# EXPERIMENTATION ON SUSTAINABLE CONCRETE BY ADDITION OF STEEL FIBRES AND INDUSTRIAL WASTES

**Sarvesh Pastay[1], Mahaboobali Nadaf[2]**

*[1]M.Tech Student Civil Engineering Dept. Jain college of engineering Belagavi, Karnataka, India*
*[2]Asst Prof. Civil Engineering Dept. Jain college of engineering Belagavi, Karnataka, India*

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**Abstract -** *The aim of this study is to look at the mechanical and durability qualities of hybrid fiber reinforced concrete made with Fly Ash, RHA, and LP as partial replacement of cement Pozzolanic materials, on the other hand, improve strength over time. RHA is a pozzolanic substance with high reactivity. When RHA is mixed with OPC, it not only strengthens the concrete. At low replacement levels and later in life, using a ternary blend of OPC, RHA, and FA improves the mortar's strength dramatically. FA and RHA are both very good at improving mortar corrosion resistance.*

***Key Words*: Rice Husk Ash, Fly Ash, Lime, Polypropylene, Mechanical Properties etc.**

## 1. INTRODUCTION

In today's construction sector, concrete has become an unavoidable construction material. This is one of the biggest environmental threats. Supplementary Cementitious Materials (SCMs) are used in concrete to reduce the amount of cement used, which helps to solve the problem. It not only benefits the economy and the environment, but it also improves the characteristics of concrete. Because the majority of SCMs are by-product materials from the industrial and agricultural sectors, using them in concrete has been shown to be a cost-effective alternative to disposal. The Calcium- Silicate- Hydrate (C-S-H)gel gives strength to concrete, whereas the Ca (OH)2 in hydrated cement paste degrades concrete quality. It is an unfavourable material that reduces the strength of the concrete. When SCMs are mixed with Portland cement concrete, the amorphous silica in the SCMs combines with additional Calcium hydroxide to produce C-S-H gel, gives concrete strength and minimises permeability while also increasing the concrete's longevity. Because of the pozzolanic and filler effects, adding SCMs to concrete improves its characteristics. The addition of SCMs to Portland cement concrete improves the strength and durability of the finished product[1]. Studied HFRC SCCs with a high volume of coarse FA [2].Mono and hybrid steel fibres with hooked ends and straight steel fibres were employed [3]. The durability of glass fibre was also studied [4]. The durability qualities of fibrillated PP fibre reinforced high performance concrete were carried out [5] According to much research, the qualities of blended cement concrete are improved by these ingredients [6].

### 1.1 SUMMARY OF CURRENT EXPERIMENTATIONS

1. To compare the mechanical properties of concrete in mono and hybrid form with steel, carbon, and fibrillated polypropylene fibre (PP).

2. To see how SCMs affect the mechanical properties of mono-fibre and hybrid fibres added into concrete during longer cure times.

3. To determine the durability properties of concrete with the best mono and hybrid fibres, such as water absorption, sorptivity and RCPT tests.

### 1.2 METHODOLOGY

Sample Individually, 0.25 percent and 0.5 percent of PP and carbon fibres is added to concrete. When carbon fibres are mixed with polypropylene fibres in a hybrid form, the total weight fraction of cementitious materials is kept between 0.25 and 0.5 percent. Steel fibres will be mixed with mono PP fibre, mono carbon fibre, and carbon-PP hybrid fibre systems at 0.5%, 1%, and 1.5% volume fractions, respectively. Curing times for the concrete specimens will be 28 days and the required tests for strength and durability tests are carried out after that.

## 2. MATERIALS INCORPORATED IN PROJECT

### 2.1 CEMENT

OPC 53 grade JK SUPER cement is employed for experimental investigation. Various tests were carried out to know the properties of cement. The results obtained are shown in the table below.

**Table -1:** Results of cement

| Tests conducted | Results | IS Standards |
|---|---|---|
| Std. consistency | 31% | 35% |
| Initial setting | 32mins | 30mins |
| Final setting | 290mins | 600mins |
| Sp. Gravity | 3.11 | 3.1 |

## 2.2 FINE AGGREGATE

The fine aggregate employed was sand collected from the local distributors and passed through a 4.75mm sieve. The sand met IS 383-2016 grading Zone II.

**Table -2:** Test Results of F. Agg.

| Particulars | Results |
|---|---|
| Fineness modulus | 3.3 |
| Sp. Gravity | 2.65 |
| Water absorption | 1% |

## 2.3 COARSE AGGREGATE

Coarse aggregates are selected which meets the requirements of IS specifications. Various tests are conducted to know the properties of CA which were angular in shape and free from dirt/oil.

**Table -3:** Test Results of C. Agg.

| Particulars | Results |
|---|---|
| Fineness modulus | 3.91 |
| Sp. Gravity | 2.75 |
| Water absorption | 0.43% |

## 2.4 FLY ASH (FA)

Class F Fly Ash was obtained Raichur Thermal Power Station and chemical properties are almost similar to RHA with Specific Gravity of 2.4.

## 2.5 RICE HUSK ASH (RHA)

The RHA employed in this experiment had the composition as show in table and is having specific gravity as 2.3 as specified by the distributor.

**Fig -1**: RHA

## 2.6 LIMESTONE POWDER

In this experiment, a locally available Lime powder is used and is having specific gravity as 2.8. Table 11 shows the chemical composition of Lime powder

**Table -4:** Limestone powder properties

| Chemical Composition | % |
|---|---|
| $SiO_2$ | 6.83 |
| $Al_2O_3$ | 4.14 |
| CaO | 55.71 |
| $Fe_2O_3$ | 4.5 |

## 2.6 STEEL FIBER

Hooked end fibres (steel fibres) are used. Selected fibers are having length of 35mm, 0.45mm as diameter and aspect ratio of 78. It has tensile strength ranging from 800 to 1000 MPa.


**Fig –2**: Steel fiber

## 2.7 POLYPROPYLENE (PP) FIBER

The length of PP was 6mm, the dia. - 0.04 mm, the specific gravity was 0.91, and the strength (tensile) was between 350 to 450 MPa.

## 2.8 CARBON(C) FIBER

Carbon fibres with a L= 12 mm and a diameter = 11 microns were used in this experiment. According to the manufacturer, the carbon content was 95% and the tensile strength was 4300 MPa.

## 2. MIX DESIGN.

**Table 5 – Shows mix proportion**

| Mix proportion | | |
|---|---|---|
| **Cement** | **F. Agg** | **C.Agg** |
| 1 | 1.73 | 3.11 |

## 3. TESTS CONDUCTED ON CONCRETE.

### 3.1 SLUMP CONE TEST.

Slump cone test was used to check the workability of cement following the standard procedure of test.

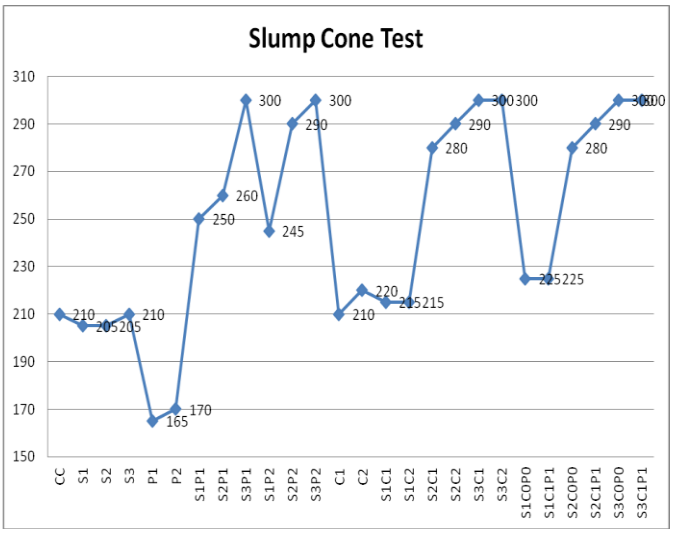


**Fig –3**: Results of slump cone

### 3.2 VEE-BEE CONSISTOMETER TEST.

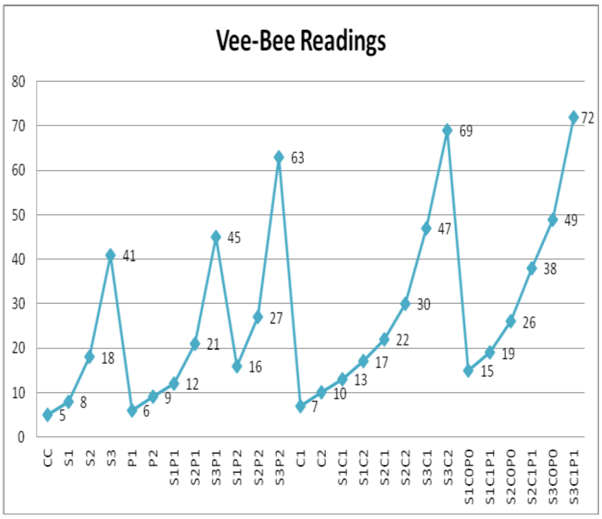


**Fig –4**: Results of Vee-Bee test

- The Vee-Bee time for Steel Polypropylene Hybrid Fiber Reinforced Concrete (SPHFRC) varied between 12 and 63 seconds.
- Steel fiber additions of 0.5, 1, and 1.5 percent increased the Vee Bee time by 5, 15, and 36seconds, respectively.
- The Vee Bee time increased by 1 and 4 seconds for polypropylene fibers at 0.25 percent and 0.5 percent, respectively.
- Carbon Fiber Reinforced Concrete had a Vee-Bee time of 2 to 5 seconds (CFRC).
- In the current investigation, the Vee-Bee time for Steel-Carbon Hybrid Fiber Reinforced Concrete (SCHFRC) was between 13 and 69 seconds.
- The Vee-Bee time was increased when fibrillated PP fiber was added to the SCHFRC mix. At a 1.5 percent volume fraction of steel fibers, workability is reduced and fiber balling occurs. As a result, workability is further reduced, and a balling effect of fibers occurs, resulting in a concrete mix that is not fully compacted. This effect is stronger in Steel-Carbon-Polypropylene Hybrid Fiber Reinforced concrete (SCPHFRC) mixes than in Steel Carbon Hybrid Fiber Reinforced Concrete (SCHFRC) mixes

### 3.3 COMPRESSIVE STRENGTH TEST.

This test was conducted in accordance with IS 516-1999. This is carried out to know the capacity of concrete to withstand loads before failure. The standard size of the cube is used to cast the concrete. Tests were conducted for different interval of time 7,28 and 56 days of curing.

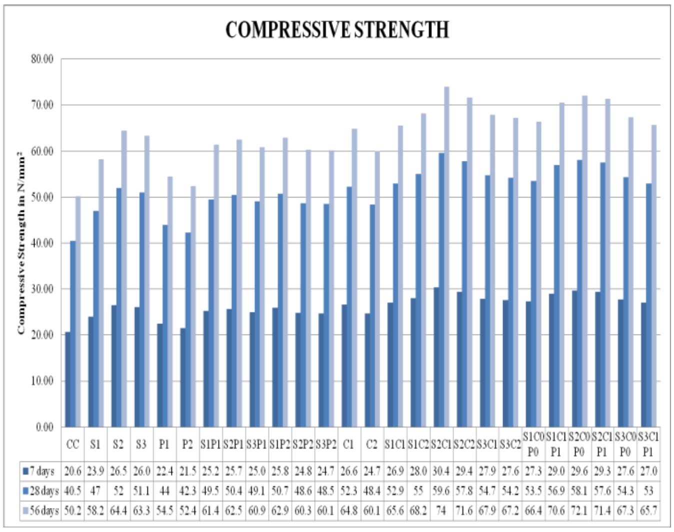


**Fig –5**: Shows results of Comp test.

In comparison to normal concrete,

- Compressive strength improvement in SFRC increased by 15.93%, 28.29%, and 26.12% for concrete mixes containing 0.5%, 1%, and 1.50% volume percentage of steel fibers, respectively.

- The maximum compressive strength gain in a 1% steel fiber blend is 28.29 percent, 8.54 percent in a 0.25 percent PP fiber blend, and 29.06 percent in a 0.25 percent carbon fiber blend.

- When compared to mix S1, the hybrid mixes S1P1 and S1P2 show significant beneficial synergy. Strength enhancement over control concrete is up to 22.24% in S1P1 and 25.22% in S1P2 mixes, compared to 15.95% in S1.

- The compressive strength improvement in S1C1 is 30.60% at 28 days, and the compressive strength improvement in S1C2 is 35.74%.

- At 0.5 percent volume fraction of steel fibers, only S1C0P0 and S1C1P1 mixes exhibit a greater beneficial synergy impact than S1C1 and S1C2 mixes. The maximum strength of the mixes S1C0P0 and S1C1P1 at 28 days is increased by 32.17% and 40.54%, respectively, when compared to the control concrete.

- However, at 1 percent and 1.5 percent volume fractions of steel fiber, all other SCPHFRC blends exhibit negative synergy when compared to all SCHFRC mixes. Compressive strength is lower in S2C0P0 to S3C1P1 mixes than in S2C1 to S3C2 mixes.

### 3.4 SPLIT TENSILE STRENGTH TEST.

This test is followed on UTM and the specimen is having specifications like 150mm dia, 300mm as height. Tests are conducted in accordance to IS 5816-1999. The casted specimens are tested at an interval of 28 and 56days of curing.

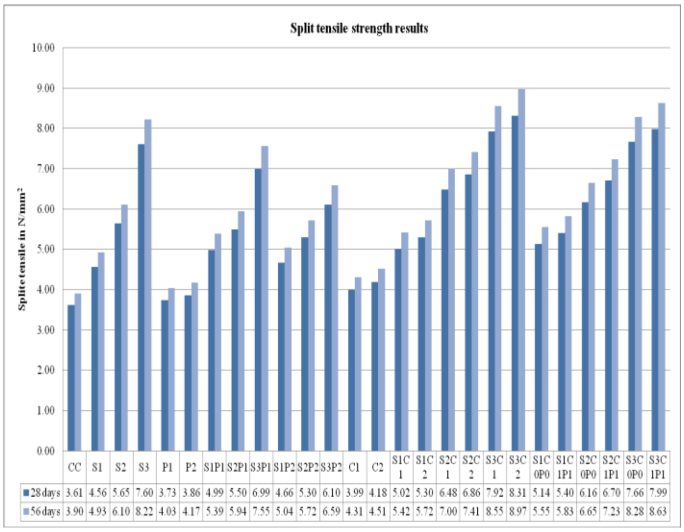


**Fig –6**: Shows results of Split tensile test.

For the percentages employed, the split tensile strength of steel, PP, and carbon in mono form increases with fiber content. It also increases for steel-carbon hybrid FRC in terms of percentages used. However, when polypropylene is utilized in a hybrid form with more than a certain percentage of steel fibers, the splitting tensile strength decreases.

- Due to fiber hybridization, a significant beneficial synergy is observed in the mixes S1P1 and S1P2 when 0.5 percent steel volume fraction is used.

- From the above table, the strength of other hybrid fiber mixes S2P1 to S3P2 is lower than that of mono fiber mixes S2 and S3. At higher fiber dosage ratios, hybridization is less effective in increasing splitting tensile strength as it is in compressive strength. In comparison to the conventional concrete, the strength enhancement in the hybrid mix S1P1 is up to 38.06 percent, 29.17 percent in the S1P2 mix, and 26.39 percent in the S1 mix.

- At 28 days, the splitting tensile strength improvement in SCHFRC mix S1C1 is 38.89% and in mix S1C2 it is 46.67% compared to control concrete. When the results are compared to SPHFRC, SCPHFRC, and SCHFRC systems, only the mix of S1C0P0 and S1C1P1 at 0.5 percent volume fraction of steel fibers shows a positive synergistic effect.

- The highest percentage increases are 42.22 % and 49.44 % for the S1C0P0 and S1C1P1 combinations, respectively.

- At 1% and 1.5 % volume fractions of steel fibers, SCPHFRC mixtures exhibit a negative synergy as compared to SCHFRC blends. The SCHFRC mixes were more powerful than the SCPHFRC mixtures. Chen and Liu (2005) reported a similar discovery in which the carbon-steel hybrid fiber combination outperformed the carbon-PP-steel fiber combination.

### 3.5 FLEXURAL STRENGTH TEST.

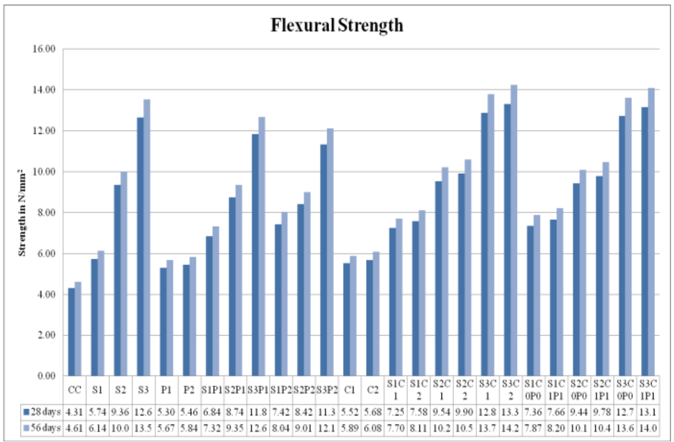


**Fig –7**: Shows results of Flexural test.

- At 28 days, the strength of mix S1 is 33.18 percent more than that of the control concrete. When PP is added to this mono steel mix, the strength increases by 58.70% in the mix S1P1 and 73.55% in the mix S1P2 compared to the control concrete after 28 days.

- Flexural strength is lower in hybrid mixes S2P1, S2P2 and S3P1, S3P2 than in mono mixes S2 and S3 at 1% and 1.50% volume fractions, respectively. This reduction is due to the increased number of fibers in the matrix, which causes higher porosity and the formation of weak interface zones.

- The insertion of fibers completely changes the failure characteristics. The specimen does not fail suddenly after the initial cracking occurs. The randomly oriented fibers that traverse the fractured portion prevent crack propagation and section separation.

### 3.6 WATER ABSORPTION TEST.

According to ASTM C 642-97, the water absorption test was done on cube specimens. Test was carried out at 7 days and 28 days interval.

The water absorption was found out using-

- Formula $= \frac{W2 - W1}{W1} x100$

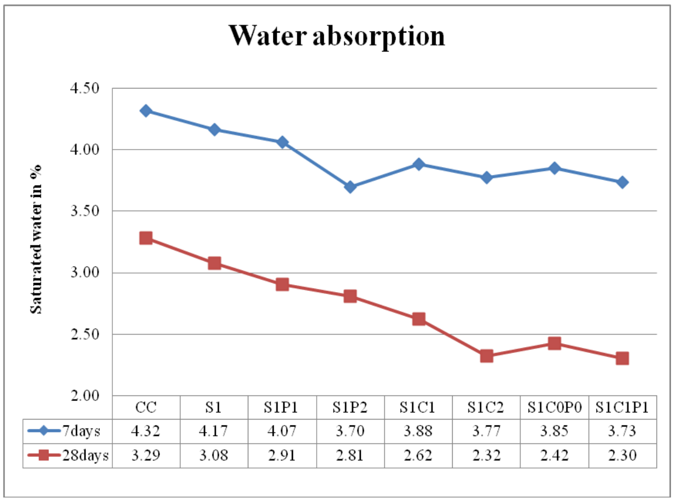


**Fig –8**: Shows results of Water Absorption test.

- At 7 and 28 days, the water absorption percentage in the control mix is 4.32 percent and 3.33 percent, respectively. Saturated water absorption in mono and hybrid fibrous mixtures is lower when compared to conventional concrete. The application of fibers reduces the absorption of water in concrete.

- Water absorption is lower during the 28 days when compared to the 7 days. This reduction in water absorption is caused by the presence of pozzolanic elements in the mix. At all curing times, water absorption in SPHFRC mix is lower than in SFRC mix.

## 4. CONCLUSIONS

- Workability reduces as fibre dosage increases in both mono and hybrid fibre types. Given the workability standards, the maximum volume percentage of steel fibre advised for hybrid combinations should not exceed 0.5 percent.

- At 0.5 percent steel volume fraction produces a greater positive effect in the mixes S1C0P0 (0.5 percent steel + 0.125 percent carbon + 0.125 percent PP) and S1C1P1 (0.5 percent steel + 0.25 percent carbon + 0.25 percent PP) for all mechanical properties. At 28 days, the maximum compressive, split tensile and flexural strength of the mix S1C1P1 (0.5 percent steel + 0.25 percent carbon + 0.25 percent PP) increased by 40.53 percent, 49.44 percent, and 77.73 percent, respectively, compared to the conventional concrete.

- When compared to conventional concrete at 28 days, the maximum compressive, split tensile, and flexural strength of the mix S1C1P1 (0.5 percent steel + 0.25 percent carbon + 0.25 percent PP) at 90 days is increased to 67.68%, 77.78%, and 116.71%, respectively.

- The maximum compressive, splitting tensile, and flexural strength of the S1P2 (0.5 percent steel + 0.5 percent PP) mix improved by 25.22 percent, 29.17 percent, and 73.55 percent, respectively, after 28 days when compared to the control concrete.
- The best SCHFRC hybrid combinations mechanical properties are S1C1 (0.5 percent steel + 0.25 percent carbon) and S1C2 (0.5 percent steel + 0.5 percent carbon).When compared to conventional concrete, the maximum compressive, split tensile and flexural strength at 28 days are improved by 35.74 percent, 46.67 percent, and 75.87 percent, respectively, in the mix S1C2 (0.5 percent steel + 0.5 percent carbon).
- At 28 days, the water absorption percentage in the control mix is 4.32. Water absorption is lower in mono and hybrid fibrous mixtures as compared to conventional concrete. The minimum water absorption in S1C1P1 (0.5 percent steel + 0.25 percent carbon + 0.25 percent PP) at 7 and 28 days is 3.74 percent and 2.31 percent, respectively.
- When compared to all other hybrid mixes, the beam with mix S1C1P1 (0.5 percent steel + 0.25 percent carbon + 0.25 percent PP) has a better positive synergy effect at 0.5 percent volume fractions of steel fibres, whereas mix S2C2 (1 percent steel + 0.5 percent carbon) performed well at 1 percent volume of steel fibres. The maximum ultimate load carrying capacity of the beam is increased by up to 51.98% in S1C1P1 (0.5 percent steel + 0.25 percent carbon + 0.25 percent PP) at 0.5 percent volume fractions of steel fibres and up to 75.95% in S2C2 (1 percent steel + 0.5 percent carbon) at 1% volume fractions of steel fibres.
- When compared to the normal beam, the energy absorption capacity of the mix S1C1P1 (0.5 percent steel + 0.25 percent carbon + 0.25 percent PP) is raised by 117 percent, and it is increased by 226.67 percent in the mix S2C2 (1 percent steel + 0.5 percent carbon).
- As a result, it is determined that adding steel, carbon, and fibrillated polypropylene fibre in hybrid form can considerably improve the qualities of quaternary blended concrete with SCMs.

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IS Codes Used

• IS: 10262:2009 (Specification for concrete mix design).

• IS: 456: 2000 (Plain & Reinforced concretecode of Practice).

• IS: 383:1970 (Specification for coarse & fine aggregate).