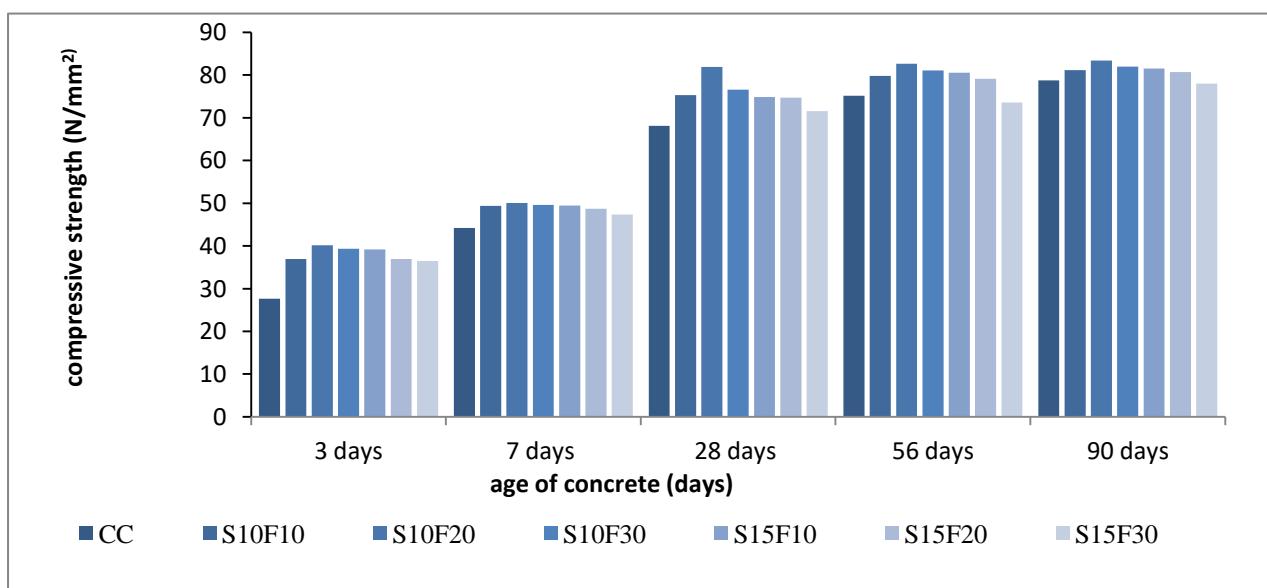
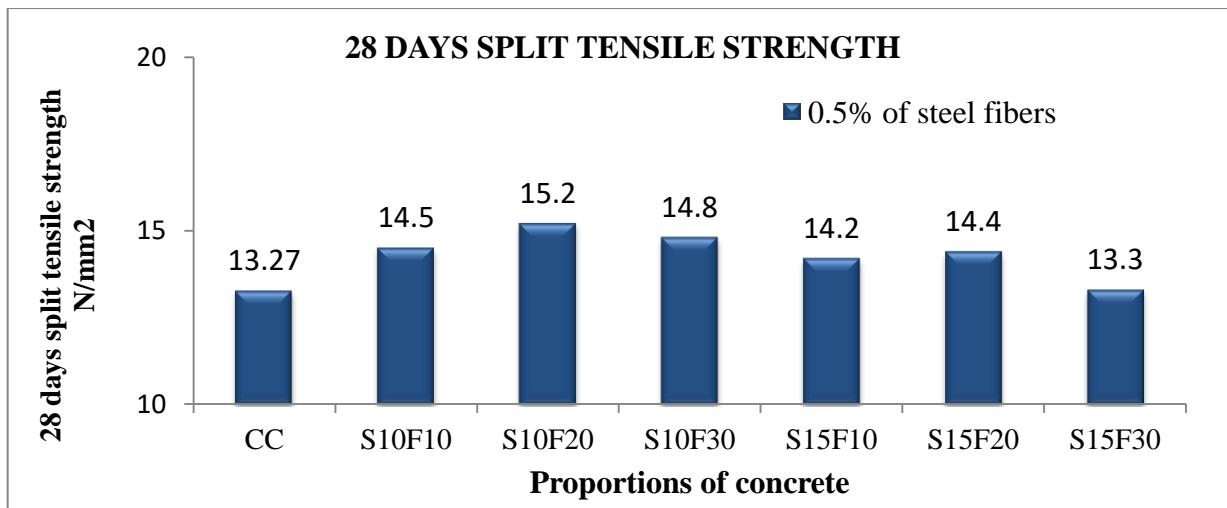
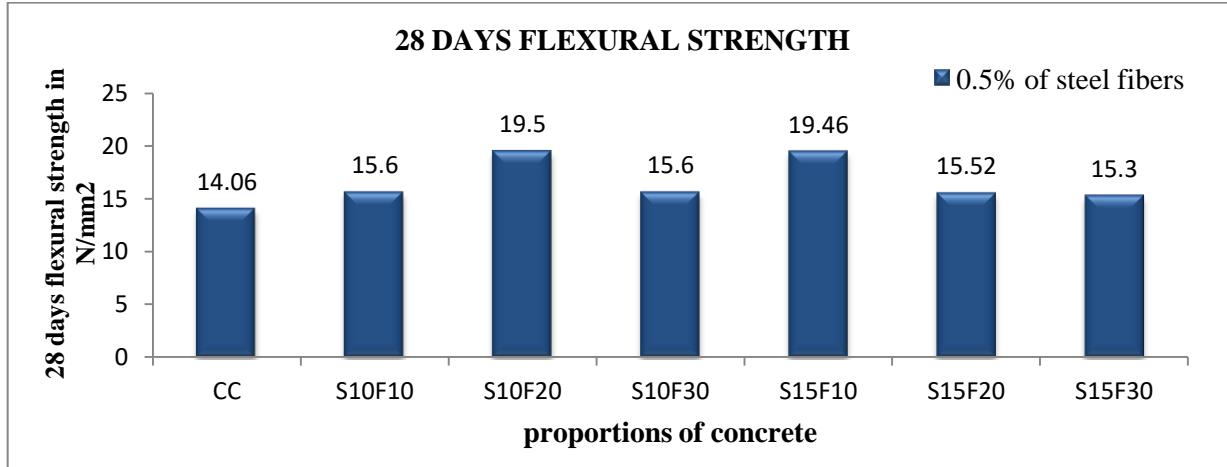


Fig 5.1: Compressive Strength comparison of concrete for various percentages of Silica Fume and Fly Ash

**Fig 5.2:** Tensile strength of HSFRC at 28 days for various percentages of Silica Fume and Fly Ash**Fig 5.3:** Flexural strength of HSERC at 28 days for various percentages of Silica Fume and Fly Ash

## VI. CONCLUSIONS

Based on the results obtained from the present investigation the following conclusions were made;

1. By the addition of steel hook fibers in concrete leads to increase in compressive strength and makes concrete into ductile.
2. In split tensile and flexural tests, we notices that crack width reduced due to the presence of steel fibers when compared with conventional specimen.
3. When the cement is replaced with 10% silica fume and 20% fly ash gives the optimum compressive strength, split tensile strength and flexural strength.
4. At 10% silica fume and 20% fly ash replacement to cement, compressive strength were increased up to 20.34% when compared with conventional concrete for 28 days.
5. At 10% silica fume and 20% fly ash replacement to cement, split tensile strength were increased up to 60.85% when compared with conventional concrete for 28 days.
6. At 10% silica fume and 20% fly ash replacement to cement, flexural strength were increased up to 38.74% when compared with conventional concrete for 28 days
7. The addition of silica fume and fly ash as replacement to cement, its normal consistency and initial setting time increases with increase in percentage and final setting time decreases with increase in percentage.
8. The use of mineral admixtures in concrete causes considerable reduction in the volume of large pores at all ages and thereby reduces the permeability of concrete mixes because of its high fineness and formation of C-S-H gel.

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