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# Strength and Durability Properties of Steel Fiber Reinforced Concrete by Partial Replacement of Cement using Fly Ash

K.SATEESH KUMAR[1], ROUNAK HUSSAIN[2], K.BHARGAVI[3]

[1]PG Scholar, Dept of Civil Engineering, SVTM College of Engineering & Technology, Madanapalle, JNTU Ananthapur, AP, India, E-mail: satheesh.8x143@gmail.com.

[2]Assistant Professor, Dept of Civil Engineering, SVTM College of Engineering & Technology, Madanapalle, JNTU Ananthapur, AP, India.

[3]Assistant Professor, Dept of Civil Engineering, MTIE College of Engineering & Technology, Palamaneru, JNTU Ananthapur, AP, India.

**Abstract:** Concrete is very strong in compression but weak in tension. As a Concrete is a relatively brittle material, when subjected to normal stresses and impact loads. The tensile strength of concrete is less due to widening of micro-cracks existing in concrete subjected to tensile stress. Due to presence of fiber, the micro-cracks are arrested. The introduction of fibers is generally taken as a solution to develop concrete in view of enhancing its flexural and tensile strength. Fly ash is the fine powder major waste material, which limits by the application of the material, by the addition of small amount of short randomly distributed steel fibers in concrete remedies for weaknesses of concrete, such as low growth resistance, high shrinkage cracking, low durability, the ability of excellent tensile strength, flexural strength, ductility and crack arrest. Therefore, it has been applied abroad various professional fields of construction, irrigation works and architecture. This project deals with Investigation for M-50 grade of concrete having mix proportion 1:1.65:3.05 with water cement ratio 0.4 to study the compressive strength, split tensile strength and Flexural strength of steel fiber reinforced concrete (SFRC) containing fibers of an interval of 0%, 0.5%, 1%, 1.5% and 2.5% Steel fibers of 50 aspect ratio were used. The percentage of Fly Ash by weight is to be increased by 10% to 20% for the replacement cement. After curing the specimen were tested as per relevant codes BIS. A result data obtained has been analyzed and compared with a control specimen. A relationship between Compressive strength vs. days, spilt tensile test vs. days and flexural strength vs. days represented graphically. Result data clearly shows percentage increase in 3,7,28, 56 & 90days Compressive strength for M-50 Grade of Concrete attains a maximum strength at 20% of fly ash with addition of steel fibers at the intervals of 2% it is observed split tensile strength and flexural strength are on higher side for 2.5% fibers as compared to that produced from 0%, 0.5%, 1%. 1.5% and 2% fibers using fly ash at 10% & 20%.

**Keywords:** SFRC (Steel Fiber Reinforced Concrete), FA (Fly Ash), SF (Steel Fibers).

## I. INTRODUCTION

Wireless Concrete is most constantly used construction material in the world. The rapid growth of production in industries gave birth to numerous kinds of waste by-products which are environmentally hazard and creates problems when it storage. Always, construction industry has been at forefront in consuming these waste products in large quantities of fly ash comes from most of the industry is replacing to the cement can decreases the environment effects. In the global warming efforts to reduce the emission of $CO_2$and green house gases as well as replacing to cement with a material of pozzolanic characteristics, such as the fly ash, the cement and the concrete industry together can meet the growing demand in the construction industry to control pollution. India is a one of the resourceful country of fly ash generation with an output of over 110 million tones and more also, but utilization is still below 20% in spite of quantum jump in last 3-4 years. At present most of the power plants are having used Electro Static Precipitators (ESP) through which fly ash is collected in different chambers according to its particular size. Hence, uniformly good quality of fly ash can be collected from these power plants. Concrete is characterized by brittle failure material, which is the nearly complete loss of loading capacity, once failure is initiated. By the characterized of concrete, which limits the application of fibers in concrete increase concrete properties as an engineering materials. The demand of steel fibers in concrete are generally used in civil construction field the most popular are due to its improvement resistance to cracking, fatigue, abrasion, impact, durability, and conventional reinforced concrete. Concrete is very strong in compression but weak in tension. As a Concrete is a brittle material, when subjected to normal stresses and impact loads. The tensile strength of concrete is less due to widening of micro-cracks existing in concrete subjected to tensile stress. Due to presence of fiber, the micro-cracks are arrested. The introduction of fibers is generally taken as a solution to develop concrete in view of enhancing its flexural and tensile strength. Hence addition of fibers in concrete to the volume of fraction can has a good matrix bonded relation between the concrete and steel fibers.

## II. MATERIALS USED

### A. Fly Ash

Fly ash is the combustion of pulverized coal in thermal power plants as a byproduct. It is removed by electrostatic precipitators or mechanical collectors as a fine particle residue from the combustion gasses. Formation of ash which comes out by the natural processes of the combustion of coal in the furnace of the boiler at temperature in the range of 1300–1450$^0$C in the presence of nearly 20% excess air. Bottom ash constitutes approx 20% of the total ash content of the coal; the remainder which enters the convective zones of the boiler is called fly ash. The pozzolanic activity of fly ash it is essential that it has carbon content constant. The specification for fly ash for use as pozzolanic is given in IS 3812 part I (1966). Indian fly ashes exhibit greater variation in their chemicals composition and physical properties. Some of the properties of fly ash which has effect on strength and quality of concrete are discussed and classified its types also.

Fly ash is generally captured from the chimneys of coal-fired power plants, whereas bottom ash is removed from the bottom of the furnace. In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now requires that it be captured prior to release. Depending upon the source and makeup of the coal being burned, the components of the fly ash produced vary considerably, but all fly ash includes substantial amounts of silicon dioxide ($SiO_2$) (both amorphous and crystalline) and calcium oxide. Fly ash is commonly used to supplement Portland cement in concrete production, where it can bring both technological and economic benefits, and is increasingly finding use in the synthesis of geopolymers and zeolites.

**Fig.1. Dumped Fly Ash.**

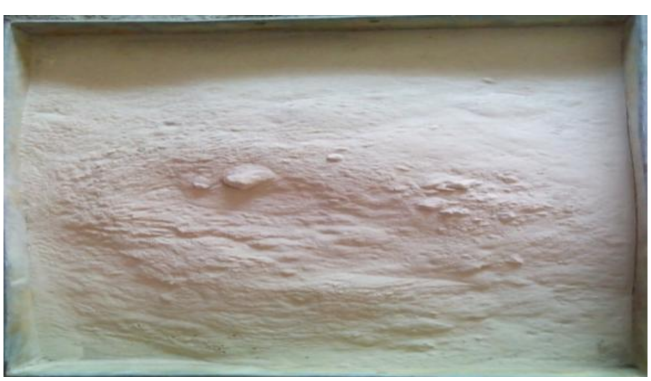

**Fig.2. Fly Ash.**

### B. Types of Fly-Ash (As per ASTM C 618)

#### 1. Class F fly ash

The burning older anthracite which is harder and bituminous coal typically produces Class F fly ash it has pozzolanic in nature, and contains less than 20% lime (CaO). Possessing pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementations compounds. Alternatively, the addition of a chemical activator such as sodium (water glass) to a Class F ash can leads to the formation of a geopolymers.

#### 2. Class C fly ash

Fly ash produced from the burning of younger lignite or sub bituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash will harden and gain strength over time. Class C fly ash generally contains more than 20% lime. Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulfate ($SO_4$) contents are generally higher in Class C fly ashes.

### C. Chemcial Composition of Fly Ash

The four major compounds are:

i. Tricalcium silicate ($3CaOSiO_2$)
ii. Dicalcium Silicate ($2 CaOSiO_2$)
iii. Tricalcium Aluminate ($3CaOAl_2O_3$)
iv. Tetracalcium Alumino Ferrit ($4CaOAl_2O_3Fe_2O_3$)

$C_3S$and $C_2S$ are the most important compounds responsible for strength. Together, they constitute 70 to 80% of cement. During the course of reaction of $C_3S$and $C_2S$ with water, calcium silicate hydrate and calcium hydroxide are formed.

$$2(3CaO.SiO_2) + 6H_2 \rightarrow 3CaO.2SiO_2.3H_2O+3Ca(OH)_2$$

$$2(2CaO.SiO_2) + 4H_2O \rightarrow 3CaO.2SiO_2.3H_2O + Ca(OH)_2$$

**TABLE 1. Properties of Fly ash**

| Sl. No | Properties | Results |
|---|---|---|
| 1 | Specific gravity | 2.25 |
| 2 | Fineness | 9% |

### B. Steel Fibres

A fiber is a small piece of reinforcing material posses certain properties by its own, where as comparing to different types of fibers, Steel fibers are most common used fiber. These fibers are used in concrete as crack arrester and would substantially improve its static and dynamic properties. The addition of steel fibres in concrete mass dramatically increase the properties of concrete such as compressive strength, tensile strength, flexural strength, impact strength increases significantly. Fibers has found many application in civil engineering field based on provide safe, efficient, economical design for the present but also for extended future application also. Steel hook fibers compliance to the requirements by a code specification **ASTM A820** types of fibers are defined and properties are satisfied.

**1. Properties of Steel Hookfibres**

Regarding to the technical report that produced the details by steel fibers industry are in given details by the supplier. The properties of steel fibers used in this project details are given below as per the requirements of codes **ASTM A820.**

**Type** : Hooked End

**Nominal Dimensions**

Diameter : 0.60 mm

Length : 30 mm

Aspect Ratio L/D : 50

Tolerance for D/ L ± 10 %

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.

**Fig.3. Sample of Steel hook fiber.**

**2. Steel Fibers Reinforced Concrete**

Concrete is the most preferred widely and single largest used structural material in the world with an annual production of over seven billion tons. For a variety of reasons, much of this concrete is cracked. The reason for concrete to suffer cracking may be attributed to structural, environmental or economic factors, but most of the cracks are formed due to the inherent weakness of the material to resist tensile forces. The steel fiber reinforced concrete has the ability of excellent tensile strength, flexural strength, shock resistance, fatigue resistance, ductility and crack arrest.

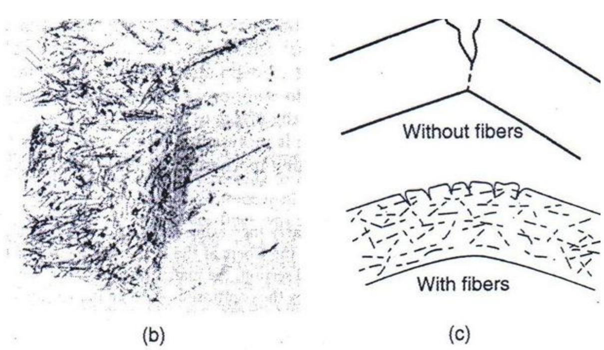


**Fig.4. Steel Fibers Reinforced Concrete Racking Shown With Fibers and Without Fibers**

**C. Cement**

Ordinary Portland cement is graded according to strength, contains good characteristic properties mainly it is depend on the chemical composition, burning and fineness of grinding.

**1. The properties of cement are**

- Cement gives good strength to the concrete.
- Cement is a good binding material.
- Workability of cement is good.
- Cement is good resistance to the moisture.

**2. Physical Properties Ordinary Portland Cement**

Portland cement of 53 grades was selected for the experimentation. It was dry, and in the form of powder and are not having lumps, because it was not exposed to moisture. Initial setting time of 40 minutes, Final setting time of 360 minutes and Specific Gravity of cement is 3.11. This tested were taken according to the Code specifications as per **IS 4031-1988.**

**Table II. Properties Ordinary Portland Cement Chemical Composition of Cement**

| S.No | Characteristic of cement | Value | Code specifications (IS4031-1988) |
|---|---|---|---|
| 1 | Fineness of cement | 94.76% | <10 |
| 2 | Normal consistency of cement | 33% | Not specified |
| 3 | Initial setting Time | 40 minutes | >30 |
| 4 | Final setting time | 350 minutes | <600 |
| 5 | Specific gravity | 3.11 | Not specified |
| 6 | Soundness(mm) | 1 | <10 |

The chemical composition of the cement was analyzed according to standard procedure laid down in **IS 4032: 1968.** The results of the analysis of cements are presented in below Table.

**TABLE III. Chemical composition of Cement**

| S.NO | Oxide composition | Present Content |
|---|---|---|
| 1 | CaO | 65.49 |
| 2 | $SiO_2$ | 21.67 |
| 3 | $Al_2O_3$ | 5.97 |
| 4 | $Fe_2O_3$ | 3.85 |
| 5 | $SO_3$ | 1.66 |
| 6 | MgO | 0.78 |
| 7 | $K_2O$ | 0.46 |
| 8 | $Na_2O$ | 0.12 |

The percentage composition of the major compounds (known as the Bogue compounds) present in the test Cement given below.

**TABLE IV. Shows the Percentage Composition of the Major Compounds Present in the Test Cement.**

| S.No | Name of the Compound | % present in Cement |
|---|---|---|
| 1 | Tri Calcium Silicate ($3CaO.SiO_2$) | 51.49 |
| 2 | Dicalcium Silicate ($2CaO.SiO_2$) | 23.37 |
| 3 | Tricalcium aluminates ($3CaO.Al_2O_3$) | 9.31 |
| 4 | Tetra calcium alumina ferrite ($4CaO.Al_2O_3.Fe_2O_3$) | 11.70 |

### D. Fine Aggregate

The sand used throughout the experimental work was obtained from the Muthureveluvanka near Chittoor, Chittoor district, Andhra Pradesh. This type of sand was used by many of researchers as an ingredient in cement mortar. According to **IS 650:1966,**

**TABLE V. Properties of Fine Aggregate (sand)**

| S.No | Properties | Results |
|---|---|---|
| 1 | Specific gravity | 2.59 |
| 2 | Bulking of sand | 3% |
| 3 | Bulk Density<br>I-Loose state<br>II-Compacted state | <br>17.9 KN/$m^3$<br>19.5 KN/$m^3$ |
| 4 | Particle size variation | 0.15 to 4.75 |
| 5 | Water absorption forsand | 1% |
| 6 | Bulk Density of Sand | 1460 |
| 7 | Fineness modulus of sand. | 3.8 |
| 8 | Grading of Sand | Zone-II |

### E. Coarse Aggregate

Coarse aggregates, which are free from organic impurities and silt. The coarse aggregate of physical properties were taken according to the codes specification as per Indian standard specifications **IS 383-1970**. The Coarse aggregate are the crushed stone is used for making concrete. The commercial stone is quarried, crushed, and graded. Much of the crushed stone used is granite, limestone, and trap rock. The last is a term used to designate basalt, gabbros', diorite, and other dark- collared, fine- grained igneous rocks. Graded crushed stone usually consists of only one kind of rock and is broken with sharp edges. The sizes are from 0.25 to 2.5 in (0.64 to 6.35 cm), although larger sizes may be used for massive concrete aggregate.The density is 2,723 kg/m3, the specific gravity 2.68, and the crushing strength 158 to 220 Mpa.

**TABLE VI. Properties of Coarse Aggregate**

| S.No | Properties | Value |
|---|---|---|
| 1 | Specific Gravity | 2.68 |
| 2 | Bulk Density:<br>I-Loose state<br>II-Compacted state | <br>14.13 KN/$m^3$<br>16.88 KN/$m^3$ |
| 3 | Water Absorption | 0.41% |
| 4 | Flakiness Index | 13.19% |
| 5 | Elongation Index | 20.49% |
| 6 | Crushing Value | 14.72% |
| 7 | Impact Value | 6.08% |
| 8 | Fineness Modulus | 6.26 |

## III. MIX DESIGN FOR M50 GRADE OF CONCRETE

**TABLE VII. Target Mean Strength = 58.25N/mm²**

| Grade Designation | M50 |
|---|---|
| Type of Cement | OPC 53 Grade |
| Maximum Nominal size of aggregate | 20 mm |
| Minimum content of Cement | 400 Kg/m³ |
| Maximum Water Cement ratio | 0.40 |
| Specific Gravity of Cement | 3.11 |
| Specific Gravity of Coarse aggregate | 2.68 |
| Specific Gravity of Fine aggregate | 2.583 |

**TABLE VIII. Ratio of Mix Proportion: 1: 1.65: 3.05**

| | Water | Cement | Fine aggregate | Coarse aggregate |
|---|---|---|---|---|
| **Proportion by Weight** | 160kg | 400kg | 661.51kg | 1220.19kg |
| **Proportion by Ratio** | 0.4 | 1 | 1.65 | 3.05 |

## IV. RESULTS AND DISCUSSION

This chapter discussed about comparison between controlled concrete and using fly ash at 10% & 20% replacement of cement the different proportions of steel fibers at 0%, 0.5%, 1%, 1.5%, 2% & 2.5% shows the graphical and tabulation of compressive strength, split tensile strength and flexural strength**.** The cubes, cylinder and beams were taken tested 3, 7, 28, 56 and 90 days and results were obtained and the graphical views were shown in the below tabulations.

### A. Compressive Strength

The compressive strength of the project fly ash replacement to cement and addition of steel fibers to the concrete at the 0%, 0.5%, 1%, 1.5%, 2%, 2.5% and controlled concrete cubes were tested at 3, 7, 28, 56 & 90 days using compressive strength testing machine. It is able to provide load up to 2000kN.

**Table IX. Variation of Compressive strength of different ages made with 10% fly ash as replacement to cement and steel hook fibers at 0%, 0.5%, 1%, 1.5%, 2%, and 2.5%.**

| S. NO | Cement+ Admixture | Average Compressive Strength (Mpa) | | | | |
|---|---|---|---|---|---|---|
| | | 3 days | 7 days | 28 days | 56 days | 90 days |
| 1 | **100%OPC** | 22.65 | 30.81 | 56.59 | 62.22 | 71.54 |
| 2 | **90%OPC+ 10%FA+ 0% SF** | 24.07 | 32.14 | 61.30 | 67.25 | 77.18 |
| 3 | **90%OPC+ 10%FA+ 0.5% SF** | 24.37 | 32.81 | 62.92 | 68.14 | 78.14 |
| 4 | **90%OPC+ 10%FA+ 1% SF** | 25.03 | 33.33 | 63.70 | 69.62 | 79.14 |
| 5 | **90%OPC+ 10%FA+ 1.5% SF** | 26.66 | 34.66 | 65.25 | 70.74 | 81.34 |
| 6 | **90%OPC+ 10%FA+ 2% SF** | 27.92 | 37.70 | 67.18 | 72.37 | 82.73 |
| 7 | **90%OPC+ 10%FA+ 2.5% SF** | 22.44 | 36.96 | 63.77 | 70.51 | 78.76 |

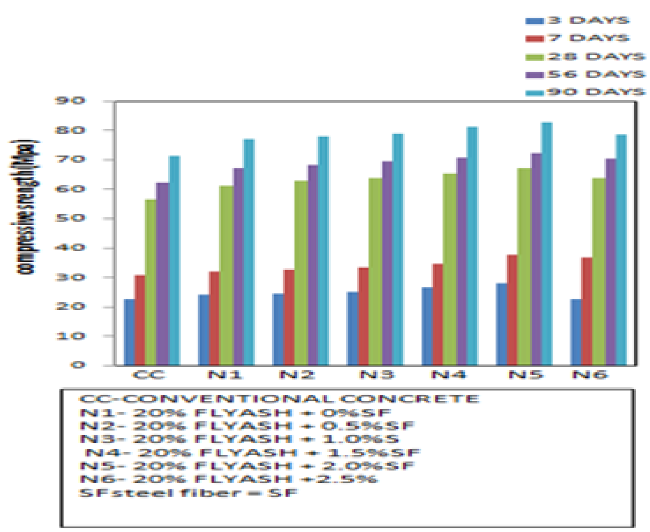


**Fig.5. shows bar chart Variation of Compressive strength of different ages with 10% fly ash as replacement to cement and steel hook fibers at 0%, 0.5%, 1%, 1.5%, 2%, 2.5%**

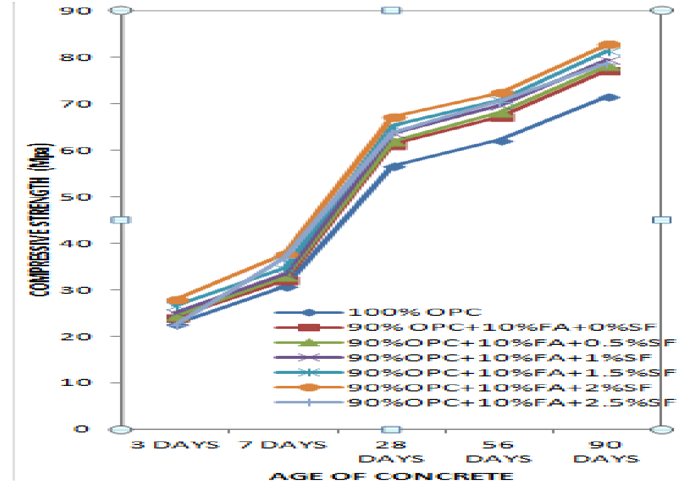


**Fig.5. Shows Variation of Compressive Strength of Different Ages Made With 10% Fly Ash as Replacement to Cement And Steel Fibers At 0%, 0.5%, 1%, 1.5%, 2%, 2.5%.**

**TABLE X. Variation of Compressive strength of different ages made with 20% fly ash as replacement to cement and steel fibers at 0%, 0.5%, 1%, 1.5%, 2%, 2.5%.**

| S. No | Cement + Admixture | Average Compressive Strength (Mpa) | | | | |
|---|---|---|---|---|---|---|
| | | 3 days | 7 days | 28 days | 56 days | 90 days |
| 1 | **100%OPC** | 22.6 | 30.8 | 56.5 | 62.2 | 71.5 |
| 2 | **80%OPC+ 20%FA+ 0%SF** | 24.8 | 32.4 | 61.7 | 67.8 | 78.4 |
| 3 | **80%OPC+ 20%FA+ 0.5%SF** | 26.2 | 33.8 | 62.6 | 69.2 | 78.8 |
| 4 | **80%OPC+ 20%FA+ 1% SF** | 27.3 | 34.3 | 63.0 | 70.2 | 80.2 |
| 5 | **80%OPC+ 20%FA+ 1.5%SF** | 28.2 | 35.5 | 64.9 | 71.8 | 80.7 |
| 6 | **80%OPC+ 20%FA+ 2% SF** | 29.5 | 36.6 | 66.4 | 73.5 | 82.0 |
| 7 | **80%OPC+ 20%FA+ 2.5%SF** | 27.6 | 35.3 | 63.7 | 71.7 | 81.7 |

From the above graphs the compressive strength of cubes were tested 3, 7, 28, 56 & 90 days and the variation of strength increases shown in the above graph at different ages of concrete. The strength compared with the conventional concrete and 20% of fly ash replacement to the cement and using steel fibers as admixture at the intervals 0%, 0.5%, 1%, 1.5%, 2%, 2.5%. By the above graphs indicated that the compressive strength increases at 10% fly ash and addition of steel fibers at 2% gets the maximum value when compared to the other proportion and at 2.5% the compressive strength value decreases.

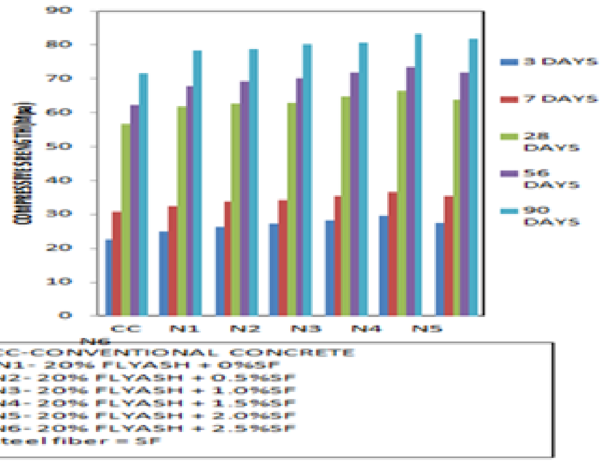


**Fig.6. Shows Variation of Compressive Strength of Different Proportion of 20% Fly Ash as Replacement to Cement and Steel Fibers at 0%, 0.5%, 1%, 1.5%, 2%, 2.5% at Different Age.**

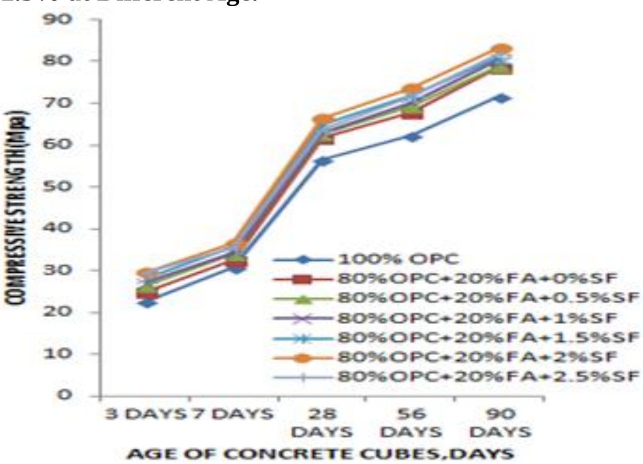


**Fig.7. Shows Variation of Compressive Strength Curves At of Different Proportion of 20% Fly Ash as Replacement to Cement And Steel Fibers At 0%, 0.5%, 1%, 1.5%, 2%, And 2.5% At Different Age.**

**B. Split Tensile Test**

The test were carried out conforming the code IS 5816-1999 to obtain split tensile strength at the age of 28 days.

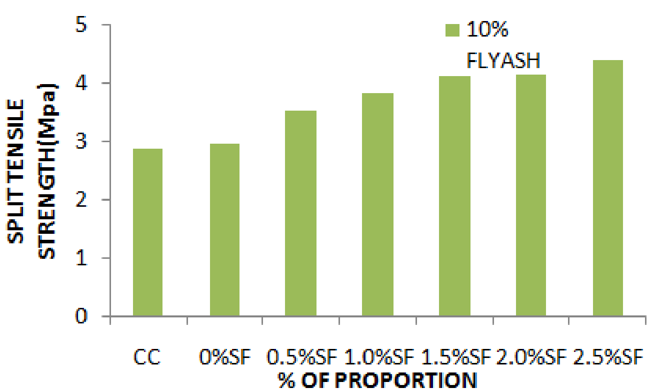


**Fig.8. Variation of Split Tensile Strength (28days) of Different Proportion of Steel Hook Fibers at 10% Fly Ash as Replacement to Cement.**

**TABLE XI. Variation of Split strength (28 days) of 10% & 20% of fly ash as replacement to cement and steel fibers at 0%, 0.5%, 1%, 1.5%, 2%, 2.5%.**

| S. No | Details | Averge Split tensile strengh(Mpa) of 28 Days |
|---|---|---|
| 1 | CONTROLLEDCONCRETE | 2.88 |
| 2 | 90%OPC+10% FA + 0% SF | 2.95 |
| 3 | 90%OPC+10% FA+0.5% SF | 3.51 |
| 4 | 90%OPC+10%FA + 1% SF | 3.83 |
| 5 | 90%OPC+10%FA+ 1.5% SF | 4.1 |
| 6 | 90%OPC+10% FA + 2% SF | 4.15 |
| 7 | 90%OPC+10% FA+2.5% SF | 4.38 |
| 8 | 80%OPC+20% FA + 0% SF | 3.1 |
| 9 | 80%OPC+20% FA+0.5% SF | 3.5 |
| 10 | 80%OPC+20%FA + 1% SF | 3.8 |
| 11 | 80%OPC+20%FA+ 1.5% SF | 4.15 |
| 12 | 80%OPC+20% FA + 2% SF | 4.4 |
| 13 | 80%OPC+20% FA+2.5% SF | 4.6 |

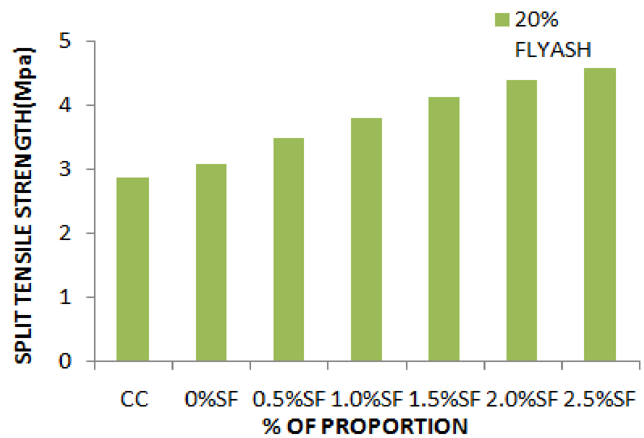


**Fig.9. Variation of Split Tensile Strength (28days) of Different Proportion of Steel Hook Fibers at 20% Fly Ash as Replacement to Cement.**

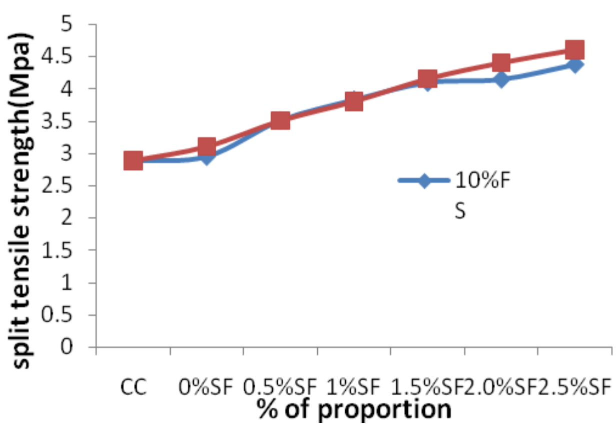


**Fig.10. Showing the Comparison of Variation of Split Strength (28Days) of 10% & 20% of Fly Ash as Replacement to Cement and Steel Fibers at 0%, 0.5%, 1%, 1.5%, 2%, 2.5%.**

From above graph it is observed that the split tensile strength shows that the strength is increases with addition of steel hook fibers. At 2.5%steel hook fibers at 20% fly ash replacement to cement shows maximum split tensile strength 4.8N/mm$^2$.

**TABLE XII. Durability Test Water Absorption Test Results**

| S. no | Sample | Wet weight (kgs) | Dry weight (kgs) | Water absorption in % |
|---|---|---|---|---|
| 1 | CC | 0.958 | 0.942 | 1.70 |
| 2 | FA10%+SF0% | 0.978 | 0.963 | 1.56 |
| 3 | FA10%+SF0.5% | 0.989 | 0.975 | 1.44 |
| 4 | FA10%+SF1% | 0.990 | 0.981 | 0.92 |
| 5 | FA10%+SF1.5% | 0.992 | 0.986 | 0.61 |
| 6 | FA10%+SF2% | 0.995 | 0.990 | 0.52 |
| 7 | FA10%+SF2.5% | 0.998 | 0.994 | 0.42 |
| 8 | FA20%+SF0% | 0.984 | 0.970 | 1.75 |
| 9 | FA20%+SF0.5% | 0.996 | 0.984 | 1.22 |
| 10 | FA20%+SF1% | 0.999 | 0.989 | 1.01 |
| 11 | FA20%+SF1.5% | 1.08 | 0.998 | 0.82 |
| 12 | FA20%+SF2% | 1.133 | 1.128 | 0.5 |
| 13 | FA20%+SF2.5% | 1.192 | 1.189 | 0.3 |

At 20% of fly ash with 2.5% of steel hook fibers gives low water absorption.

**TABLE XIII. Strength Comparison**

| Test | FA10 SF 0% | FA 10 SF 0.5% | FA10 SF 1% | FA 10 SF 1.5% | FA 10 SF 2% | FA 10 SF 2.5% |
|---|---|---|---|---|---|---|
| **Compressive strength** | **7.6** | **10** | **11.1** | **13.2** | **15.7** | **11.2** |
| **Split Tensile Strength** | **2.3** | **17.9** | **24.8** | **29.7** | **30.6** | **34.2** |
| **Flexural Strength** | **19.4** | **31.7** | **35.5** | **43** | **45.1** | **48.4** |

**Table XIV. 28 Days Strength Comparison in Percentage of 10% Fly Ash with Steel Hook Fibers at Different Proportion**

| Test | FA 20 SF 0% | FA 20 SF 0.5% | FA 20 SF 1% | FA 20 SF 1.5% | FA 20 SF 2% | FA 20 SF 2.5% |
|---|---|---|---|---|---|---|
| **Compressive strength** | **8.28** | **9.69** | **10.2** | **12.80** | **14.8** | **11.22** |
| **Split Tensile Test** | **7.10** | **17.71** | **24.2** | **30.60** | **34.5** | **37.39** |
| **Flexural Test** | **25.6** | **27.50** | **37.6** | **40.82** | **47.2** | **48.65** |

## V. CONCLUSIONS

Based on the results obtained from the present investigation, the following conclusions were made, they are:

1. Normal consistency increases with increase in the fly ash content.
2. Setting time and soundness decreases with the increase in grade of cement.
3. With the increasing fly ash 10% & 20% into the cement the increasing the life of concrete structures by improving concrete durability, besides exhibiting good workability and better strength.
4. Workability is decreased gradually when concrete mix is done with the steel fibers as compared to the controlled concrete.
5. When the cement is replaced with 10% &20% fly ash and addition of the steel hook fibers gives and increases the optimum compressive strength, split tensile strength and flexural strength.
6. In split tensile and flexural test, we noticed that crack width reduced due to presence of steel fiber when compared with control specimen.
7. At 10% fly ash with 2% of steel hook fibers optimum compressive strength were increased up to 15.76 % when compare with controlled concrete for 28 days.
8. At 20% fly ash with 2.5 % addition of steel hook fibers the split tensile strength were increased 37.39 % increased when compare with controlled concrete for 28 days.

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**Author's Profile:**

**K.Sateesh Kumar** received B.Tech degree from MJRCET PILERU, JNTU Ananthapur. Currently pursuing M.Tech in SVTM College of Engineering & Technology, Madanapalle, JNTU Ananthapur. His interest includes Concrete Technology & Surveying.

**Rounak Hussain** received B.Tech degree from KSR College of Technology, ANNA University, Chennai. Received M.Tech degree from KSR College of Technology, ANNA University, Chennai. Currently he is working as Assistant professor in CIVIL Engineering dept. of SVTM MADANAPALLE, JNTU, Ananthapur. His interests include Concrete Technology.

**K.Bhargavi**, received B.Tech degree from SVCET CHITTOOR, JNTU, Ananthapur in 2013. Received M.Tech degree from from SVCET CHITTOOR, JNTU, Ananthapur in 2015. Currently she is working as a Assistant Professor in MTIE college of Engineering & Technology. Her interests include Concrete Technology & Transportation Engineering.