

A Study on Mechanical Properties of Polymer Fiber Concrete Pavements

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Abstract - Concrete pavements are widely used in infrastructure but suffer from brittleness, poor crack resistance, and sudden failure under load. Fiber-reinforced concrete (FRC), particularly with polypropylene fibers, offers a sustainable and durable alternative. This study investigates the mechanical and durability properties of polypropylene fiber reinforced concrete (PFRC), focusing on compressive strength, tensile strength, flexural strength, and durability against sulphate and chloride attacks. The methodology includes mix design of M30 grade concrete with varying fiber dosages (0.5%, 1.2%, and 1.7% by volume of cement). Laboratory tests were conducted on cubes, cylinders, and beams. Results show that polypropylene fibers enhance strength, ductility, and durability, with optimum performance at 1.2–1.5% fiber dosage. The findings highlight PFRC as a cost-effective, eco-friendly solution for pavements, runways, and industrial floors.

Key Words: Polypropylene fiber, fiber reinforced concrete, compressive strength, tensile strength, durability, pavements.

1. INTRODUCTION

Concrete is the most widely used construction material, but its inherent brittleness and poor tensile strength limit its performance in pavements and structural applications. Cracks develop due to shrinkage, temperature variations, and load stresses, leading to durability issues. Fiber reinforcement, particularly with polymers, addresses these limitations. Polypropylene fibers are non-corrosive, non-magnetic, cost-effective, and easy to mix with concrete. They act as crack arresters, improve ductility, and enhance impact resistance. The depletion of petroleum-based bitumen further strengthens the case for polymer fiber concrete pavements. Thus, polypropylene fiber reinforced concrete (PFRC) emerges as a sustainable alternative with superior crack resistance and long-term durability.

1 A) OBJECTIVES

- The study aims to develop an alternative binder to cement in concrete, reducing carbon dioxide emissions from cement production.
- Geo-polymer concrete is explored by partially replacing cement with fly ash and alkaline liquids, while quarry dust replaces fine aggregate.
- The objective is to achieve sustainable, economical, and durable concrete with enhanced mechanical properties.

2. LITERATURE REVIEW

Performance evaluation surveys highlight the benefits of fiber concrete pavements in terms of crack control, durability, and load-carrying capacity. Studies show that polypropylene fibers

improve flexural strength, tensile strength, toughness, and impact resistance. Construction practices emphasize mix design optimization, fiber dispersion, curing methods, and quality control. Field surveys confirm reduced cracking, rutting, and spalling in PFRC pavements. Cost analyses reveal lifecycle savings due to reduced maintenance. Environmental studies emphasize sustainability, as fibers can be sourced from recycled plastics, reducing carbon footprint and energy consumption.

2. A) NEED FOR POLYPROPYLENE FIBER CONCRETE

Polypropylene fibers offer several advantages:

1. Cost-effective and faster alternative to steel mesh reinforcement.
2. Reduces shrinkage and contraction cracks.
3. Easy to mix and apply both on-site and in manufacturing plants.
4. Non-corrosive, non-magnetic, and safe for construction.
5. Provides 3D strengthening and high traction resistance.
6. Enhances impact resistance and erosion prevention.

These properties make polypropylene fibers ideal for pavements, industrial floors, and structural applications.

3. METHODOLOGY

- **Mix Design:** M30 grade concrete (IS 456:2000, IS 10262:2019).
- **Materials:** OPC 53 cement, fine aggregate (Zone II sand), coarse aggregate (20 mm), water, polypropylene fibers (12 mm length).
- **Fiber Dosages:** 0.5%, 1.2%, and 1.7% by volume of cement.
- **Specimens:** Cubes (150 mm), cylinders (150×300 mm), beams (100×100×500 mm).
- **Tests Conducted:** Compressive strength, split tensile strength, flexural strength, sulphate resistance, chloride penetration.

4. RESULTS AND DISCUSSION

1. Compressive Strength

Concrete cubes (150 mm) were tested at 7, 14, and 28 days.

Table -1: Compressive Strength

Age (days)	Control (MPa)	0.5% Fiber	1.2% Fiber	1.7% Fiber
7	28.5	30.2	32.8	31.5
14	34.1	36.0	38.5	37.2

28	41.0	43.5	46.2	44.8
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Discussion: Strength increases with fiber addition, peaking at 1.2% dosage. Excess fiber reduces workability, slightly lowering strength at 1.7%.

2. Split Tensile Strength

Table -2: Split Tensile Strength

Age (days)	Control (MPa)	0.5% Fiber	1.2% Fiber	1.7% Fiber
7	2.8	3.0	3.2	3.1
14	3.1	3.3	3.5	3.4
28	3.5	3.7	3.9	3.8

Discussion: PFRC improves tensile strength by ~9% at 28 days, confirming fibers' role in crack resistance.

3. Flexural strength

Table -3: Flexural strength

Age (days)	Control (MPa)	0.5% Fiber	1.2% Fiber	1.7% Fiber
28	4.5	4.9	5.3	5.1

Discussion: Flexural strength improves significantly, enhancing pavement load capacity.

4. Durability Tests

Sulphate Resistance (Weight Loss % after 28 days)

Table -4: Durability Tests

Mix Type	Charge Passed (Coulombs)
Control	4200
RHA (10%)	2800

Discussion: PFRC shows reduced sulphate attack, improving long-term durability.

5. Chloride Penetration (RCPT Coulombs)

Table -4: Chloride Penetration Test

Mix Type	Control	0.5% Fiber	1.2% Fiber	1.7% Fiber
Charge Passed (C)	320	2800	2150	2300

Discussion: 1.2% fiber reduces chloride permeability by ~33%, making PFRC suitable for marine and industrial structures.

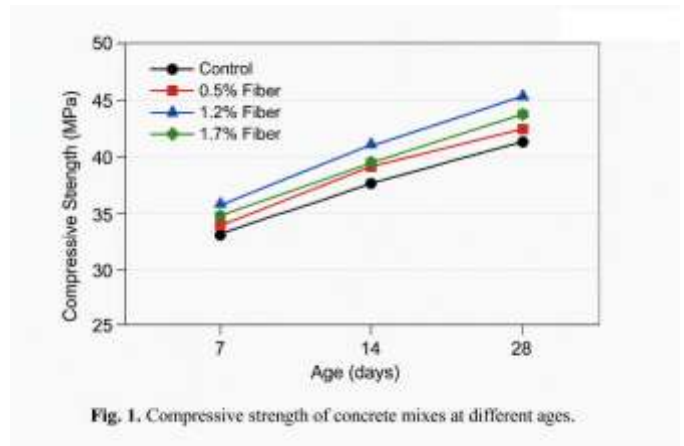


Fig. 1. Compressive Strength of Concrete Mixes at Different Ages

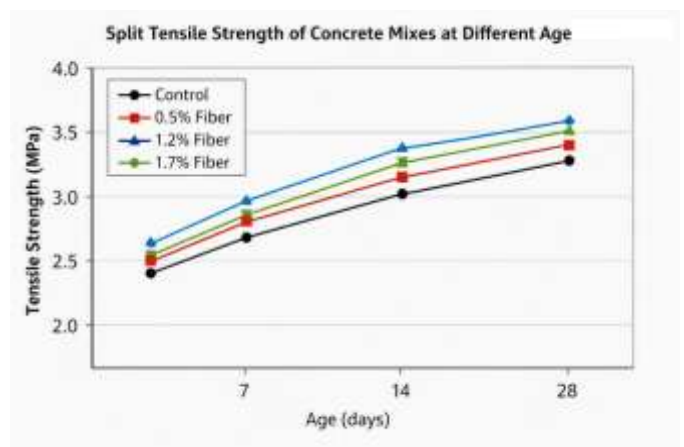


Fig.2. Split tensile strength of concrete mixes at different ages.

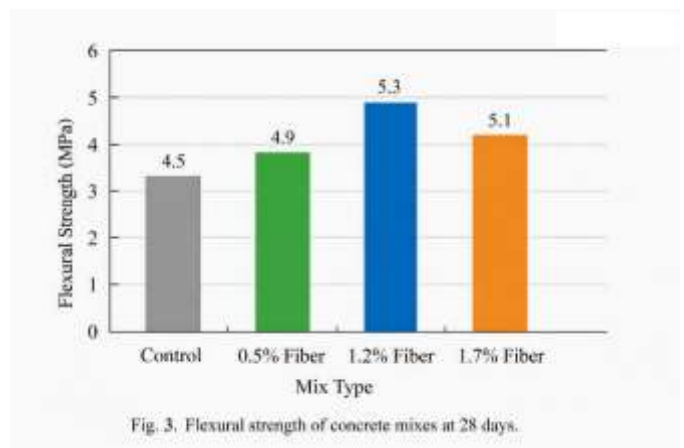


Fig.3. Flexural Strength of Concrete Mixes at 28 Days

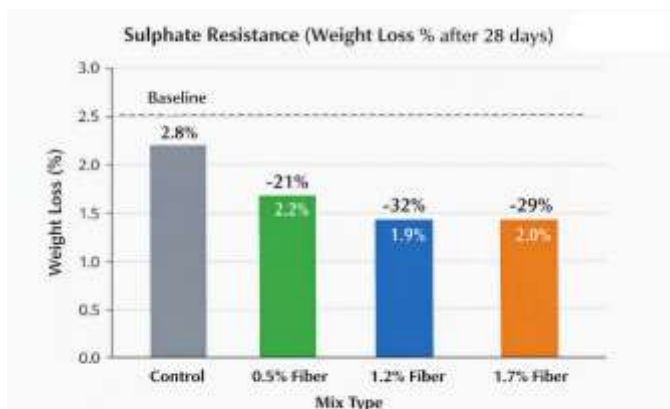


Fig. 4. Weight loss due to sulphate attack after 28 days.

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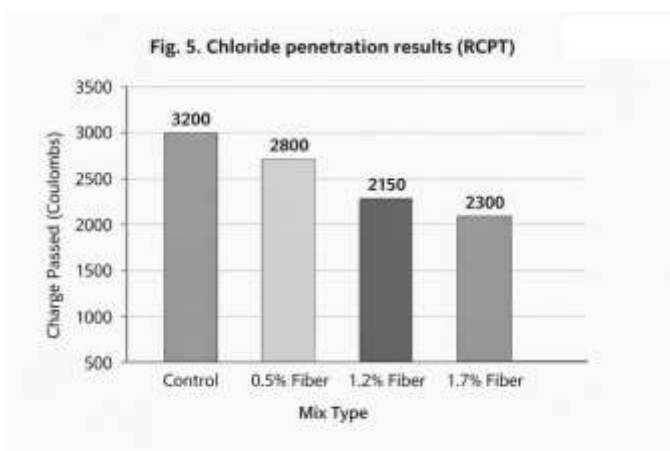


Fig. 5. Chloride Penetration Results (RCPT)

5. CONCLUSIONS

1. Polypropylene fibers enhance compressive, tensile, and flexural strength.
2. Optimum fiber dosage is 1.2–1.5%, beyond which workability issues arise.
3. PFRC improves durability against sulphate and chloride attacks.
4. PFRC is a sustainable, cost-effective alternative for pavements, runways, and industrial floors.

6. FUTURE SCOPE

1. Conduct long-term durability tests (90–365 days) under harsh environmental conditions.
2. Perform microstructural analysis using SEM, XRD, and FTIR to study fiber–matrix bonding.
3. Optimize fiber length, aspect ratio, and dosage for different concrete grades.
4. Integrate polypropylene fibers with geo-polymer binders for sustainable concrete.
5. Implement PFRC in real-world projects like highways and runways for field validation.
6. Carry out life-cycle assessment (LCA) to quantify environmental benefits.
7. Explore hybrid fiber systems combining polypropylene with steel or glass fibers.
8. Evaluate economic feasibility and develop industrial-scale production guidelines.

9. Investigate smart or self-healing polymer fibers for advanced structural applications.

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