

# Comparative Analysis of Fibre Reinforced Concrete: A Study on Mechanical and Durability Properties

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**Abstract**—This project focuses on studying the strength and durability of fibre reinforced concrete (FRC). To improve the mechanical properties of concrete, two types of fibres such as polypropylene (PP) and steel fibres has been used. The objective of this is to study the characterization of fibre reinforced concrete and to determine the optimum mix proportion of PP and SF Fibres of M40 grade concrete that gives higher strength. It includes material such as cement, fly ash, aggregates, and fibres . The cement is replaced with fly ash by 25%. The mix design following IS10262:2019 and IS 456:2000. Fibres were added in varying proportions from 0% to 1% such as [Pp-1% Steel-0%], [Pp-0.75% Steel-0.25%], [Pp-0.5% Steel-0.5%], [Pp-0.25% Steel-0.75%], [Pp-0% Steel-1%] in a standard M40 concrete mix. For different mix proportions the casting and testing, for compressive strength, split tensile strength, flexural strength, workability, and water absorption at 14,28 and 56 days has been carried out as per IS. The results showed that adding fibres, especially steel fibres, made the concrete stronger and more durable. The best performance was achieved when (M1) 1% steel fibre was used without polypropylene, giving a compressive strength of 54.67 N/mm<sup>2</sup> and tensile strength of 4.85 N/mm<sup>2</sup>. Although workability decreased with fibre addition, the improvement in performance outweighed this limitation. The study concludes that FRC, especially steel fibre-rich mixes, provides superior strength and durability, making FRC a promising material for future construction practices.

**Index Terms**—Fiber Reinforced Concrete (FRC), Steel Fibers, Polypropylene Fibers, Hybrid Fibers, Compressive Strength, Split Tensile Strength, Workability.

## I. INTRODUCTION

Concrete is the most widely used construction material in the world due to its high compressive strength, versatility, and relatively low cost. However,

conventional concrete suffers from certain drawbacks, including low tensile strength, limited ductility, and a tendency to develop cracks under load or environmental stress. These shortcomings reduce its long-term durability and service life, particularly when subjected to dynamic loading, impact, or harsh environmental conditions. To overcome these limitations, the concept of fibre-reinforced concrete (FRC) has been introduced. FRC is a composite material in which discrete fibres are uniformly dispersed within the cement matrix. The inclusion of fibres helps control the initiation and propagation of cracks, thereby improving tensile strength, toughness, and resistance to impact and shrinkage.

Different types of fibres can be used, each imparting unique characteristics to the concrete. Steel fibres enhance mechanical strength and toughness, glass fibres contribute to high tensile performance and improved aesthetics, synthetic fibres such as polypropylene or nylon reduce shrinkage and improve ductility, while natural fibres like coir or sisal offer a sustainable and cost-effective alternative with moderate improvements in strength. The performance of FRC depends on the type, size, and volume fraction of fibres used. In addition to mechanical improvements, FRC also enhances durability by reducing permeability and increasing resistance to freeze-thaw cycles, abrasion, and chemical attack. Nevertheless, challenges such as reduced workability and higher costs remain key considerations. This study aims to present a comparative analysis of fibre-reinforced concrete using different fibre types. The objective is to evaluate their influence on the fresh and hardened properties of concrete, including workability, compressive strength, tensile strength, flexural performance, and durability. The outcomes of

this research will provide insights into the advantages and limitations of different fibre categories and guide the selection of suitable fibres for various structural and construction applications. Concrete is the most widely used construction material globally, owing to its economy, versatility, and high compressive strength. However, it remains inherently brittle and exhibits poor tensile strength, leading to early crack formation and limited ductility especially under tensile, flexural, or dynamic loading conditions. To address these limitations, fibre-reinforced concrete (FRC) has gained attention in both academic and practical domains. In FRC, discrete fibres such as steel, glass, synthetic polymers (e.g., polypropylene or polyvinyl alcohol), or natural fibres are randomly distributed within the cementitious matrix. These fibres bridge cracks and help delay crack propagation, significantly enhancing toughness, ductility, and residual strength after cracking.

FRC not only enhances the hardened properties of concrete but also offers practical benefits during construction. It can reduce labour and construction time by eliminating or minimising rebar placement and improve long-term durability by maintaining tighter crack control, thus reducing permeability and maintenance costs. Despite these advantages, some practical and economic challenges remain. Reduced workability, increased material costs, and a lack of familiarity among contractors sometimes limit widespread adoption. The effectiveness of FRC depends significantly on the fibre type, dosage, and mix design. A systematic comparative study across different fibre categories steel, glass, synthetic, and natural can provide valuable insights into optimising FRC for both mechanical performance and sustainability. This paper seeks to fill that gap by evaluating the fresh and hardened properties, durability, and practical feasibility of various FRC types.

## II. LITERATURE REVIEW

1) Sriram M., et.al. (2021) Hybrid fibre reinforced concrete (HFRC) with steel and polypropylene fibres improves toughness, crack resistance, and durability. Steel fibres enhance strength, while polypropylene fibres reduce shrinkage and increase ductility. Together, they provide greater compressive, flexural, and tensile strength than single fibres, with further gains when combined with mineral admixtures. HFRC

shows strong potential for pavements, offshore works, and repair applications, offering improved performance and sustainability in modern construction.

2) K Shyam Prakash et al. (2017) Several studies show that partial replacement of natural sand with quarry dust enhances concrete strength. Compressive and flexural strengths generally increase up to an optimum level, after which they decline. Research reports improvements of about 2–4% at 25–100% replacement, with the highest flexural gain (~17.8%) at 50%. Another study identified 40% replacement as the optimum level, beyond which strength decreases.

3) Aminuddin Jameran et.al (2015). Studies on hybrid steel–polypropylene fibre concrete under elevated temperatures show that steel-dominant mixes retain higher strength after heating. At 400°C, the 100% steel mix maintained 47.7 MPa compressive strength, while PP-rich mixes lost strength due to fibre melting. A 75:25 steel-to-PP ratio performed best, offering a balance between strength retention and crack resistance. Overall, hybrid fibres enhance fire resistance, but excessive PP reduces performance at high temperatures.

4) Tuqa W. Ahmed et.al. (2021) Research on polypropylene fibre (PPF) reinforced concrete shows improvements in tensile strength, ductility, crack resistance, and durability. The optimum fibre content is around 0.3–0.5%, beyond which workability decreases. While compressive strength results vary, PPF consistently enhances flexural and tensile strength, especially when combined with pozzolanic materials such as silica fume. In recycled aggregate concrete, PPF reduces porosity and offsets material weaknesses. Hybrid fibre systems further improve post-cracking performance. Overall, PPF is corrosion-resistant, cost-effective, and effective for enhancing durability in structural applications.

5) Yenny Nurchasanch et.al. (2016) Studies on steel fibre reinforced concrete under elevated temperatures show that increasing fibre content improves strength and heat resistance. Mixes with 1–1.5% steel fibres demonstrated higher compressive strength and elasticity, with 23.5 MPa recorded at 600°C for the 1.5% mix. Fibres reduced crack growth and carbonation depth, enhancing durability. However, the

benefits plateau beyond a 1.5% dosage. Overall, steel fibres improve fire resistance, strength, and energy absorption, making them effective for fire-prone infrastructure.

6) S. Ragavendra et.al. (2017) Research on fibre reinforced concrete (FRC) shows that adding discrete fibres improves mechanical strength, crack resistance, and durability. Comparisons of hooked and corrugated steel fibres indicate that both enhance performance, with 1% corrugated steel fibre mixes achieving the highest compressive strength at 28 days, while hooked fibres provide greater tensile strength. Overall, steel fibre reinforced concrete (SFRC) significantly improves ductility and impact resistance, making it suitable for pavements, bridge decks, and offshore structures.

7) Dheeresh Kumar Nayak, et al (2022). Studies on fly ash (FA) as a partial cement replacement highlight both environmental and performance benefits. FA reduces CO<sub>2</sub> emissions from cement production and addresses the disposal challenges of this industrial byproduct. It improves concrete's workability, durability, and long-term strength, though early-age strength may decline. With its pozzolanic properties, both Class F and Class C FA have been successfully used worldwide in sustainable construction. Overall, FA contributes to eco-friendly infrastructure by lowering environmental impact while enhancing material performance.

8) Provera's. Patil etal (2024) Research on high-strength concrete (HSC) incorporating fly ash shows that partial replacement of cement at 15–20% improves durability and sustainability while reducing cement consumption. Fly ash reduces shrinkage, chloride penetration and sorptivity, enhancing service life and resistance to water absorption. Studies on M65 grade mixes designed as per IS codes report that fly ash concrete can achieve equal or higher strength compared to conventional mixes, making it an effective and eco-friendly option for high-performance construction.

### III. METHODOLOGY

The study follows an experimental research design aimed at comparing the performance of concrete reinforced with different types of fibres. The research

includes the preparation of concrete mixes with various fibre types and dosages, followed by tests to evaluate fresh properties, mechanical strength, and durability.

#### Materials :

1. Cement: Ordinary Portland Cement (OPC) of 53 grade was used in the study. It provides high early strength and better durability, which is suitable for structural concrete. The cement used conforms to the specifications of IS 12269:2013, ensuring consistency and quality in strength development.

2. Fly Ash: Class fly ash was used as a partial replacement for cement to enhance the workability, long-term strength, and sustainability of the concrete mix. It conforms to IS 3812 (Part 1):2013 and helps reduce cement consumption while improving the environmental performance of concrete.

3. Fine Aggregate: Natural River sand conforming to IS 383:2016 was used as fine aggregate. It was clean, well-graded, and passed through a 4.75 mm sieve. The sand provides good workability and helps in achieving a dense and cohesive mix suitable for concrete production.

4. Coarse Aggregate: Crushed angular coarse aggregates of 20 mm nominal size were used in accordance with IS 383:2016. These aggregates provide higher strength and better interlocking properties, which enhance the load-bearing capacity and overall performance of the concrete.

5. Fibres: Two types of fibres steel and polypropylene were used to prepare the fibre-reinforced concrete mixes. Hooked-end steel fibres (30–50 mm) improved strength and crack resistance, while polypropylene fibres (12–20 mm) enhanced ductility and reduced shrinkage cracks. The fibre proportions varied from 0% to 1% by the weight of cement as per the experimental design.

#### Mix Design :

The concrete mix will be designed for M40 grade as per IS 10262:2019. A control mix (without fibres) will be prepared for comparison.

Fibres (PP and SF) will be added in varying proportions from 0% , to 1.0%, by volume of cement.

#### Preparation of Specimens :

Mixing: Materials will be mixed in a drum mixer as well as hand mixing is done to ensure uniform fibre dispersion.

Casting: Standard moulds will be used to prepare specimens:

Cubes (150 × 150 × 150 mm) for compressive strength.

Cylinders (150 mm diameter × 300 mm height) for split tensile strength.

Curing: Specimens will be demolded after 24 hours and cured in water for 14,28, and 56 days.



Testing Procedures

Fresh Properties

Slump Test – to assess workability

Compaction Factor Test – to evaluate ease of compaction.

Mechanical Properties

Compressive Strength Test (IS 516) at 14, 28 and 56 days. Split Tensile Strength Test (IS 5816).

Durability Tests

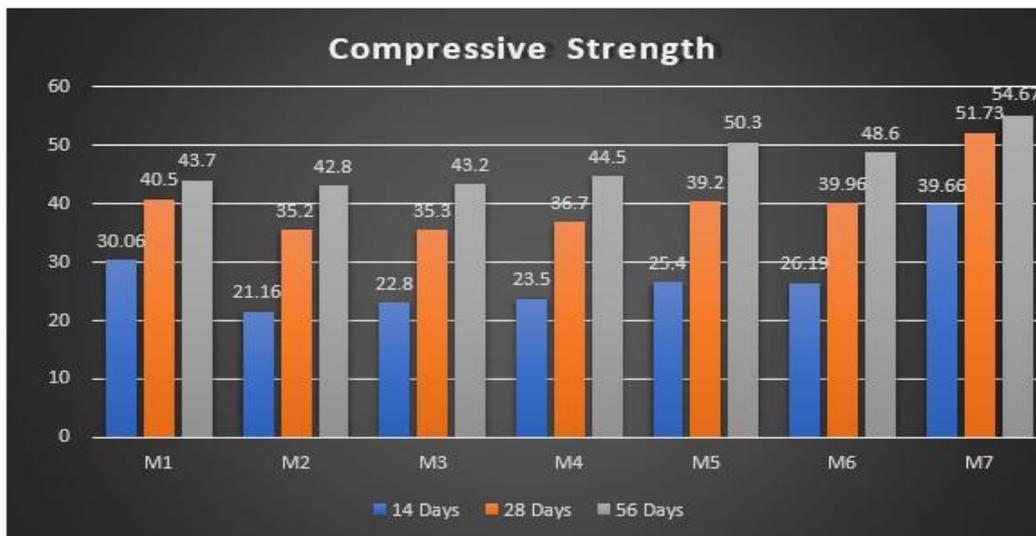
Water Absorption Test – to measure porosity.

IV. RESULTS & DISCUSSION

1. Compressive Strength

Sr No	Mix ID	Description	Compressive Strength (N/mm <sup>2</sup> )		
			14 Days	28 Days	56 Days
1	M1	Conventional Concrete	30.06 N/mm <sup>2</sup>	40.5 N/mm <sup>2</sup>	43.7 N/mm <sup>2</sup>
2	M2	Fly Ash Mix (25%)	21.16 N/mm <sup>2</sup>	35.2 N/mm <sup>2</sup>	42.8 N/mm <sup>2</sup>
3	M3	PP 1% – Steel 0%	22.8 N/mm <sup>2</sup>	35.3 N/mm <sup>2</sup>	43.2 N/mm <sup>2</sup>
4	M4	PP 0.75% – Steel 0.25%	23.5 N/mm <sup>2</sup>	36.7 N/mm <sup>2</sup>	44.5 N/mm <sup>2</sup>
5	M5	PP 0.5% – Steel 0.5%	25.4 N/mm <sup>2</sup>	39.2 N/mm <sup>2</sup>	50.3 N/mm <sup>2</sup>
6	M6	PP 0.25% – Steel 0.75%	26.19 N/mm <sup>2</sup>	39.96 N/mm <sup>2</sup>	48.6 N/mm <sup>2</sup>
7	M7	PP 0% – Steel 1%	39.66 N/mm <sup>2</sup>	51.73 N/mm <sup>2</sup>	54.67 N/mm <sup>2</sup>

Table No. 01 Compressive Strength of Various Fibre-Reinforced Concrete Mixes at Different Curing Ages



Graph No. 01 Compressive Strength of Various Fibre-Reinforced Concrete Mixes at Different Curing Ages

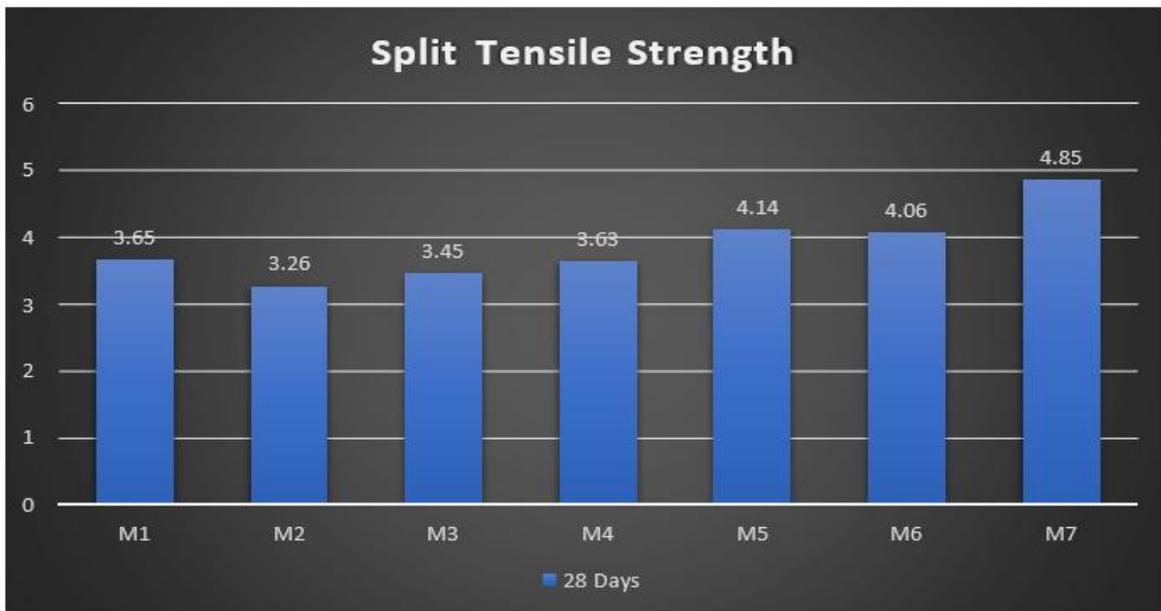
The results clearly indicate that the inclusion of fibres significantly influences the compressive strength of concrete. The steel fibre-dominant mix (M7) achieved the highest compressive strength across all curing periods—39.66 N/mm<sup>2</sup> at 14 days, 51.73 N/mm<sup>2</sup> at 28 days, and 54.67 N/mm<sup>2</sup> at 56 days reflecting the superior crack-bridging and load-transfer capabilities of steel fibres. Compressive strength increased

proportionally with the inclusion of steel fibres, while polypropylene fibres contributed to ductility and crack control. The hybrid mixes demonstrated synergistic effects, combining the advantages of both fibre types. Hence, steel fibre-rich concrete (M6 and M7) provides the best mechanical performance and durability among all tested mixes.

2. Split Tensile Strength

Sr. No.	Mix ID	Description	Water Absorption (%)	28 Days
1	M1	Conventional Concrete	2.35	3.65
2	M2	Fly Ash Mix (25%)	2.10	3.26
3	M3	PP 1% – Steel 0%	2.25	3.45
4	M4	PP 0.75% – Steel 0.25%	2.00	3.63
5	M5	PP 0.5% – Steel 0.5%	1.80	4.14
6	M6	PP 0.25% – Steel 0.75%	1.95	4.06
7	M7	PP 0% – Steel 1%	1.88	4.85

Table No. 02 Split Tensile Strength and water absorption of Concrete Mixes at 28 Days



Graph No. 02 Split Tensile Strength of Concrete Mixes at 28 Days

The results show a direct relationship between fibre content and the split tensile strength of concrete. The steel fibre-dominant mix (M7) achieved the highest tensile strength of 4.85 N/mm<sup>2</sup>, demonstrating the superior crack-bridging and bonding capacity of steel fibres. Moreover, mixes with higher steel fibre content (M5–M7) exhibited lower water absorption values (around 1.65– 1.88%), indicating improved impermeability and durability. The results confirm that the inclusion of fibres especially steel and hybrid

combinations enhances both the tensile strength and durability of concrete, making such mixes more suitable for high-performance structural applications

V. FINDINGS

The compressive strength results in Table 01 show that the conventional mix (M1) had a 28-day strength of 40.5 N/mm<sup>2</sup>. The Fly Ash Mix (M2) exhibited lower early strength (21.16 N/mm<sup>2</sup> at 14 days) due to slower

pozzolanic reaction but reached 42.8 N/mm<sup>2</sup> at 56 days. PP fibre mixes (M3) slightly improved strength, while hybrid mixes (M4–M6) showed greater gains as steel fibre content increased. M5 (PP 0.5% – Steel 0.5%) displayed a balanced performance with 50.3 N/mm<sup>2</sup> at 56 days, and the steel-dominant mix (M7) achieved the highest strengths at all ages, reflecting superior crack-bridging and load-carrying capacity.

The split tensile strength results in Table 02 indicate similar trends. M1 recorded 3.65 N/mm<sup>2</sup>, M2 was slightly lower (3.26 N/mm<sup>2</sup>), PP fibre mixes (M3–M4) improved tensile strength to 3.45–3.63 N/mm<sup>2</sup>, and hybrid mixes (M5–M6) further increased it to 4.06–4.10 N/mm<sup>2</sup>. The steel fibre–dominant mix (M7) reached 4.85 N/mm<sup>2</sup>. Higher steel content also reduced water absorption (≈1.65–1.88%), improving impermeability.

Fibre addition, especially steel and hybrid fibres, enhances both strength and durability. As steel fibre content increases, concrete exhibits better mechanical performance, crack resistance, and reduced water penetration, making steel fibre–rich mixes ideal for high-strength, durable structural applications.

## VI. CONCLUSION

The experimental investigation on fibre-reinforced concrete demonstrates that the incorporation of fibres significantly improves the overall performance of conventional concrete. From the experimental investigation, it can be concluded that the addition of fibres significantly influences the mechanical and durability properties of concrete. The conventional concrete mix (M1) provided a benchmark with compressive strengths of 40.5 N/mm<sup>2</sup> at 28 days and 43.7 N/mm<sup>2</sup> at 56 days. Mixes containing only polypropylene fibres (M2, M3, M4) initially exhibited lower compressive strength at 14 days but showed gradual improvement at later ages, approaching the strength of conventional concrete by 56 days. However, these mixes recorded slightly higher water absorption, indicating reduced impermeability.

Hybrid mixes with both polypropylene and steel fibres (M5 and M6) demonstrated balanced performance with compressive strengths close to 50 N/mm<sup>2</sup> at 56 days, enhanced split tensile strength, and lower water absorption compared to pure polypropylene mixes. The best results were achieved by the steel fibre–dominant mix (M7), which attained compressive strengths of

51.73 N/mm<sup>2</sup> at 28 days and 54.67 N/mm<sup>2</sup> at 56 days, along with the highest split tensile strength and acceptable water absorption. Although the addition of fibres reduced workability, particularly in hybrid and steel-rich mixes, the improvements in strength, crack resistance, and durability outweighed this drawback. Overall, the study confirms that steel fibre–dominant concrete offers superior performance and is most suitable for high-strength and durable structural applications.

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