Strength And Durability Assessment of Steel and Polypropylene Fiber Reinforced Concrete

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doi.org/10.64643/IJIRTV12I10-204346-459

***Abstract*—This study investigates the mechanical performance and durability of concrete reinforced with steel fibers (SF) and polypropylene fibers (PPF) under acidic and sulfate environments. Concrete mixes including plain concrete and hybrid fiber reinforced concrete (HFRC) were prepared and cured for 28 days. The optimum fiber content was considered for the hybrid mix. Specimens were tested for compressive strength and then exposed to 5% sodium sulfate (Na_2SO_4) and sulfuric acid (H_2SO_4) solutions for specified durations. After exposure, tests were conducted to evaluate residual strength, weight change, and surface deterioration. The results indicate that hybrid fiber concrete shows improved strength and better resistance to chemical attack compared to conventional concrete. The study highlights the effectiveness of hybrid fibers in enhancing durability in aggressive environments.**

I. INTRODUCTION

Concrete is one of the most widely used construction materials due to its high compressive strength, durability, and versatility. However, conventional concrete is brittle and weak in tension, making it prone to cracking.

To overcome these limitations, fiber reinforced concrete (FRC) is developed by adding fibers to improve crack resistance and durability. Steel fibers enhance strength and toughness by bridging cracks, while polypropylene fibers help control micro- cracks and improve durability due to their non- corrosive nature. The combination of both fibers results in hybrid fiber reinforced concrete (HFRC), which provides better overall performance.

Durability is a major concern when concrete is exposed to aggressive environments such as acidic and sulfate conditions. These chemical attacks can cause deterioration and strength loss. Hence, studying the behavior of hybrid fiber concrete under such conditions is important for ensuring long-term performance.

II. OBJECTIVES

- To study the effect of steel and polypropylene fibers on concrete strength.
- To compare compressive strength of ordinary and hybrid fiber concrete.
- To evaluate the performance of hybrid fiber reinforced concrete.
- To study the resistance of concrete against acid attack using sulfuric acid.
- To study the effect of sulfate attack using sodium sulfate solution.
- To assess durability under aggressive chemical conditions.

III. LITERATURE REVIEW

Hybrid fiber reinforced concrete improves compressive, tensile, and flexural strength along with durability due to reduced permeability and better crack control. [1] The combination of steel fibers and fly ash enhances sulfate resistance by refining the concrete matrix and limiting crack propagation.[2] Polypropylene fiber reinforced concrete shows improved resistance to sulfate attack by delaying crack formation and maintaining structural integrity. [3] Fiber reinforcement enhances durability by reducing permeability and increasing resistance to chemical and environmental attacks. [4] The addition of fibers reduces sorptivity and improves abrasion resistance, thereby enhancing durability performance. [5] Hybrid fiber concrete shows improved mechanical properties due to the combined action of steel and polypropylene fibers.

[6] Fiber incorporation improves both mechanical properties and durability by controlling cracks and reducing permeability. [7] Sulfate attack causes expansion and cracking, and reducing permeability is essential to improve resistance. [8] Fiber reinforced concrete exhibits better resistance to acid attack with reduced surface deterioration and improved matrix integrity. [9] Fiber reinforced concrete improves resistance to chemical corrosion by limiting the ingress of aggressive agents [10]

IV. MATERIALS USED

A. Cement
Ordinary Portland Cement (OPC) of 53 grade was used as the binding material in concrete. It was stored in a dry condition to prevent moisture absorption and ensure proper strength development.

B. Coarse Aggregate
Crushed stone aggregate of 20 mm maximum size was used to provide strength and rigidity to the concrete. The aggregates were clean, free from impurities, and washed before use.

C. Fine Aggregate
Locally available river sand passing 4.75 mm sieve was used as fine aggregate. It helps in filling voids and improving the workability and strength of concrete.

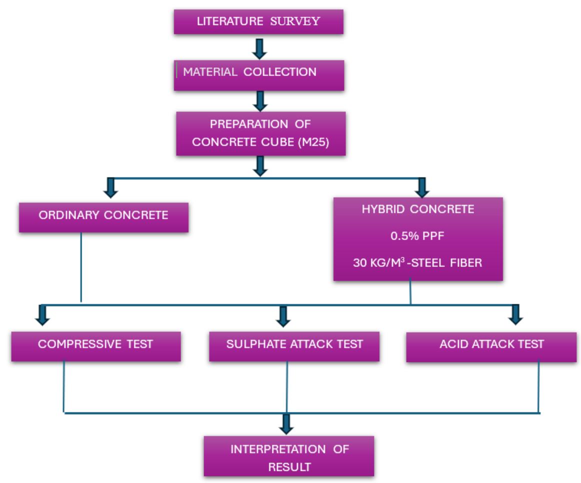
D. Steel Fibre
Steel fibres were used as secondary reinforcement to improve strength, toughness, and crack resistance. They help in controlling crack propagation and enhance load-carrying capacity.

E. Polypropylene Fibre
Polypropylene fibres were used to control plastic shrinkage cracks and improve durability. They also reduce permeability and enhance resistance to chemical attack.

F. Sulphuric Acid
Sulphuric acid solution (pH ≈ 3) was used to study the acid resistance of concrete. It causes deterioration by reacting with cement compounds and reducing strength.

G. Sodium Sulphate
Sodium sulphate solution was used to evaluate sulphate resistance of concrete. It reacts with cement products to form expansive compounds, leading to cracking and strength loss.

V. METHODOLOGY



VI. RESULT AND DISCUSSION

1. Compressive Strength Results (28 Days)

Mix Type	Compressive Strength (Mpa)	% Increase Vs Ordinary
Ordinary Concrete	30	-
Hybrid Fiber Concrete (Sf+Ppf)	36	+20%

Reason

- Steel fibers bridge macro-cracks, increasing load-carrying capacity.
- Polypropylene fibers control micro-cracks, improving matrix integrity.
- Combined (hybrid) effect results in higher strength and delayed failure.

2. Acid Attack Test (H_2SO_4)

Mix Type	Compressive Strength (Mpa)	% Increase Vs Ordinary	Weight Loss
Ordinary Concrete	22	27%	6-8%
Hybrid Fiber Concrete (Sf+Ppf)	28	22%	3-5%

Reason

- Acid reacts with cement → forms gypsum, causing surface damage.
- Ordinary concrete loses more strength due to high permeability.
- Hybrid fiber concrete shows:

○ Reduced cracking
○ Lower permeability
○ Fibers hold structure together

Hence, less strength loss and weight loss.

3. Sulfate (Alkali) Attack Test (Na_2SO_4)

Mix Type	Compressive Strength (MPa)	Strength Loss (%)	Expansion / Damage
Ordinary Concrete	25	17%	Moderate cracking
Hybrid Fiber Concrete	31	14%	Minor cracking

Reason

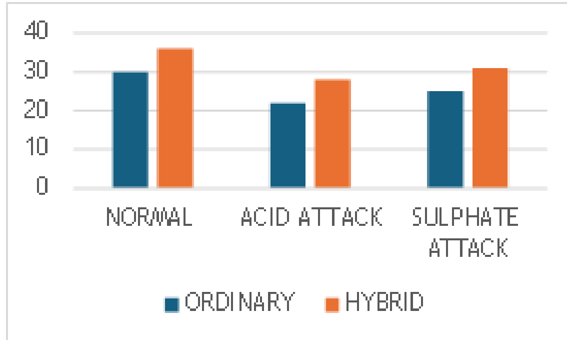
- Sulfate reacts with cement → forms ettringite, causing expansion & cracks.
- Ordinary concrete develops internal stresses → cracking.
- Hybrid fiber concrete:

○ Fibers control crack propagation
○ Reduce internal expansion damage

➞ Hence, better sulfate resistance.

4. Overall Performance Comparison

Property	Ordinary Concrete	Hybrid Fiber Concrete
Compressive Strength	Lower	Higher
Crack Resistance	Poor	Excellent
Acid Resistance	Poor	Better
Sulfate Resistance	Moderate	Good
Durability	Low	High



VII. CONCLUSION

The study concludes that hybrid fiber reinforced concrete (HFRC) exhibits improved mechanical and durability properties compared to conventional concrete. The combined use of steel and polypropylene fibers enhances compressive strength and effectively controls crack formation. Under acid and sulfate exposure, HFRC shows reduced strength loss and better resistance due to lower permeability and improved matrix integrity. The results indicate that hybrid fiber reinforcement significantly increases the service life of concrete in aggressive environments. Hence, HFRC can be considered a suitable material for structures exposed to chemical attack.

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