Experimental Study on Mechanical and Durability Performance of Hybrid Fiber Reinforced Concrete

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Abstract—

Concrete remains the primary construction material worldwide due to its compressive strength and versatility; however, its inherent brittleness and low tensile capacity limit structural performance under flexural and dynamic loading. The inclusion of discrete fibers has emerged as an effective technique to enhance crack resistance and ductility. This research investigates the combined influence of steel fibers and polypropylene fibers on the mechanical and durability characteristics of M30 grade concrete. Various hybrid fiber proportions were incorporated and tested for compressive strength, split tensile strength, flexural strength, water absorption, and chloride ion penetration resistance. Experimental findings demonstrate that the synergistic action of hybrid fibers significantly improves tensile and flexural properties while maintaining compressive strength within acceptable structural limits.

Fiber and 0.25% polypropylene fiber by volume. The study confirms that hybrid fiber systems enhance crack control, durability, and post-cracking behavior, making them suitable for heavy-duty and infrastructure applications.

Keywords— Hybrid fiber concrete, mechanical strength, durability, steel fiber, polypropylene fiber, crack control.

I. INTRODUCTION

Concrete is widely adopted in civil engineering works because of its ability to resist compressive forces and its adaptability in structural design. Despite these advantages, conventional concrete exhibits brittle failure behavior and limited tensile strength. Micro-cracking begins at early stages due to plastic shrinkage, thermal effects, and applied loads. These micro-cracks gradually propagate, affecting long-term durability and service life.To overcome this limitation, fibers are incorporated into the concrete matrix. Steel fibers enhance load-carrying capacity and energy absorption, whereas polypropylene fibers are effective in minimizing plastic shrinkage cracking and improving surface integrity. A hybrid fiber system combines the advantages of both macro and micro fibers, leading to improved structural performance.

Although individual fiber systems have been extensively studied, research focusing on hybrid combinations under Indian material and environmental conditions remains limited. Therefore, this study evaluates the mechanical and durability characteristics of hybrid fiber reinforced concrete (HFRC).

III. METHODOLOGY

An experimental study was conducted to evaluate the mechanical and durability properties of Hybrid Fiber Reinforced Concrete (HFRC).

3.1 Materials

M30 grade concrete was prepared using OPC 53 grade cement, river sand (Zone II), 20 mm crushed coarse aggregate, hooked-end steel fibers, polypropylene fibers, and a polycarboxylate-based superplasticizer. All materials complied with relevant Indian Standards

3.2 Mix Proportions

Concrete mix was designed as per IS 10262:2019. Four mixes were prepared with varying fiber contents:

Mix ID	Steel Fiber (%)	Polypropylene Fiber (%)
HF0	0	0
HF1	0.5	0.10
HF2	1.0	0.25

3.3 Specimen Preparation and Curing

Concrete was mixed uniformly, placed in moulds, compacted using vibration, and demoulded after 24 hours. Specimens were cured in water at 27 ± 2°C until testing age (7 and 28 days).

Prepared specimens:

- Cubes (150 mm) – Compressive strength
- Cylinders (150 × 300 mm) – Split tensile strength
- Prisms (100 × 100 × 500 mm) – Flexural strength

3.4 Testing Procedure

Mechanical tests conducted as per IS 516 included:

- Compressive strength
- Split tensile strength
- Flexural strength

Durability tests included:

- Water absorption
- Rapid Chloride Penetration Test (RCPT)

Average values of three specimens were recorded and compared with the control mix to determine optimum fiber content.

IV. RESULTS AND DISCUSSION

4.1 Compressive Strength

The compressive strength of hybrid fiber mixes showed a moderate increase compared to conventional concrete. Mix HF2 (1% steel + 0.25% polypropylene fiber) achieved the highest improvement at 28 days. The increase is attributed to improved crack arresting and better stress redistribution within the concrete matrix. However, further increase in fiber content (HF3) did not result in significant strength gain due to reduced workability and possible fiber clustering.

4.2 Split Tensile Strength

A significant enhancement in split tensile strength was observed in all fiber-reinforced mixes. The hybrid system effectively controlled crack propagation through fiber bridging action. HF2 exhibited the maximum improvement, indicating an optimal synergy between macro steel fibers and micro polypropylene fibers.

4.3 Flexural Strength

Flexural performance improved considerably with fiber inclusion. Steel fibers contributed to higher load-carrying capacity after first crack formation, while polypropylene fibers reduced micro-crack development. The hybrid combination demonstrated better post-cracking behavior compared to the control mix.

4.4 Durability Performance

Water absorption values decreased in hybrid mixes, suggesting reduced permeability. Rapid Chloride Penetration Test results indicated lower charge passed values for HF2, confirming improved resistance to chloride ion ingress. The reduced crack width and enhanced matrix integrity contributed to better durability characteristics.

4.5 Overall Performance Evaluation

Among all mixes, HF2 (1% steel + 0.25% polypropylene fiber) provided the best balance between strength, durability, and workability. The results confirm that hybrid fiber incorporation enhances tensile behavior and crack resistance without adversely affecting compressive strength.

V. CONCLUSION

Based on the experimental investigation on Hybrid Fiber Reinforced Concrete (HFRC), the following conclusions are drawn:

1. The incorporation of hybrid fibers improved the mechanical performance of concrete, particularly tensile and flexural strength.
2. Compressive strength showed a moderate increase with fiber addition, indicating that hybridization does not adversely affect load-bearing capacity.
3. Split tensile and flexural strengths significantly increased due to effective crack bridging and stress redistribution provided by steel and polypropylene fibers.
4. Durability performance improved, as indicated by reduced water absorption and lower chloride ion penetration values.
5. The optimum fiber combination was found to be 1% steel fiber and 0.25% polypropylene fiber, which provided the best balance between strength, durability, and workability.
6. Hybrid Fiber Reinforced Concrete is suitable for applications such as industrial floors, pavements, and structures subjected to dynamic or seismic loading.

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