

# An Experimental Investigation On the Mechanical Properties of Hooked End Steel Fibers and Polypropylene Fiber Reinforced Concrete

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## Abstract

In recent years, the use of different types of fibers such as steel, glass, polypropylene, and carbon has gained significant attention for enhancing the properties of concrete. Fiber-reinforced concrete (FRC), composed of cement, water, aggregates, and discrete fibers, and has shown improved mechanical properties, particularly in tension-prone applications. This experimental investigation focuses on evaluating and comparing the mechanical properties of M40 grade concrete reinforced with Hooked end steel fibers at varying contents of 0.3%, 0.6%, 0.9%, and 1.2% with 0.2% of Polypropylene fiber. The study compares the properties of concrete, such as compressive strength, split tensile strength, flexural strength and impact strength, to determine the optimum content of fibers. It is found that the compressive strength increased significantly due to the presence of 0.6% of steel fibers and 0.2% of polypropylene fibers. Maximum split tensile strength is obtained at 0.3% steel and polypropylene fibers, while maximum flexural strength is obtained at 0.6% of steel fibers with 0.2% polypropylene fibers. With 0.2% polypropylene fiber and 0.6% hooked end steel fiber shows a significant increase in Compressive strength when its compared to the control mix, indicating that the addition of fibers enhances the tensile strength of given mix. The polypropylene fibers proved to be crack resistance compared reduce (i.e.; plastic shrinkage improved durability). Moreover, from an economic perspective, polypropylene fibers turned out to be less expensive compared to steel fibers. Results affirm that the fiber reinforcement at optimal ratios can substantially improve the mechanical properties of concrete and lead to better structural performance.

**Key Words:** Steel fiber, Polypropylene fiber, Compressive Strength, Split tensile strength.

## 1. Introduction

Concrete is one of the most widely used construction materials across the world due to its versatility, durability, and excellent compressive strength. It can be easily moulded into any desired shape and is generally produced using cost-effective and materials such as cement, aggregates, and water. However, despite its many advantages, conventional concrete is inherently weak in tension and brittle in

nature, leading to sudden failure under tensile or impact loads.

Researchers and engineers have developed Fiber Reinforced Concrete (FRC), a composite material in which short, discrete fibers are uniformly distributed and randomly oriented within the concrete matrix. The addition of fibers significantly enhances several mechanical and durability properties of concrete, such as toughness, impact resistance, ductility, and crack control.

Now a days, intensive research and technological advancements have led to the development of a variety of fibers, including steel, polypropylene, glass, and carbon fibers, each offering distinct advantages.

## Significance of Fiber Reinforced Concrete (FRC)

FRC is a composite material made by incorporating discrete, short fibers uniformly distributed throughout the concrete matrix. These fibers act as crack arresters and help bridge micro-cracks, thereby enhancing the mechanical properties and durability of the concrete. Fibers used in FRC can be classified into different types based on material, such as steel fibers, synthetic fibers (e.g., polypropylene, nylon), glass fibers, carbon fibers, and natural fibers (e.g., coir, jute).

Each type of fiber imparts specific characteristics to the concrete. For instance, steel fibers significantly improve flexural toughness, post-crack load-carrying capacity, and impact resistance. In contrast, polypropylene fibers are more effective in controlling plastic shrinkage cracks and improving resistance to fire-induced spalling.

The behaviour of FRC is influenced by various factors, including fiber type, shape, aspect ratio, volume fraction, and orientation within the mix. The addition of fibers alters not only the mechanical strength but also the workability, ductility, and long-term performance of concrete.

The ever-increasing demands on concrete structures in terms of durability, loadbearing capacity, and crack resistance have led to the development of fiber-reinforced concrete (FRC). Among the various types of fibers used, steel fibers and polypropylene fibers are the most commonly adopted due to their distinct mechanical properties and effectiveness in enhancing the properties of concrete.

## Objectives and Scope of the Present Work

- To evaluate the effect of hooked end steel fibers on mechanical properties
  - The study aims to investigate how different percentages of hooked end steel fibers (0.3%, 0.6%, 0.9%, and 1.2%) influence the mechanical properties of M40 grade concrete, particularly compressive strength and split tensile strength at 7 and 28 days of curing.
- To analyze the combined effect of steel fibers and polypropylene fibers
  - The project includes a constant addition of 0.2% polypropylene fibers along with varying steel fiber content to study their combined influence on strength characteristics, crack resistance, and overall performance of concrete.
- To study the workability characteristics of fiber-reinforced concrete
  - The scope includes evaluating changes in workability (slump value) with increasing fiber content and determining the suitable dosage of super plasticizer required to maintain proper consistency and

ease of placement.

- To determine the optimum percentage of steel fiber content
- Based on experimental results, the study aims to identify the optimum percentage of hooked end steel fibers that provides maximum strength and performance without significantly affecting workability or causing material segregation.
- To compare fiber-reinforced concrete with conventional M40 concrete
- The objective is to compare the mechanical performance of fiber-reinforced concrete with normal M40 concrete (0% fibers) and highlight improvements in strength, durability, and crack resistance for practical engineering applications.

## **MATERIALS USED AND METHODOLOGY**

This study involved conducting preliminary tests on the collected materials to evaluate their properties. Cement, fine aggregates, coarse aggregates, and water were tested as per standard procedures, and an M40 grade concrete mix was designed with a proportion of 1:2.23:3.03:0.34. Concrete specimens in the form of cubes and cylinders were cast and cured for specified durations. After curing, compressive strength, split tensile strength tests were conducted. The results were compared with those of conventional concrete and fiber reinforcement concrete.

### **Materials**

- **Cement**
- **Fine Aggregate**
- **Coarse Aggregate**
- **Hooked end Steel Fibers**
- **Polypropylene Fibers**
- **PCE CAC–Hyper fluid Plus**

### **Cement:**

Cement is a fine mineral powder and one of the essential binding materials used in construction. It plays a crucial role as the primary constituent of concrete and is widely used due to its strength and versatility. When mixed with water, cement forms a paste that binds aggregates together and hardens over time, even under water. The physical and chemical properties of cement can vary depending on its composition and fineness, which influence the strength and durability of the final concrete product. In this experimental investigation, 53 Grade Ordinary Portland Cement (OPC) of the JSW brand is used. The physical properties of the selected cement were determined through standard laboratory tests and found to be within the permissible limits prescribed by the relevant Indian Standard codes.

## Aggregates

Aggregates are granular materials, such as sand, gravel, and crushed stone, used as a fundamental component in concrete, asphalt, and road bases. They provide bulk strength and stability to construction projects, influencing the overall performance and durability of the structure.

### Types of Aggregate:

- **Fine Aggregate**
- **Coarse Aggregate**

### Fine Aggregate:

Fine aggregate is an essential ingredient in concrete and mortar, consisting of naturally occurring sand that passes through a 4.75 mm IS sieve. It plays a vital role in filling the voids between coarse aggregates, improving the workability, strength, and durability of the concrete mix.

According to IS 383:2016, classify the fine aggregate into four types according to its grading as fine aggregate of grading zone-1 to grading zone-4. The four grading zones become progressively finer from grading zone-1 to grading zone-4. 90% to 100% of the fine aggregate passes through the 4.75mm IS sieve, and 0 to 15% passes through the 150 micron IS sieve, depending upon its grading zone.

### Coarse Aggregate:

Coarse aggregate refers to uncrushed gravel or stone resulting from natural disintegration, as well as crushed gravel or stone, with particle sizes greater than 4.75 mm. It is a key component in concrete, contributing significantly to its strength and durability. The coarse aggregate results from sieve analysis and properties are presented in Tables 3.4 and 3.5. In this project, a graded mix of 20 mm and 12 mm aggregates was used to achieve better compaction and improved mechanical properties of the concrete. Specific gravity is 2.63, and water absorption is 0.4%.

### Hooked End Steel Fiber:

Hooked-end steel fibers are widely used in fiber-reinforced concrete to enhance its mechanical performance, particularly in controlling cracking and improving post-cracking behavior. In this project, fibers of length 30 mm and diameter 0.5 mm, giving an aspect ratio of 60, provide an optimal balance between workability and strength. The hooked ends act as mechanical anchors within the concrete matrix, significantly improving the bond between the fiber and cement paste, thereby increasing resistance to pull-out under tensile stress. This leads to improved tensile strength, flexural strength, and energy absorption capacity (toughness) of the concrete. The selected aspect ratio of 60 is considered effective for crack bridging, as longer fibers with sufficient slenderness can arrest micro-cracks and delay their propagation into macro-cracks. Additionally, these fibers help in enhancing ductility and reducing brittle failure, which is a typical characteristic of conventional concrete. However, excessive fiber content may reduce workability due to increased internal friction. Overall, the use of hooked-end steel fibers of these dimensions contributes to improved structural performance and durability of M40 grade concrete by providing better crack control and load redistribution capabilities.

## **Polypropylene Fibers:**

In this investigation, monofilament polypropylene fibers were used. These fibers were incorporated into the concrete mix to provide micro reinforcement. Monofilament polypropylene fibers are thin, continuous synthetic filaments made of polypropylene, characterized by their lightweight nature, hydrophobicity, chemical inertness, and resistance to corrosion and alkali attack.

Their mechanism of action lies in their ability to bridge micro-cracks within the cementitious matrix at an early stage, thereby delaying crack propagation and reducing crack width. When uniformly dispersed in the mix, these fibers improve dimensional stability, reduce permeability, and enhance surface integrity. As a result, they provide improved resistance against the ingress of water, chlorides, and other aggressive agents, ultimately contributing to greater durability of concrete.

These fibers are particularly advantageous in applications such as overlays, slabs, pavements, industrial floors, water-retaining structures, and thin-section elements, where shrinkage-induced cracking and durability concerns are critical.

These parameters are essential for determining their efficiency in reinforcing concrete at the microstructural level and ensuring improved performance of Fiber-Reinforced composites.

## **CAC–Hyper fluid Plus (Super Plasticizer)**

CAC–Hyper fluid Plus (H1) is a high-performance super plasticizer used in concrete technology to significantly improve the workability and strength characteristics of concrete without increasing the water content. It is typically based on advanced polymer technology, such as modified polycarboxylate ethers, which provide superior dispersion of cement particles. When added to a concrete mix, CAC–Hyper fluid Plus (H1) reduces the surface tension between cement grains, allowing them to spread more uniformly throughout the mix. This results in a highly fluid and cohesive concrete with excellent flow properties, making it particularly suitable for applications like self-compacting concrete, heavily reinforced sections, and structures with complex formwork where proper compaction is difficult. One of the key advantages of this super plasticizer is its ability to achieve high water reduction, often in the range of 20–30%, which leads to increased compressive strength, improved durability, and reduced permeability.

## **MIX DESIGN**

The design of concrete mix involves selecting suitable properties of ingredients of concrete and determining the relative quantities required to produce a concrete with the required strength, durability, Workability and economically. The quantities for 1 m<sup>3</sup> of concrete and the proportion of mix.

### **Mix Design for M40 Grade of Concrete:**

In the present work as per, IS 10262-2009 and IS 456-2000 have been used to get proportions for M40 grade Concrete and the mix design is as follows.

**STIPULATIONS FOR PROPORTIONING:**

- a) Grade of Concrete : M 40
- b) Type of Cement : OPC 53 Grade  
(confirming IS 12269:2013)
- c) Maximum size of Aggregates : 10mm and 20 mm (IS 383:2016)
- d) Minimum Cement content : 364kg/m<sup>3</sup>  
(IS 456:2000)
- e) Maximum Water – Cement ratio : 0.40
- f) Workability : Medium
- g) Exposure condition : Moderate (RCC)
- h) Chemical Admixtures : Super Plasticizer  
(CAC–Hyper fluid Plus (H1))

**TEST DATA FOR MATERIALS**

- i. Cement used : OPC 53 grade
- ii. Specific gravity of Cement : 3.13
- iii. Specific Gravity of Coarse Aggregates : 2.60
- iv. Specific Gravity of Fine Aggregates : 2.51
- v. Water Absorption of Coarse Aggregates : 0.93%
- vi. Grading of Fine Aggregates : Conforming to Grading Zone-II

**TARGET MEAN STRENGTH:**

$$\begin{aligned}
 f_{ck}' &= f_{ck} + 1.65S \\
 &= 40 + 1.65 \times 5.0 \\
 f_{ck}' &= 48.25 \text{ N/mm}^2
 \end{aligned}$$

For concrete (as per Is456:2000), the split tensile strength is:

$$f_{ct} = 0.56 \sqrt{f_{ck}} = 0.56 \sqrt{48.25} = 0.56 \times 6.95 = 3.89 \text{ Mpa}$$

**WATER-CEMENT RATIO (W/C):**

Compare Compressive strength/ (w/c) ratio graph:

Compressive Strength for 28 days = 48.25 N/mm<sup>2</sup> (mean), We must ensure curve (2)

Adopt W/C=0.34

From table (2), Section 8.12, IS456:2000 For M40,  
 For RCC, Extreme exposure IS456:2000 Maximum w/c =0.40

**Determine volume of coarse aggregate from grading zone and size:**

(Ref: clause 5.5, IS10262:2019) 20mm=0.62(Zone-II)

Coarse aggregate ratio=0.62 For w/c=0.34

Adjustment= (0.34-0.5)/0.05x0.01

=-0.032

Coarse aggregate ratio=0.62- 0.032 =0.588

**MIX CALCULATIONS:**

Volume of concrete = 1 m<sup>3</sup> Entrapped air=1%=0.01m<sup>3</sup>

Volume of cement = (mass of cement/ sp.gravity of cement) x 1/1000

= (364/3.12) x 1/1000

= 0.11629 m<sup>3</sup>

Volume of water = (mass of water/ sp.gravity of water) x 1/1000

= (124/1.0) x 1/1000

= 0.124 m<sup>3</sup>

Volume of Fine and Coarse Aggregate= [volume of concrete- (volume of cement+ volume of water+ volume of entrapped air)]

= [1.0 – (0.11629+0.124+0.01)] = 0.74971 m<sup>3</sup>

Volume of Coarse Aggregate=0.588x0.74971=0.4408 m<sup>3</sup> x 10<sup>3</sup>

Mass of Coarse Aggregate= 0.74971X 0.588 X 2.51 X 10<sup>3</sup> = 1106.481kg/m<sup>3</sup> Volume of Fine Aggregate= (1-0.588) x 0.74971=0.412x0.74971=0.3089 m<sup>3</sup>

Mass of Fine Aggregate = 0.74971X 0.412X 2.60 X 10<sup>3</sup> = 803.08 kg/m<sup>3</sup>

**Mix Proportions:**

Cement content =364 kg/m<sup>3</sup> Water content = 121.619kg/m<sup>3</sup>

Fine aggregate content = 814.322 kg/m<sup>3</sup>

Coarse aggregate content = 1106.408 kg/m<sup>3</sup>

**Mix Ratio:**

Cement	:	Fine Aggregate	:	Coarse Aggregate	:	W/C ratio
<b>1</b>		<b>2.23</b>		<b>3.03</b>		<b>0.34</b>

**SPECIMEN CALCULATIONS:**

Volume of one cube =  $(0.15 \times 0.15 \times 0.15) \times 1.10 = 0.0037125 \text{ m}^3$

Volume of 6 cubes =  $0.0037125 \times 6.0 = 0.022275 \text{ m}^3$

Volume of one cylinder =  $(\pi \times 0.075^2 \times 0.3) \times 1.10 = 0.005831 \text{ m}^3$  Volume of three cylinders =  $0.005831 \times 3 = 0.0175 \text{ m}^3$

Total volume of 6 cubes and 3 cylinders =  $0.039775 \text{ m}^3 = 0.040 \text{ m}^3$

Weight of cement =  $364 \times 0.040 = 14.56 \text{ kg}$  Weight of water =  $121.619 \times 0.040 = 4.864 \text{ litre}$

Weight of fine aggregate =  $814.322 \times 0.040 = 32.57 \text{ kg}$  Weight of coarse aggregate =  $1106.408 \times 0.040 = 44.256 \text{ kg}$

**DESIGN FOR M40 (Mix Proportions for Hooked end Steel fiber reinforced concrete):****Hooked end steel fibers Quantity:**

Use fibers (0.3 to 1.2%)

WF1 = (volume of concrete x fiber percentage x Density of steel) 0.3% =  $0.040 \times 0.003 \times 7850 = 0.942 \text{ kg}$

0.6% =  $0.040 \times 0.006 \times 7850 = 1.884 \text{ kg}$

0.9% =  $0.040 \times 0.009 \times 7850 = 2.826 \text{ kg}$

1.2% =  $0.040 \times 0.012 \times 7850 = 3.768 \text{ kg}$

**EXPERIMENTAL STUDY**

Testing of concrete plays a crucial role in quality control and in ensuring the reliability of cement concrete works. A systematic approach to testing, including raw materials, fresh concrete, and hardened concrete, is an essential part of any concrete quality assurance program. This ensures better performance in terms of both strength and durability.

Such tests help in achieving optimal efficiency in material usage and provide confidence in the structural performance of concrete. The test methods adopted should be straightforward, reliable, and practical for both field and laboratory conditions.

**Specimen Casting and Curing****Preparation of Concrete Specimens:**

In this project, concrete specimens were cast to evaluate the mechanical properties of fibers-reinforced concrete using varying percentages of steel and polypropylene fibers. Concrete cube, cylinder, and prism moulds were made of steel or cast iron, possessing sufficient strength to resist deformation. The inside faces and ends were machined to provide smooth surfaces and tight-fitting joints. The moulds were manufactured in two halves, bolted together for ease of removing the specimens and cleaning.

Cylinder moulds were normally 150 mm in diameter and 300 mm in height, while cube moulds

typically had sides of 150 mm. Prism moulds measured 100 mm × 100 mm × 500 mm are shown in Fig.5.1. The moulds rested on heavy baseplates, fastened using clamps. Before assembly, the faces and flanges of the moulds were cleaned thoroughly to remove any dirt or hardened mortar, ensuring proper fitting of the sections. Standard moulds of 150 mm × 150 mm × 150 mm were used for compressive strength tests, 150 mm diameter × 300 mm height cylinder moulds for split tensile strength tests, and 100 mm × 100 mm × 500 mm prism moulds for flexural strength tests.

Steel moulds with smooth, machined surfaces and tight-fitting joints were employed. Before casting, the moulds were thoroughly cleaned and coated with mould oil to prevent the concrete from sticking. The faces of the moulds were thinly coated with oil to prevent leakage during filling, and oil was also applied between the base of the mould and the baseplate. Excess oil was removed by wiping with a soft cloth, as it could adversely affect the concrete. The concrete mix, including fibers, was placed in the moulds using a scoop in three layers. Each layer was compacted using a tamping rod to remove air voids and ensure proper compaction. For denser mixes, vibration was used to achieve maximum density. The top surface was levelled with a steel float.

### **Curing of Concrete:**

After 24 hours of casting, the concrete specimens were carefully demoulded to avoid any damage. The demoulded cubes are shown in Fig. 5.4. All specimens were immediately transferred to a curing tank filled with clean water as shown in Fig.5.5. Curing was carried out at a controlled room temperature of approximately  $27 \pm 2^{\circ}\text{C}$  to ensure proper hydration and strength development. The cube specimens (150 mm × 150 mm × 150 mm), used for compressive strength tests, were cured for 7, and 28 days to evaluate the strength gain over time, including the long-term performance of Fibre Reinforced concrete. The cylinders (150 mm diameter × 300 mm height) for split tensile strength and prisms (100 mm × 100 mm × 500 mm) for flexural strength were cured for 7 and 28 days only.

Throughout the curing period, all specimens were kept fully submerged in water, and the water level was regularly monitored to ensure complete immersion. This curing process ensured consistent conditions for evaluating the mechanical performance of M30 grade concrete with varying percentages of steel and polypropylene fibres.

### **Tests on Hardened Concrete:**

Hardened concrete is the stage where concrete has set and gained strength after curing. It is important to test its properties, such as compressive strength, split tensile strength, and flexural strength, to understand how well it can perform in real structures. In this study, only conventional M30 grade concrete was prepared and tested. The specimens were cured for 7 and 28 days to observe the strength development over time.

### **Compressive Strength Test:**

The compressive strength test is one of the most important tests conducted on hardened concrete

to determine its ability to resist crushing loads. In this experimental investigation, the test was performed on conventional M30 grade concrete cubes of size 150 mm × 150 mm × 150 mm. The specimens were cast, cured, and tested as per IS 516:2021. A total of three cubes were tested for each curing age of 7 and 28 days to evaluate the strength development over time. After curing, the cubes were tested using a compression testing machine (CTM) as shown in Fig.5.6 by applying load gradually until failure. The maximum load at failure was recorded, and the compressive strength was calculated using the formula:

$$\text{Compressive Strength} = \frac{\text{Maximum Load (N)}}{\text{Cross Sectional Area (mm}^2\text{)}}$$

### Split Tensile Strength Test:

The split tensile strength test is used to determine the tensile strength of concrete, which helps assess its ability to resist cracking under tension. In this study, the test was carried out on cylindrical specimens of size 150 mm diameter and 300 mm height, made using conventional M30 grade concrete. The test was performed according to IS 5816:1999.

After casting, the specimens were cured in water for 28 days to ensure proper hydration and strength development. On the 28th day, the cylinders were tested using a Compression Testing Machine (CTM) as shown in Fig.5.7. Each specimen was placed horizontally in the machine, and a compressive load was applied along its vertical diameter until failure. This method generates indirect tensile stress, causing the cylinder to split along its length. The maximum load at failure was recorded, and the split tensile strength was calculated using the formula:

$$\text{Split tensile Strength} = \frac{2P(N)}{\pi DL(\text{mm}^2)}$$

Where:

- P = Maximum load applied (N)
- D= Diameter of the cylinder (150 mm)
- L = Length of the cylinder (300 mm)

## RESULTS AND DISCUSSION

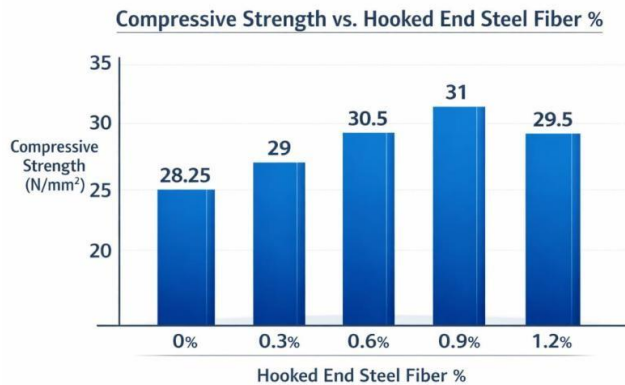
This section presents the results obtained from the experimental tests conducted on conventional M40 grade concrete. The tests include compressive strength, split tensile strength, and flexural strength performed on specimens cured for specific durations. For compressive strength, tests were carried out at 7 and 28 days, while split tensile and flexural strength tests were conducted at 28 days. The results are analyzed to understand the strength development of concrete over time and to assess its performance under different types of loading. These values will later serve as a reference for comparing with fiber-reinforced concrete in the next phase of the study.

### Compressive Strength Results

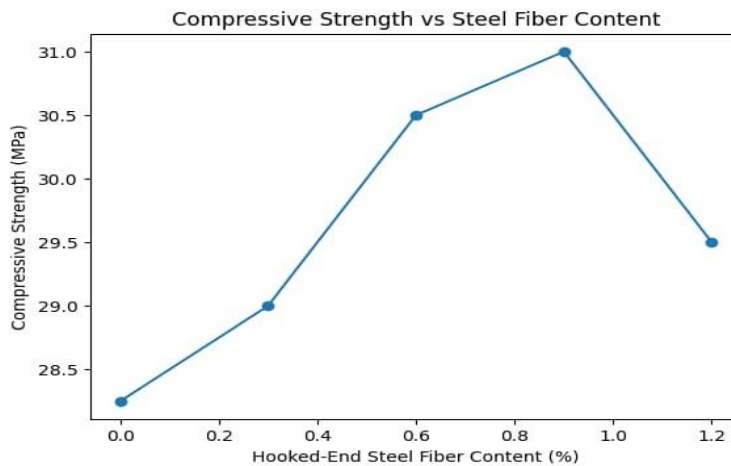
#### Compressive Strength test Results with Different Percentages of Hooked end Steel Fibers and Polypropylene Fibers

Type of Concrete	Fiber Percentages	Average Compressive Strength (N/mm <sup>2</sup> )	
		7 Days	28 Days
Control Concrete	0%	28.25	45
Concrete with Hooked end Steel Fibers with polypropylene fiber	0.30% +0.2%	29.00	50
	0.6% +0.2%	30.50	52
	0.9%+0.2%	31.00	53.50
	1.2% +0.2%	29.50	53

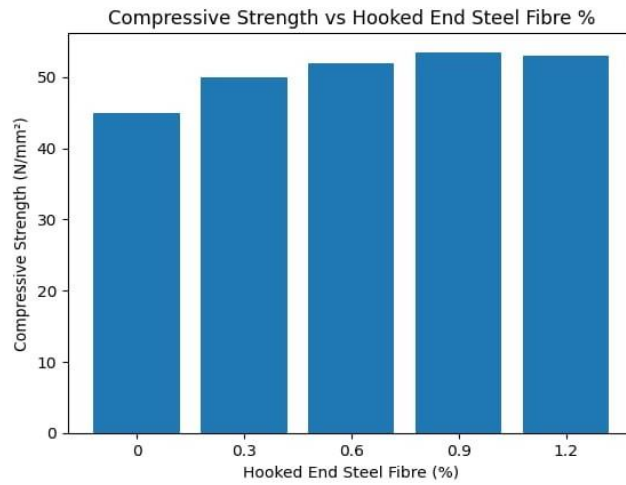
#### GRAPH REPRESENTATION OF CUBES FOR 7 DAY



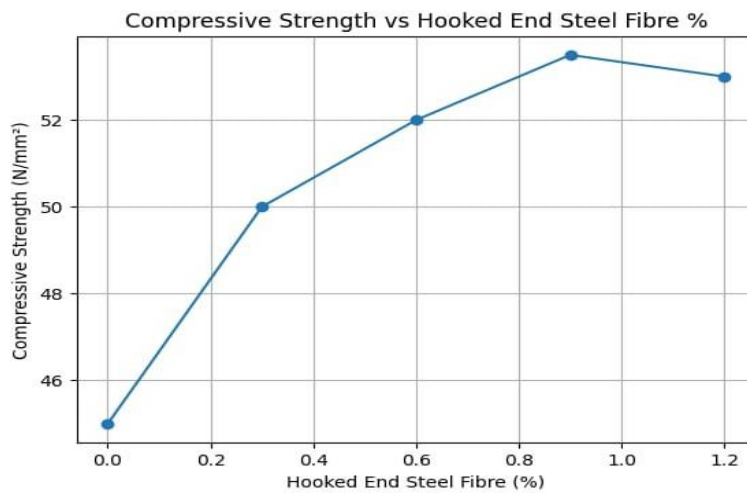
#### Linear Representation of cubes for 7 Days:



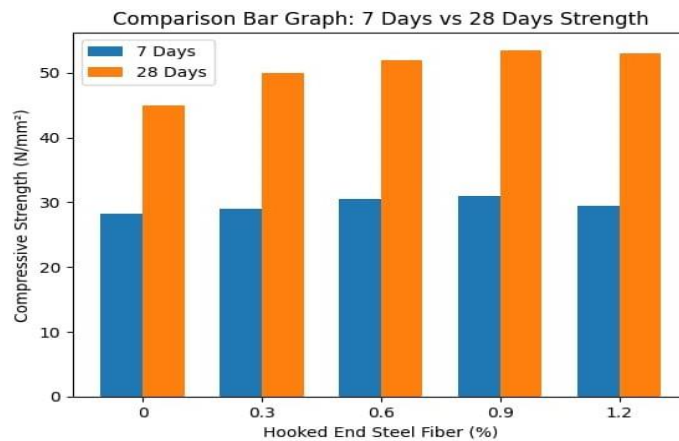
**GRAPH REPRESENTATION OF CUBES FOR 28 DAYS**



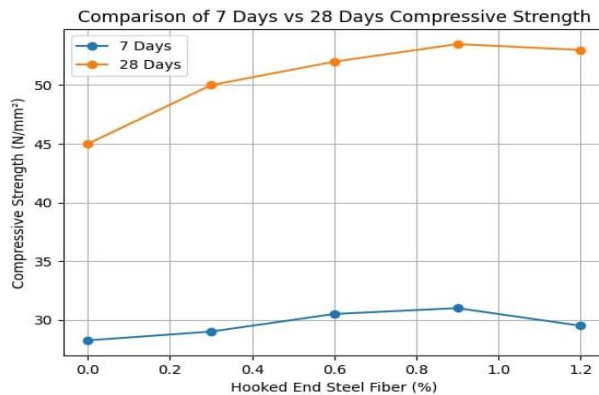
**Linear Representation of cubes for 28 Days:**



**GRAPH REPRESENTATION OF CUBES FOR 7 DAYS AND 28 DAYS**



### Linear Representation of cubes for 7 Days and 28 Days



### Variation of Cube Compressive Strength Concrete with Varying Percentages of Hooked end steel and polypropylene Fibers

The graph represents how the compressive strength of concrete changes with different fiber percentages at 7 days and 28 days of curing. It can be observed that as the fiber content increases from 0% to 0.9%, the compressive strength gradually increases for both curing periods. This indicates that the inclusion of fibers improves the strength characteristics of concrete by enhancing its resistance to cracks and improving the internal bonding.

At 0.9% fiber content, the concrete achieves its maximum compressive strength, with 31 N/mm<sup>2</sup> at 7 days and 53.50 N/mm<sup>2</sup> at 28 days. This shows that 0.9% is the optimum fiber dosage for achieving the best strength performance. However, when the fiber content is increased further to 1.2%, the compressive strength decreases slightly. This reduction may be due to poor workability, improper compaction, and the formation of voids caused by excessive fiber content.

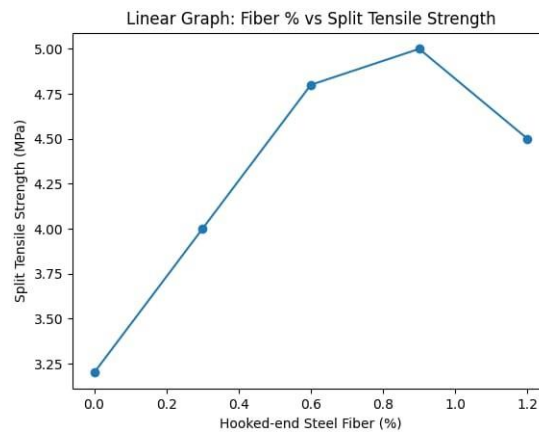
Additionally, the 28-day compressive strength is consistently higher than the 7-day strength for all fiber percentages, which is due to the continuous hydration process in concrete over time. Overall, the graph clearly indicates that adding fibers improves strength up to an optimum level, after which the strength starts to decline.

### Split Tensile Strength Results:

#### Split Tensile Strength Test Results with Different Percentages of Hooked end Steel Fibers and Polypropylene Fibers

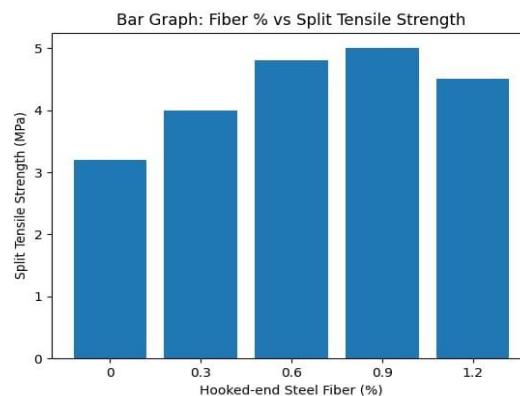
Type of Concrete	Fiber Percentages	Average Split tensile Strength (N/mm <sup>2</sup> )
Control Concrete	0% + 0.2%	3.2
Concrete With Hooked end Steel with Polypropylene fibers	0.30% + 0.2%	4.0
	0.60% + 0.2%	4.8
	0.9% + 0.2%	5.0
	1.2% + 0.2%	4.5

### Linear Representation of Cylinders for 28 Days



### Variation of Split Tensile Strength of Concrete with Different Percentages of Hooked end Steel Fibers and Polypropylene Fibers

#### GRAPH REPRESENTATION OF CYLINDERS FOR 28 DAYS



The graph represents the variation of split tensile strength of concrete with different fiber percentages, and the values clearly show a consistent trend. At 0% fiber content, the split tensile strength is 3.2 N/mm<sup>2</sup>, which is the lowest value since no fibers are present to resist cracking. When fibers are added at 0.30%, the strength increases to 4 N/mm<sup>2</sup>, indicating an improvement due to the crack-bridging effect of fibers.

As the fiber content increases to 0.6%, the tensile strength further rises to 4.8 N/mm<sup>2</sup>, showing a steady enhancement in performance. The maximum strength is achieved at 1.2% fiber content, reaching 4.5 N/mm<sup>2</sup>, which suggests that this is the optimum fiber percentage where the fibers are well distributed and most effective in improving tensile behavior.

However, when the fiber content is increased beyond this optimum level to 1.2%, the strength decreases slightly to 4.5 N/mm<sup>2</sup>. This reduction can be attributed to issues like poor workability, fiber balling, and improper compaction, which negatively affect the concrete structure.

Overall, the values demonstrate that the split tensile strength improves significantly from 3.2 N/mm<sup>2</sup> to 5.0 N/mm<sup>2</sup> with the addition of fibers up to 0.9%, and then slightly decreases, confirming that

0.9% fiber content is the most effective for enhancing tensile strength.

It is important to understand the significance of crack pattern for assessing how well performs under dynamic loads. This understanding helps evaluate its ability to withstand sudden impacts effectively. A common crack pattern observed in these tests is Radial Cracks, the cracks which extend outward from the impact point. These cracks form due to the tensile stress caused by the impact force. Radial cracks often indicate a brittle failure mode, particularly in materials with low tensile strength. Additionally, spalling of specimen is observed which refers to the detachment of fragments or chunks of concrete from the surface at the point of impact; it may occur under severe impact loads. It is observed that cracks propagate and lead to failure with fewer number of blows after crack initiation in control concrete as shown in Fig. 6.6. Whereas, in the concrete specimen with 0.9% Hooked end Steel fibers and 0.2% Polypropylene fiber takes a greater number of blows for failure after crack initiation as shown in Fig.6.7. This suggests that the fiber reinforced concrete specimen exhibits enhanced impact resistance to crack propagation and failure compared to the control mix concrete specimen.

## **CONCLUSION AND REMARKS**

### **CONCLUSION:**

1. The experimental study on M40 grade concrete with the inclusion of hooked end steel fibers and a 0.2% percentage of polypropylene fibers demonstrates a significant improvement in mechanical properties compared to conventional concrete.
2. It is observed that the compressive strength of concrete increases with the addition of steel fibers at 0.9%.
3. The maximum compressive strength of 53.50 MPa was obtained at 0.9% steel fiber content, indicating an increase of about 18–20% compared to conventional concrete.
4. However, beyond this optimum percentage (i.e., at 1.2%), a slight reduction in strength was observed, likely due to reduced workability and improper fiber distribution.
5. Similarly, the split tensile strength results also show a consistent improvement with the addition of fibers. The control concrete exhibited a tensile strength of 3.2 MPa, while the maximum tensile strength of 5.0 MPa was achieved at 0.9% steel fiber content, representing a significant enhancement in crack resistance and ductility.
6. At higher fiber content (1.2%), the tensile strength slightly decreased, indicating that excessive fibers may lead to balling effect and weak bonding.
7. Overall, the study confirms that the addition of hooked end steel fibers significantly enhances both compressive and tensile strength of M40 grade concrete, with 0.9% steel fiber content identified as the optimum dosage.

### **REMARKS:**

The inclusion of hooked end steel fibers improves load-carrying capacity, ductility, plastic shrinkage and crack resistance of concrete. Polypropylene fibers help in controlling micro-cracks and improve the durability of the mix. Strength improvement is directly related to fiber content up to an optimum level, after which performance declines.

The decrease in strength at higher fiber percentages is mainly due to:

- Reduced workability
- Difficulty in proper compaction (Ball effect)
- Non-uniform distribution of fibers

The hybrid combination of steel and polypropylene fibers provides better performance than conventional concrete. The optimum fiber content for achieving maximum strength and performance is 0.9% hooked end steel fibers with 0.2% polypropylene fibers.

This type of fiber-reinforced concrete can be effectively used in:

- Pavements
  - Industrial floors
  - Bridges
- Structures requiring high tensile strength and crack resistance

## APPLICATIONS:

1. Pavements and Industrial Flooring
2. Structural Elements (Beams, Columns, and Slabs)
3. Precast Concrete Products
4. Earthquake-Resistant Structures
5. Repair and Rehabilitation Works

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