

Experimental Investigation on Mechanical Properties of Hybrid Fiber-Reinforced Concrete Using Steel and Polypropylene Fibers

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Abstract

Concrete is inherently brittle and weak in tension, which leads to cracking and reduced durability of structures. To overcome these limitations, fiber-reinforced concrete has been widely studied. In this experimental investigation, the mechanical performance of **hybrid fiber-reinforced concrete (HFRC)** incorporating **steel fibers and polypropylene fibers** was evaluated. M30 grade concrete was designed as per IS 10262:2019. Steel fibers and polypropylene fibers were added in different combinations, and their effects on workability, compressive strength, split tensile strength, and flexural strength were studied at curing ages of 7, 14, 28, and 56 days. The results showed a slight to moderate improvement in compressive strength, significant enhancement in split tensile strength, and major improvement in

flexural strength due to hybrid fiber action. Crack behaviour analysis revealed effective control of micro-cracks by polypropylene fibers and bridging of macro-cracks by steel fibers, resulting in ductile failure behaviour. The study confirms that hybrid fiber-reinforced concrete offers improved mechanical performance compared to conventional concrete.

Keywords: Hybrid fiber concrete, Steel fibers, Polypropylene fibers, Mechanical properties, Crack behaviour

1. Introduction

Concrete is the most widely used construction material due to its availability, strength, and versatility. However, conventional concrete exhibits low tensile strength and brittle failure characteristics, leading to crack formation under various loading and environmental conditions.

Cracks reduce durability and allow ingress of aggressive agents, resulting in long-term deterioration.

Fiber-reinforced concrete has emerged as an effective solution to improve crack resistance and post-cracking behaviour. Steel fibers enhance tensile and flexural strength by bridging cracks, while polypropylene fibers are effective in controlling plastic shrinkage and early-age micro-cracks. Hybrid fiber-reinforced concrete combines the benefits of both fibers, providing multi-scale crack control and improved ductility. This study focuses on evaluating the mechanical performance of hybrid fiber-reinforced concrete using steel and polypropylene fibers.

2. Materials and Methodology

2.1 Materials

Ordinary Portland Cement (OPC) 53 grade conforming to IS 12269 was used. Natural river sand conforming to Zone II of IS 383 was used as fine aggregate, and crushed angular coarse aggregate of 20 mm nominal size was used. Potable water was used for mixing and curing.

Hooked-end steel fibers were used to improve tensile and flexural performance, while polypropylene fibers were used to control micro-cracking.

2.2 Mix Design

M30 grade concrete was designed as per IS 10262:2019 with a water–cement ratio

of 0.45. The control mix was prepared without fibers. Hybrid fiber mixes were prepared by adding steel fibers and polypropylene fibers while keeping the base mix proportions constant.

2.3 Testing Program

Workability was measured using the slump cone test. Hardened concrete tests included compressive strength, split tensile strength, and flexural strength at 7, 14, 28, and 56 days.

3. Experimental Results

3.1 Slump Test Results

Table 1. Slump values of concrete mixes

Mix ID	Steel Fibers (%)	PP Fibers (%)	Slump (mm)
CC	0.0	0.0	95
HFRC-1	0.5	0.1	78
HFRC-2	1.0	0.1	65

Workability decreased with fiber addition but remained within acceptable limits.

3.2 Compressive Strength Results

Table 2. Compressive strength at different curing ages (MPa)

Mix ID	7 Days	14 Days	28 Days	56 Days
CC	23.8	29.6	36.2	38.9
HFRC-1	25.4	31.8	38.5	41.6
HFRC-2	26.1	32.7	39.8	43.2

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Hybrid fiber concrete showed slight to moderate improvement in compressive strength at all ages.

3.3 Split Tensile Strength Results

Table 3. Split tensile strength results (MPa)

Mix ID	7 Days	14 Days	28 Days	56 Days
CC	2.35	2.78	3.10	3.28
HFRC-1	2.82	3.28	3.72	3.98
HFRC-2	3.05	3.52	4.05	4.42

A significant increase in split tensile strength was observed due to hybrid fiber action.

3.4 Flexural Strength Results

Table 4. Flexural strength results (MPa)

Mix ID	7 Days	14 Days	28 Days	56 Days
CC	3.4	4.0	4.5	4.9
HFRC-1	4.6	5.2	5.8	6.3
HFRC-2	5.2	5.9	6.6	7.2

Flexural strength showed major improvement due to steel fiber crack-bridging action.

4. Discussion

The reduction in workability with fiber addition is attributed to increased internal friction. Compressive strength showed only marginal improvement, as fibers primarily enhance tensile-related properties. Split tensile and flexural strengths showed significant and major improvements, respectively, due to effective crack control.

Polypropylene fibers controlled micro-cracks formed during early hydration, while steel fibers bridged macro-cracks at higher stress levels. As a result, hybrid fiber concrete exhibited ductile failure behaviour with higher energy absorption compared to brittle failure of conventional concrete.

5. Conclusions

The experimental investigation confirms that hybrid fiber-reinforced concrete incorporating steel and polypropylene fibers provides improved mechanical performance compared to conventional concrete. Significant improvements in tensile and flexural strength, enhanced crack resistance, and ductile failure behaviour make HFRC suitable for structural and pavement applications.

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