# Mechanical Characteristics of Hybrid Fiber Reinforced High Strength Concrete Blended with Silica Fume

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**Abstract:** This paper furnishes the results obtained from the experimental investigation of mechanical characteristics of steel fiber reinforced high strength concrete blended with silica fume as mineral admixture. The various mechanical characteristics that were studied by using the specimens like cube, cylinder and prism were cube compressive strength, split tensile strength and flexural strength of steel fiber reinforced high strength concrete of M60 grade. The study is confined to study the mechanical characteristics by using 7.5% silica fume as replacement to cement and also using steel and polypropylene fibers with volume fractions of 1%, 1.5%, and 2% with variable percentages. Test results showed an improved mechanical characteristic of high concrete by the process of hybridization of fibers.

**Keywords**: mechanical characteristics, hybrid fibers, silica fume, high strength concrete.

## Introduction

High strength concrete is being extensively used in construction industry due to its good abrasion, impact and cavitations resistance. By the usage of high strength concrete in high rise structures, resulted in economical as well as durable advantages. Structural systems in high rise structures like columns, beams and shear walls can be constructed with high strength concrete which results in decrease in dead load thereby a decrease in cross sectional dimensions of these structural systems. Along with these advantages, high strength concrete possess some disadvantages. The major one is its low tensile strength and flexural strength. In order to overcome these difficulties, fibers were imparted as secondary reinforcement in concrete, so as to improve the tensile and flexural strength of concrete.

Fiber - reinforced cementitious composites contains an ability to flex and self-strengthen before fracturing. It was developed with the motto to solve the structural problems in concrete, like the tendency to fail in a brittle manner under extensive loading. To overcome the brittle failure of high strength concrete, a strategy was made to impart the fibers in concrete which results in improved mechanical characteristics of high strength concrete.

Extensive research has been done on the inclusion of fibers in concrete and a new concept called hybridization of fibers was developed. It refers to usage of two or more fibers in concrete which imparts better improved mechanical characteristics than the use of single fiber in concrete. The objective of this paper is to determine the mechanical characteristics of hybrid fiber reinforced high strength concrete in terms of compressive, splitting tensile and flexural tests in comparison with plain high strength concrete.

## Literature review

Hooton [1] investigated on influence of silica fume replacement of cement on physical properties and resistance to sulphate attack, freezing and thawing, and alkali-silica reactivity. He reported that the maximum 28-day compressive strength was obtained at 15% silica fume replacement level at a w/b ratio of 0.35 with variable dosages of HRWRA.

Prasad et al. [2] has undertaken an investigation to study the effect of cement replacement with micro silica in the production of High-strength concrete.

Yogendran et al.[3] investigated on silica fume in High-strength concrete at a constant water binder ratio (w/b) of 0.34 and replacement percentages of 0 to 25, with varying dosages of HRWRA.The maximum 28-day compressive strength was obtained at 15% replacement level.

Lewis [4] presented a broad overview on the production of micro silica, effects of standardization of micro silica concrete-both in the fresh and hardened state.

Bhanja., and Gupta [5] reported and directed towards developing a better understanding of the isolated contributions of silica fume concrete and determining its optimum content. Their study intended to determine the contribution of silica fume on concrete over a wide range of w/c ratio ranging from 0.26 to 0.42 and cement replacement percentages from 0 to 30.

Tiwari and Momin [6] presented a research study carried out to improve the early age
compressive strength of Portland slag cement (PSC) with the help of silica fume. Silica fume from three sources- one imported and two indigenous were used in various proportions to study their effect on various properties of PSC.
Venkatesh Babu and Natesan [7] Investigated on physico-mechanical properties of High-performance concrete (HPC) mixes, with different replacement levels of cement with condensed silica fume (CSF) of grade 960-D.

## Experimental investigation

### Materials

The cement used in concrete mixes was ordinary Portland cement 53 grade as per IS 12269- 1987. The fine aggregate used was local river sand with specific gravity of 2.67. The coarse aggregate was crushed stone with size of 20 mm and specific gravity of 2.81 Silica fume obtained from Vijayawada, Andhra Pradesh which improved concrete properties in fresh and hardened states with specific gravity 2.2. To improve the workability of concrete, a super-plasticizer CONPLAST SP-430 was used. The fibers used in the study were Hooked end steel as shown in Fig. 1, Polypropylene as shown in Fig. 2, the properties were given by the manufacturers as shown in Table 1.The high strength concrete mix proportions were designed by using ACI 211-4R-1993.

Fig.1 Hooked end Steel Fibers

Fig.2 Polypropylene Fibers

Table.1 Properties of Steel and Polypropylene Fibers

| S.No | Fiber Properties | Fiber Details | |
|---|---|---|---|
| | | Steel Fiber | Polypropylene Fiber |
| 1. | Length | 35 mm | 12 mm |
| 2. | Shape | Straight | Hooked end |
| 3. | Diameter | 45 mm | - |
| 4. | Aspect Ratio | 50 | 1050 Denier |

### Preparation of test specimens

The specimens casted to determine the mechanical properties such as compressive strength, split tensile strength and flexural strength are of dimensions as follows: cube specimens 150 mm x 150 mm x 150 mm, cylinders 150 mm x 300 mm and prisms of size 100 mm x 100 mm x 500 mm. Cement, Fine aggregate, coarse aggregate and silica fume (7.5% replacement to cement) were initially mixed in dry state. Water along with super plasticizer is mixed to it and rotated in pan mixer. Later the fibers were placed in concrete in a distorted way and the mixing process continued for 3 minutes. Later the well prepared mix of hybrid fiber reinforced high strength concrete was placed into the molds with proper compaction. The molds were demoulded after 24 hours of casting and the specimens were placed in a curing tank for a period of 28 days.

### Testing Procedure

All tests were conducted using 200 T capacity of compression testing machine as per codal provisions. Table 2 Shows the designation of the specimens and its mechanical strength characteristic test results on hybrid fiber reinforced high strength concrete (HFRHSC).

## Test results & discussions

Table 2 : Results showing compressive Strength of Hybrid Fiber Reinforced High Strength Concrete

| S.No. | Mix Designation | Volume fraction of fibers (%) | (Steel+Polyproyplene) Fibers | Compressive Strength (MPa) |
|---|---|---|---|---|
| 1. | CONTROL MIX (M1) | 0 | 0 | 62.22 |
| 2. | M2 | 1 | 0.5%+0.5% | 66 |
| 3. | M3 | 1.5 | 1%+0.5% | 63.11 |
| 4. | M4 | 2 | 1.5%+0.5% | 60.88 |

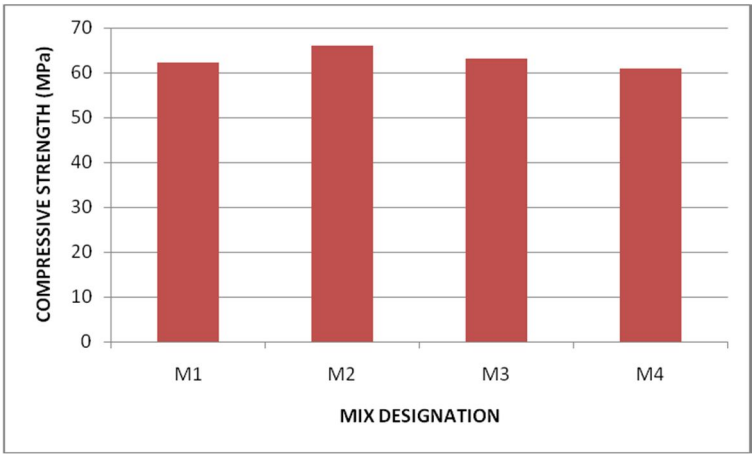


Fig.3 Graph showing compressive strength for hybrid fiber reinforced high strength concrete

From the above graph, it can be observed that the cube compressive strength is higher for the mix designation M2 – viz., M60 grade concrete with 7.5% replacement of silica fume to cement and 0.5% Steel fibers and 0.5% polypropylene fibers by weight of cement. The percentage increase in compressive strength was found to be 5.72% when compared with control mix.

Table 3 : Results showing split tensile Strength of Hybrid Fiber Reinforced High Strength Concrete

| S.No. | Mix Designation | Volume fraction of fibers (%) | (Steel+Polyproyplene) Fibers | Split tensile Strength (MPa) |
|---|---|---|---|---|
| 1. | CONTROL MIX (M1) | 0 | 0 | 6.68 |
| 2. | M2 | 1 | 0.5%+0.5% | 7.25 |
| 3. | M3 | 1.5 | 1%+0.5% | 7.10 |
| 4. | M4 | 2 | 1.5%+0.5% | 6.95 |

From the graph 4, it can be observed that the split tensile strength is higher for the mix designation M2 – viz., M60 grade concrete with 7.5% replacement of silica fume to cement and 0.5% Steel fibers and 0.5% polypropylene fibers by weight of cement. The percentage increase in split tensile strength was found to be 7.86% when compared with control mix.
From the above graph 5, it can be observed that the flexural strength is higher for the mix designation M2 – viz., M60 grade concrete with 7.5% replacement of silica fume to cement and 0.5% Steel fibers and 0.5% polypropylene fibers by weight of cement. The percentage increase in split tensile strength was found to be 40.7% when compared with control mix.

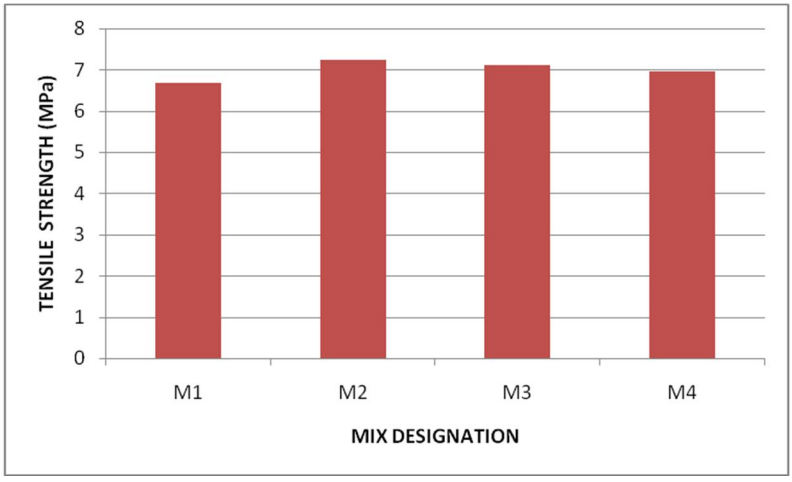


Fig.4 Graph showing split tensile strength for hybrid fiber reinforced high strength concrete

Table 4 : Results showing flexural Strength of Hybrid Fiber Reinforced High Strength Concrete

| S.No. | Mix Designation | Volume fraction of fibers (%) | (Steel+Polyproyplene) Fibers | Flexural Strength (MPa) |
|---|---|---|---|---|
| 1. | CONTROL MIX (M1) | 0 | 0 | 7.52 |
| 2. | M2 | 1 | 0.5%+0.5% | 12.68 |
| 3. | M3 | 1.5 | 1%+0.5% | 12.2 |
| 4. | M4 | 2 | 1.5%+0.5% | 11.58 |

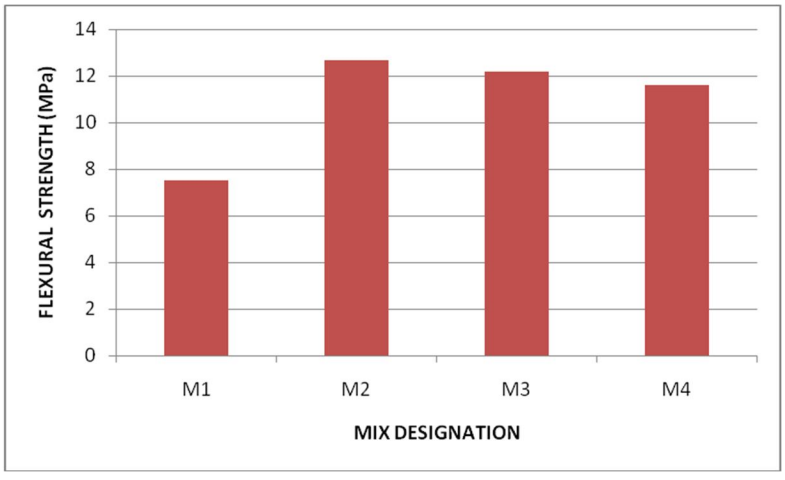


Fig.5 Graph showing flexural strength for hybrid fiber reinforced high strength concrete

## Conclusions

The compressive strength of hybrid fiber reinforced high strength concrete was improved when compared with the Controlled high strength concrete mix. It can be concluded from this investigation, that the use of 0.5 % steel fibers and 0.5% % Polypropylene fibers at each volume fraction gave optimum mechanical characteristics. The compressive strength ranged from 5.72%, 4.37% and 7.75% at volume fractions of 1%, 1.5%, 2% respectively when compared with control mix. The spilt tensile strength ranged from 7.86%, 5.91%, 3.38% at volume fractions of 1%, 1.5%, 2% respectively when compared with control mix. The flexural strength ranged from 40.7%, 38.3%, 35% at volume fractions of 1%, 1.5%, 2% respectively when compared with control mix.

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