**EFFECT OF STEEL AND SISAL FIBER ON MECHANICAL PROPERTIES OF CONCRETE**

1D.Nithiyya, 2G.Ramakrishna

1Department of Civil Engineering, Pondicherry Engineering College, Puducherry-605014.  
2Department of Civil Engineering, Pondicherry Engineering College, Puducherry-605014.  
Email: 1nithyadivagar@gmail.com, 2grkv10@pec.edu

**ABSTRACT**

Fibers are generally added to concrete to improve strength, durability, toughness. The addition of fiber to concrete to improve its strength is known as Fiber Reinforced Concrete (FRC). The combination of more than one type of fibers is known as Hybrid Fiber Reinforced Concrete (HFRC). Hybrid Fibers are used to resist formation of cracks and improve the properties of concrete. Generally, steel, polypropylene, polyester, sisal, glass and carbon fibers can be used as hybrid fibers. This paper deals with the results of mechanical properties of steel-sisal fiber reinforced concrete for various mix proportions. The specimens were casted with steel and sisal fibers in the mix proportion of 0%-0%, 40%-60% and 60%-40% with total volume fraction of 1%. The objective of this study to study the effect of inclusion of hybrid fibers on the compressive strength, modulus of elasticity and flexural strength. The results showed that the hybrid fiber reinforced concrete with mix proportion of 60% Steel and 40% Sisal shows consistently improved strength compared to the other mix proportions.

**Keywords:** hybrid fiber reinforced concrete, compressive strength, modulus of elasticity, flexural strength.

---

**I. INTRODUCTION**

Concrete is a composite material composed of fine and coarse aggregate bonded together with fluid cement (cement paste) that hardens over time. Generally, concrete is strong in compression and weak in tension. Due to this, the tensile and flexural strength of concrete is found to be lower than the compressive strength. The weakness in tension can be overcome by the use of sufficient volume
fraction of certain fibers. The addition of fibers into concrete mass can increase the compressive strength, tensile strength, flexural strength, shear strength, toughness and impact strength of concrete. The fibers used in Concrete may be of different materials like steel, carbon, glass, polypropylene etc. Hybrid Fiber Reinforced Concrete is formed from a combination of different types of fibers, which differ in material properties, remain bonded together when added in concrete and retain their identities and properties. The combining of fibers often called as hybridization [5]. It increases elastic modulus, decreases brittleness; controls crack initiation and its subsequent growth and propagation [3]. In hybrid fibers, two or more different types of fibers are rationally combined to produce a composite that derives benefits from each of the individual fibers. The hybrid combination of fibers can improve concrete properties as well as reduce the overall cost of concrete production [4].The hybrid fibers are used in rigid pavements, airfield pavements, flexible pavements, earthquake-resistant and explosive-resistant structures, mine and tunnel linings, bridge deck overlays, hydraulic structures, rock-slope stabilization etc.[6]

A. HISTORY OF HYBRID FIBER REINFORCED CONCRETE
The concept of using fibers as reinforcement is not new. Fibers have been used as reinforcement since ancient times. Historically, horsehair was used in mortar and straw in mud bricks. In the early 1900s, asbestos fibers were used in concrete, there was a need to find a replacement for the asbestos used in the concrete and other building materials once the health risks associated with the substance were discovered. By the 1960s, steel, glass, and synthetic fibers such as polypropylene fibers were used in concrete, and research in to new fiber reinforced concretes continues today [3].

B. COMBINATION OF HYBRID FIBERS
i. Hybrids Based on Fiber Constitutive Response:
One type of fiber is stronger and stiffer and provides reasonable first crack strength and ultimate strength, while the second type of fiber is relatively flexible and leads to improved toughness and strain capacity in the post-crack zone. [2]

ii. Hybrids Based on Fiber Dimensions:
One type of fiber is smaller, so that it bridges micro-cracks and therefore controls their growth and delays coalescence. This leads to a higher tensile strength of the composite. The second fiber is larger and is intended to arrest the propagation of macro-cracks and therefore results in a substantial improvement in the fracture toughness of the composite. [2]

iii. Hybrids Based on Fiber Function:
One type of fiber is intended to improve the fresh and early age properties such as ease of production and plastic shrinkage, while
the second fiber leads to improved mechanical properties. Some such hybrids are now commercially available where a low (<0.2%) dosage of polypropylene fiber is combined with a higher (~0.5%) dosage of steel fiber. [2]

II. REVIEW OF LITERATURES
Rajarajeshwari et al. (2013) conducted experimental tests on Hybrid Fiber Reinforced Concrete (HFRC). The effect of addition of mono fibers and hybrid fibers on the mechanical properties of concrete mixture is studied. Steel fibers of 1% and polypropylene fibers 0.036% were added individually to the concrete mixture as mono fibers and then they were added together to form a hybrid fiber reinforced concrete. Mechanical properties such as compressive strength, split tensile strength and flexural strength were determined. The results show that hybrid fibers improve the compressive strength marginally as compared to mono fibers. Whereas, hybridization improves split tensile strength and flexural strength noticeably. Hybridization shows 17% increase in compressive strength and boosted the split tensile strength and flexural strength by 52.87% and 34.25%. The improved mechanical properties of HFRC would result in reduction of warping stresses and short and long term cracking. Caggiano et al. (2016) presented the results of experimental tests performed on concrete specimens internally reinforced with polypropylene and steel fibers. Specifically, samples of five mixtures (plus areference plain concrete), characterized by the same total volume of fibers, but different fractions of polypropylene and steel fibers, and were tested under compression and in bending. This study was aimed to clarify the influence of different combinations of these fibers on the resulting fracture behavior of Hybrid Fiber-Reinforced Concrete (HFRC). As expected, the results obtained from compression tests highlighted a negligible influence of fibers in terms of strength and, hence, FRC specimens exhibited post-peak response more ductile than the reference ones. On the other hand, a marked re-hardening response was observed in the post-cracking behavior for specimens with higher percentage of steel fibers; however, at the same time, the corresponding results showed a relevant scatter. Combining steel and polypropylene fibers is an attractive solution for enhancing the post-cracking behavior of cement-based matrices and possibly tailoring the material response to specific structural requirements.

Pawar et al. (2015) conducted experiments to evaluate the strength of concrete cubes, cylinders and beams cast using M30 grade concrete and reinforced with flat crimped steel and polypropylene fibers. The specimens were incorporated with steel and polypropylene fibers in the mix proportions of 0-0%, 0-100%, 25-75%, 50-50%, 75-25%, 100-0% by volume at a total fraction of 1.0%. This study concluded that compressive strength is increased by 19.95%, split tensile strength increases by 41.61% and flexural strength
increases by 20.78% with respect to normal concrete. Compressive strength and flexural strength of HFRC for 75%-25%(Steel-Polypropylene) is maximum. Split Tensile Strength of HFRC Concrete increases with increasing contribution of Steel Fiber in hybridization ratio and hence it is maximum for 100%-0%(Steel-Polypropylene).

Aminuddin et al. (2015) tests on fiber reinforced concrete (FRC) to improve strength, ductility, toughness, and durability of the structures. The application of FRC includes tunnel lining, ground slab, façade and many more. However, when exposing them to high temperature such as fire, there is still little information on the impact on its mechanical properties. The main objective of the study is to understand the fundamental behavior of FRC when it is exposed to elevated temperature. However, rather than relying on one type of fiber, this study proposed of mixing two different types of fiber in concrete which will then be exposed to elevated temperature at normal temperature i.e. 27°C (room temperature), 200°C, and 400°C. The two types of fibers i.e. steel and propylene has different characteristics. The study is mainly focused on the experimental work. The fiber dosage will also be varied with percentage of steel-to-propylene of (100-0), (75-25), (50-50), (25-75) and (0-100) at 1.5% of fibers proportion from the volume of the concrete. Therefore this research is expected to answer the fundamental question whether if one type is vulnerable to fire, the other one will take place to avoid catastrophic failure of the whole structure.

Experimental work is carried out to study the impact of elevated temperature on the compressive strength, tensile strength, and flexural strength. This study concluded that when the samples exposed to elevating temperature increases, the strength of the concrete is reduced and makes the concrete become more brittle. However, the addition of fibers into the concrete mixture minimized the effects that occur in the concrete. The addition of fibers also enhanced the mechanical properties of the concrete, as the steel and polypropylene fibers inhibit the cracking growth that occurred in the concrete. Observation from the experimental work also found that for the single fiber mixture, batch of ST-PP (100-0) is better than batch of ST-PP (0-100). Meanwhile for the combined fibers, batch of ST-PP (75-25) is better than the batch of ST-PP (50-50) and ST-PP (25-75).

This paper addresses the behaviour of hybrid fiber reinforced concrete with steel and sisal fiber for different mix proportions.

III. EXPERIMENTAL WORK

Experimental work is carried out to achieve the objectives of this study. The specimens were casted with steel and sisal fibers in the mix proportion of 0%-0%, 40%-60% and 60%-40% with total volume fraction of 1%.

A. Materials

1. Cement
The cement used in concrete mixes was Ordinary Portland Cement (OPC) of 43 grade conforming to IS 8112-1989. Cement was tested in laboratories and the results are as follows:

Table 1
Properties of cement

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Description of test</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Specific gravity</td>
<td>2.60</td>
</tr>
<tr>
<td>2</td>
<td>Fineness modulus</td>
<td>8.13</td>
</tr>
<tr>
<td>3</td>
<td>Bulk density</td>
<td>1415 m³</td>
</tr>
</tbody>
</table>

2. Fine aggregate
Locally available sand was used as fine aggregate which confirms to Zone II of IS 383-1983 and the test results for fine aggregate are as follows:

Table 2
Properties of fine aggregate

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Description of test</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Specific gravity</td>
<td>2.60</td>
</tr>
<tr>
<td>2</td>
<td>Sieve analysis (conforming to IS 383-1983)</td>
<td>Zone II</td>
</tr>
<tr>
<td>3</td>
<td>Fineness modulus</td>
<td>2.67</td>
</tr>
<tr>
<td>4</td>
<td>Bulk density</td>
<td>1530 kg/m³</td>
</tr>
</tbody>
</table>

3. Coarse aggregate
Locally available coarse aggregates of size 20 mm and 12.5 mm were used. The test results are as follows:

Table 3
Properties of coarse aggregate

4. Fibers
Two types of fibers were used for this study: (i) Steel fibers (ST) (ii) Sisal fibers (SI) in different mix proportions in the concrete mixture. The properties of steel and sisal fibers are as follows:

Table 5
Properties of sisal fiber

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Description of test</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fiber length</td>
<td>50 mm</td>
</tr>
<tr>
<td>2</td>
<td>Fiber diameter</td>
<td>0.60 mm</td>
</tr>
<tr>
<td>3</td>
<td>Aspect ratio</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>Specific gravity</td>
<td>7.8</td>
</tr>
<tr>
<td>5</td>
<td>Young’s modulus</td>
<td>200000 MPa</td>
</tr>
<tr>
<td>6</td>
<td>Shape</td>
<td>Hooked end</td>
</tr>
</tbody>
</table>
### Table 6 Properties of Superplasticizer

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Physical state</td>
<td>Brown liquid</td>
</tr>
<tr>
<td>2</td>
<td>Specific gravity</td>
<td>1.20+. 0.015 @ 27°C</td>
</tr>
<tr>
<td>3</td>
<td>Chloride content</td>
<td>Nil as per IS 456 and BS 5075</td>
</tr>
<tr>
<td>4</td>
<td>Air entrainment</td>
<td>Less than 1% additional air entrained</td>
</tr>
<tr>
<td>5</td>
<td>Maximum dosage</td>
<td>0.4%-1.2% weight of cement</td>
</tr>
</tbody>
</table>

4. **Super Plasticizer**

Classic superflo sp was used to enhance the workability of mix. It enables high water retention up to 30% leading to high early and ultimate strength. The properties of super plasticizer used are as follows:

Table 6 Properties of Superplasticizer

### IV. MIX PROPORTIONS

The concrete mixes was prepared for M25 grade of concrete with water-cement ratio 0.5. The mix proportions for the mixes are tabulated below:

Table 7
Mix proportions for Hybrid Fiber Reinforced Concrete

### V. RESULTS AND DISCUSSION

#### A. Compressive strength

Cube moulds of size 150mm x 150mm x150mm were used to test the compressive strength of hybrid fiber reinforced concrete with varying percentage of steel and sisal fibers. The results of compressive strength for different mixes are tabulated below: Table 8

Test results for compressive strength

#### 1. Graphical representation of compressive strength results

The results of compressive strength shows that HFRC with mix 60% Steel and 40% Sisal shows the maximum value when compared to conventional concrete. Hybridization of steel and sisal fibers (60%-40%) shows good results when compared with other mix proportions.
The graphical representation of compressive strength is shown in fig. 8.

Fig. 8 Graphical representation of compressive strength results

**Modulus of Elasticity and poisson’s ratio**

Cylinder moulds of 300 mm height and 150 mm diameter was used to test the modulus of elasticity and poisson’s ratio. The results of modulus of elasticity and poisson’s ratio for conventional concrete and HFRC with hybridization ratio of fibers are tabulated in table 9.

Table 9
Test results for modulus of elasticity and poisson’s ratio

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Mix ID</th>
<th>Modulus of elasticity (N/mm²)</th>
<th>Poisson’s ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CC (0%-0%)</td>
<td>24100</td>
<td>0.3</td>
</tr>
<tr>
<td>2</td>
<td>M1 (40%ST-60SI)</td>
<td>25504</td>
<td>0.1</td>
</tr>
<tr>
<td>3</td>
<td>M2 (50%ST-50%SI)</td>
<td>24365</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Fig 9 Test setup for modulus of elasticity and poisson’s ratio

1. **Stress-strain graph for cylinder specimens**

The modulus of elasticity of steel fiber is higher than that of sisal fiber. High modulus of elasticity of steel fiber makes the concrete more ductile. Hence, as the percentage of steel increases, the strength of concrete also increases. The results of modulus of elasticity for 60%-40% mix (Steel-Sisal) shows the maximum when compared to conventional concrete and all other mix proportions. Fig. 10 shows the comparison of stress-strain plot for
all the mixes with different hybridization of fibers.

![Stress-Strain graphs for cylinder specimens](image)

**Fig.10 Stress-Strain graphs for cylinder specimens**

**B. Flexural strength**

Prism moulds of size 500 mm x 100mm x 100mm to test the flexural strength of conventional concrete and HFRC with different hybridization ratio. The results of flexural strength for varying percentage of steel and sisal fibers are tabulated in table 10.

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Mix ID</th>
<th>Flexural Strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CC (0%ST-0%SI)</td>
<td>4.07</td>
</tr>
<tr>
<td>2</td>
<td>M1 (40%ST-60%SI)</td>
<td>4.39</td>
</tr>
<tr>
<td>3</td>
<td>M2 (50%ST-50%SI)</td>
<td>4.17</td>
</tr>
<tr>
<td>4</td>
<td>M3 (60%ST-40%SI)</td>
<td>4.49</td>
</tr>
</tbody>
</table>

![Test setup for flexure test](image)

**Fig.11 Test setup for flexure test**

1. Graphical representation of flexural strength results
The graphical representation of results of flexural strength for conventional concrete mix and varying hybridization ratio of steel and sisal fiber is shown in fig. 12. The results for HFRC with 60%-40% shows maximum value when compared to all other mixes. Increase in percentage of steel fiber gives good results and also addition of sisal fiber increases the flexural strength of concrete in comparison with conventional concrete.

![Graphical representation of flexural strength results](image)

**Fig. 12** Graphical representation of flexural strength results

**VI. CONCLUSION**

From the present study, the following conclusions are made:

i. Hybrid Fiber Reinforced Concrete shows better results in comparison with plain conventional concrete.

ii. Compressive strength of HFRC with 60%-40% (Steel-Sisal) mix shows maximum results and it is increased by 20.3% when compared to conventional concrete.

iii. Modulus of elasticity and poisson ratio of HFRC with 60%-40% (Steel-Sisal) mix shows good results and it is increased by 8.44%.

iv. Flexural strength of HFRC with 60%-40% (Steel-Sisal) mix shows maximum results and it is increased by 10.32% when compared to conventional concrete.

v. Hence hybridization of steel and sisal fibers show good response than plain concrete without fiber. It improves the mechanical properties of concrete.

**ACKNOWLEDGMENT**

I would like to express my deepest sense of respect and indebtedness to Dr.G.Ramakrishna, Professor, for his consistent support, guidance, encouragement and advice.

**REFERENCES**


