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STUDY ON MECHANICAL AND DURABILITY PERFORMANCE OF HYBRID FIBER REINFORCED CONCRETE COMPARED TO PLAIN RCC

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Research Paper

ABSTRACT

Concrete, while the most widely used construction material, suffers from inherent brittleness and low tensile strength. Fiber Reinforced Concrete (FRC) has been introduced to overcome these drawbacks. However, single-fiber systems improve only selective properties. Hybrid Fiber Reinforced Concrete (HFRC), which combines fibers of varying characteristics, offers improved crack resistance, ductility, and durability. This paper reviews major literature on HFRC and presents comparative insights against conventional Reinforced Cement Concrete (RCC). Experimental results on M25 grade concrete mixes using steel, glass, and polypropylene fibers are summarized. Key findings reveal significant improvements in compressive, tensile, flexural, bond, and impact strengths, along with enhanced durability against acid, sulphate, and marine environments. The study demonstrates that hybridization of fibers yields synergistic effects, positioning HFRC as a promising material for aggressive environments and critical infrastructure.

KEYWORDS: Hybrid Fiber Concrete, Plain RCC, Durability, Tensile Strength, Flexural Strength, Literature Review

1. INTRODUCTION

Concrete is essential in modern construction but has limitations such as brittleness and poor tensile performance. While conventional reinforcement addresses tensile stress along specific axes, micro-cracking and durability issues remain. FRC enhances ductility, crack control, and impact resistance. Yet, single fibers often enhance only selected properties. HFRC integrates two or more fibers to balance micro- and macro-crack control. This study reviews recent literature and experimentally evaluates HFRC versus plain RCC to identify its potential advantages in practical applications.

2. LITERATURE REVIEW

A selection of recent research studies on HFRC are summarized in Table I. The review highlights improvements in strength, ductility, and durability, with most studies emphasizing the positive hybrid effect. However, few directly compare HFRC to plain RCC under both mechanical and durability tests

Table 1: Summary of Literature on HFRC

Author(s)	Year	Fiber Type(s)	Key Findings
Zhang et al.	2024	Steel + PP	Synergistic effects, toughness, and durability improved
Ram et al.	2023	Steel + Carbon	Strength gains even at 0.25% fiber content
Singh et al.	2024	Steel + ECC	Enhanced seismic performance of RC joints
Konapure & Kangiri	2024	Steel + PP	M25 mixes showed 20–25% strength gains
Arunkumar et al.	2022	Glass + PP	Eco-friendly HFRC with wood ash improved strength

3. RESEARCH GAP

While several studies validate hybrid fiber systems, few directly benchmark them against conventional RCC. Durability under aggressive exposures has also received less focus.

4. METHODOLOGY

Materials and Methods

4.1 Materials

- Cement: OPC 53 Grade.
- Fine Aggregate: River sand (IS:383).
- Coarse Aggregate: Crushed granite, max. size 20 mm.
- Fibers:
    - Steel (crimped, aspect ratio 64, tensile strength 1100 MPa).
    - Glass (chopped strands, aspect ratio 428, tensile strength 1700 MPa).
    - Polypropylene (aspect ratio 240, tensile strength 400 MPa).
- Water: Potable tap water.
- Admixture: Master Glenium SKY 8233 superplasticizers.

4.2 Mix Design M25 grade mix as per IS:10262-2009:

- Cement 437.7 kg/m^3
- Fine aggregate 624 kg/m^3
- Coarse aggregate 1172 kg/m^3
- Water–cement ratio: 0.45

Hybrid fiber mixes included:

Steel Fibers

Glass Fibers

Polypropylene Fibers

- Steel + PP: 1% steel + 0.15%, 0.30%, 0.45% PP.Glass + PP: 0.03% glass + 0.15%, 0.30%, 0.45% PP

The experimental program used M25 grade concrete. OPC 53 cement, natural sand, and crushed granite were used with steel, glass, and polypropylene fibers. Mix proportions are given in Table II. Tests conducted include workability (slump), compressive, split tensile, flexural, bond, and impact strengths, along with durability studies (acid, sulphate, marine).

Table 2: Mix Proportions for RCC and HFRC (kg/m^3)

Mix ID	Cement	Sand	Coarse Agg.	Water	Steel Fiber (%)	Glass Fiber (%)	PP Fiber (%)
A0 (RCC)	437.7	624	1172	197	-	-	-
A2	437.7	624	1172	197	1.0	-	0.30
B2	437.7	624	1172	197	-	0.03	0.30

5.TEST

The materials such as cement, fine aggregate, coarse aggregate, three different types of fibers (namely steel, glass and polypropylene fibers) are used in the present work. The materials used and their properties, concrete mix design, preparation of test specimens and various testing methods have adopted to examine the behavior of the specimens.

Workability Test

Workability is defined as the capability with which the concrete is handled, transported and placed in forms with least loss of homogeneity. The slump cone test is adopted to determine workability which is commonly accepted and is simple in operation.

Mechanical Properties

Compressive, split tensile and flexural strength tests were conducted to find the optimum percentage of hybrid fibers which can be used for casting of Cube specimens.

1. Potable water, steel fibers, and polypropylene fibers.
2. Mix Design: M30 grade concrete mix was designed using IS 10262:2019.
3. Fiber Dosages: Steel and polypropylene fibers were used in hybrid combinations with varying total dosages of 0%, 0.75%, 1.00%, and 1.25% by volume.
4. Casting and Curing: Standard 150 mm cube specimens were cast and cured in water for 28 days.
5. Testing: Compressive strength tests were conducted on a compression testing machine as per IS 516:1959

Compressive Strength Test

The compressive strength test was carried out as per IS : 516 - 1959 to determine the compressive strength at the age of 7 and 28 days on the 150 mm x 150 mm x 150 mm size concrete cube specimens. Testing was done on a 2000 kN capacity Compression Testing Machine (CTM) with the following procedure.

Splitting Tensile Strength Test

The splitting tensile strength test was conducted to determine the tensile strength of cylindrical specimens of size 150 mm in diameter and 300 mm long. The test procedures were conducted as per IS: 5816 - 1999 [42]. The splitting tensile strength was executed to the specimens after 7 and 28 days of curing.

Flexural Strength Test

The flexural strength test was conducted to determine the flexural strength of concrete by subjecting a plain concrete beam to flexure under transverse loads. Two-point load method was adopted to calculate the flexural strength. Test was carried out as per IS : 516 - 1959 [35] at the age of 7 and 28 days on the 100 mm x 100 mm x 500 mm prism specimen.

Bond Strength Test

The load bearing capacity of a RC structure was significantly influenced by the bond behaviors between concrete and reinforcing bars. The bond strength of the concrete specimens was determined by using the pullout test as per IS: 2770 (Part I) - 1967

Impact Strength Test

The impact resistance of the specimen was determined by using drop weight method of impact test recommended by ACI committee 544 [3] procedure. The test specimen consists of concrete disc 152 mm diameter by 63.5 mm thick. Test was carried out at the age of 28 days on the concrete disc specimen.

Durability Studies

The following tests were performed to study the durability properties of concrete: Water Absorption Capacity and Volume of Permeable Voids Tests

Chemical Resistance Tests
Acid Resistance Test
Sulphate Resistance Test
Marine Environment Test

Water Absorption Capacity and Volume of Permeable Voids Tests

The Water Absorption Capacity (WAC) was determined on 100 mm cubes as per ASTM C642 - 2006 [15] by drying the specimens in an oven at a temperature of 1050C to constant mass and then immersing in water after cooling to room temperature.

The Volume of Permeable Voids (VPV) was obtained from the volume of the water absorbed by an oven dry specimen or the volume of water lost on oven drying a water saturated specimen at 1050C to constant mass.

Durability Classification as per ASTM C642 - 2006

Classification	Volume of permeable voids (VPV) % by volume	Water absorption capacity (WAC) % by weight
Excellent	<14	<5
Good	14-16	5.0-6.0
Normal	16-17	6.0-7.0
Marginal	17-19	7.0-8.0
Bad	>19	>8

Chemical Resistance Tests

For acid resistance, sulphate resistance and marine environment tests, the specimens were cured in potable water for 28 days under normal temperature. After water curing the specimens were placed in the acid, sulphate and marine curing environment for a period of 28, 56 and 90 days.

Acid Resistance Test – HCl And H2SO4

The acid resistance test was carried out on 100 mm cube specimens by immersing the specimens in acid solutions (5% of Hydrochloric acid (HCl), 5% of Sulphuric acid (H2SO4) as per ASTM C267 - 2001 [14].

Sulphate Resistance Test - Na2SO4

Sulphate resistance of concrete was determined by immersing cube specimens of size 100 mm in 10% of sodium sulphate solution (Na2SO4) in accordance with the ASTM C1012 - 2015 The specimen was weighed and immersed in Na2SO4 solution for a period of 28, 56 and 90 days. After the period of immersion in Na2SO4 solution,

Marine Environment Test

The marine environment test was performed on 100 mm size cube specimens by immersing the specimens in marine water. Concrete in marine environment faces real-time physical, chemical and mechanical deterioration processes. The marine water was prepared in the laboratory as per ASTM D1141 - 1998 [13] is given in Table 3.14. The specimens immediately after 28 days of curing were weighed and kept in marine water prepared in the laboratory for 28, 56 and 90 days

6. RESULTS AND DISCUSSION

Experimental results indicate HFRC consistently outperformed RCC. Key performance comparisons are illustrated in Figures 1–7.

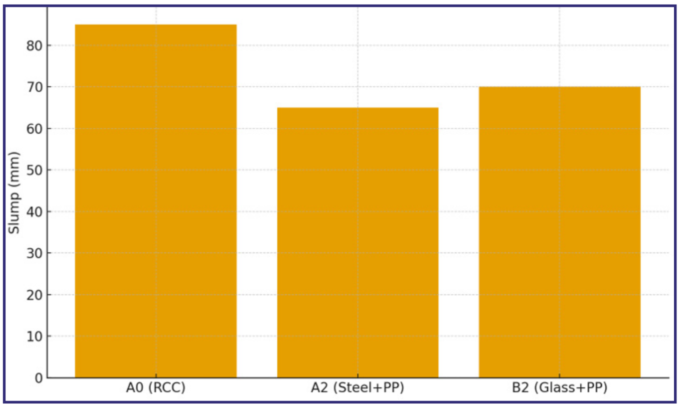

Fig. 1: Slump Values of RCC and HFRC Mixes

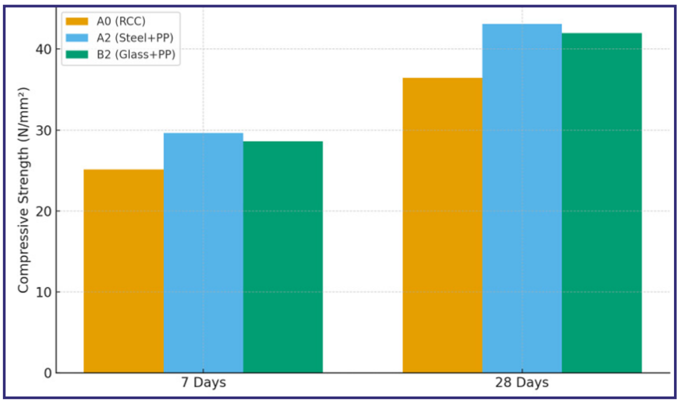

Fig. 2: Compressive Strength of RCC and HFRC Mixes

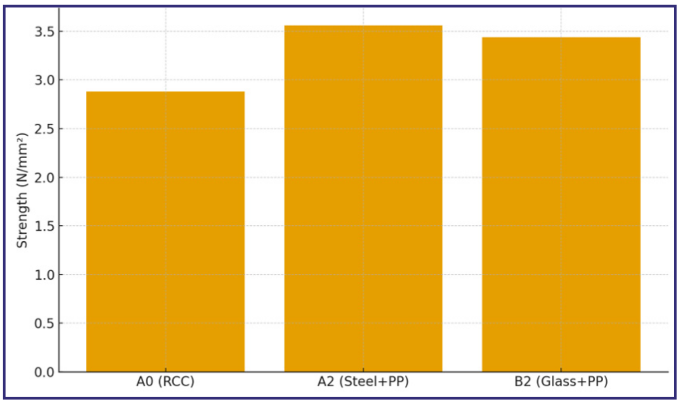

Fig. 3: Split Tensile Strength at 28 Days

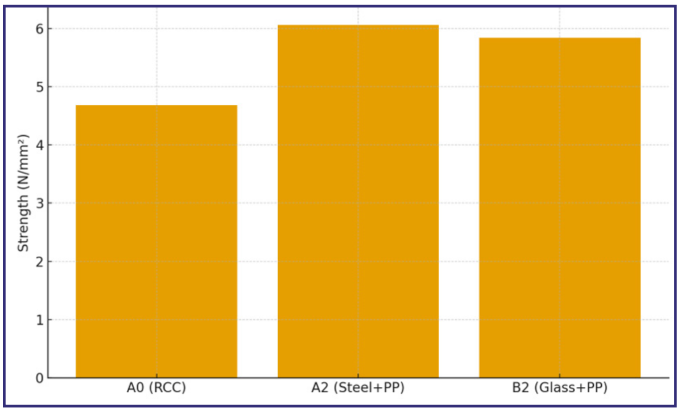

Fig. 4. Flexural Strength at 28 Days

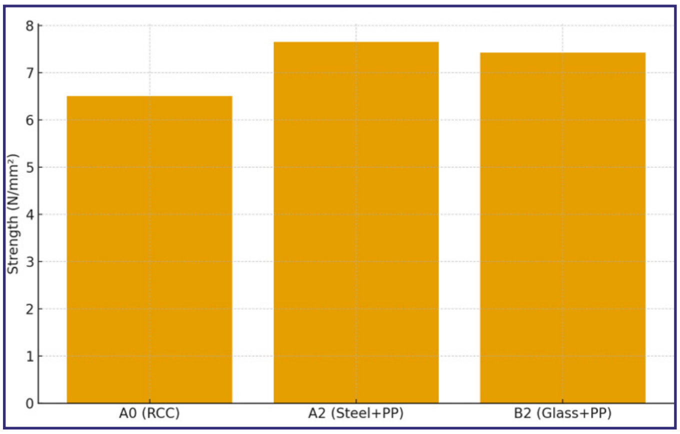

Fig. 5: Bond Strength at 28 Days

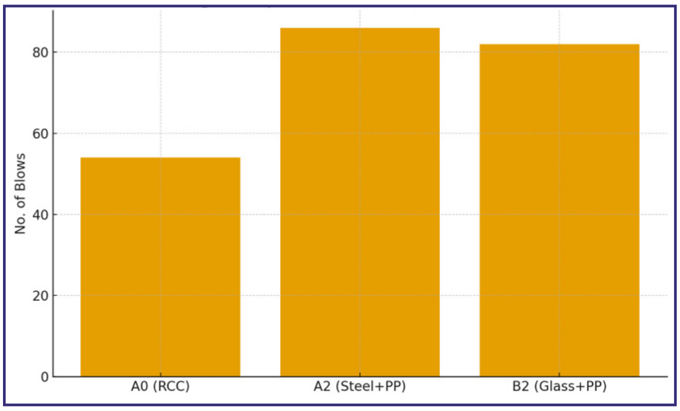

Fig. 6: Impact Resistance (No. of Blows)

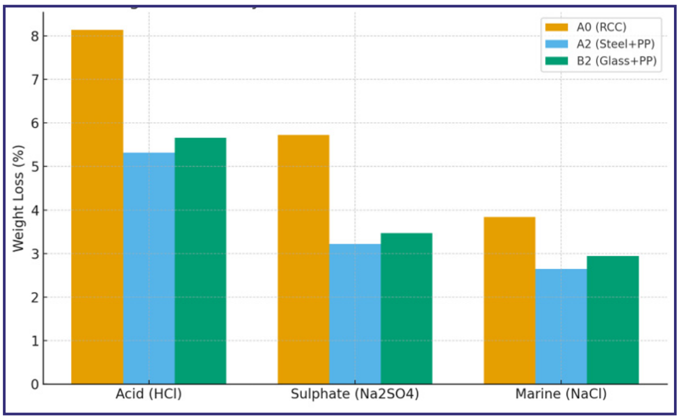

Fig. 7. Durability Performance of RCC and HFRC Mixes

7. CONCLUSIONS

1. HFRC enhances compressive, tensile, flexural, bond, and impact strengths compared to RCC.
2. Optimum performance observed at 1% steel + 0.30% polypropylene fibers.
3. Durability improved under acid, sulphate, and marine exposure.
4. Hybridization ensures better crack control and service life.
5. HFRC is suitable for aggressive environments and critical structures.

8. FUTURE SCOPE

Future work should investigate long-term durability, chloride penetration, freeze-thaw effects, life-cycle cost analysis, and field-scale applications of HFRC.

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