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COMPARATIVE DURABILITY STUDY OF CONCRETE USING STEEL FIBER AND RECYCLED PLASTIC FIBER

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ABSTRACT

- *Rapid growth in infrastructure development has significantly increased the demand for durable and sustainable construction materials. Conventional concrete, though widely used, suffers from inherent brittleness, low tensile strength, and susceptibility to cracking, which adversely affects its durability.*
- *Fiber reinforcement is an effective technique to enhance the durability and mechanical performance of concrete. Steel fibers improve strength, toughness, and load-bearing capacity, while recycled plastic fibers provide an environmentally sustainable solution by utilizing plastic waste and improving crack resistance.*
- *This study presents a comparative investigation on the durability performance of concrete reinforced with steel fibers and recycled plastic fibers. Experimental tests were conducted to evaluate water absorption, permeability, resistance to chemical attack, and compressive strength.*

- **KEYWORDS:** *Steel Fiber Reinforced Concrete (SFRC), Recycled Plastic Fiber, Durability of Concrete, Fiber-Reinforced Concrete (FRC), Sustainable Construction Materials, Water Absorption, Permeability, Acid Resistance, Crack Resistance, Compressive Strength, Eco-Friendly Concrete, Waste Plastic Utilization.*

I. INTRODUCTION

- Concrete is the most widely used construction material in the world due to its high compressive strength, durability, versatility, and cost-effectiveness. It is composed of cement, fine aggregates, coarse aggregates, and water. Despite its advantages, conventional concrete has inherent limitations such as low tensile strength, brittleness, and poor resistance to cracking, which can significantly affect its long-term durability and performance.
- Durability of concrete is a critical factor in determining the service life of structures. It refers to the ability of concrete to resist environmental effects such as moisture ingress, chemical attack, temperature variations, and abrasion without significant deterioration. Cracks developed in concrete act as pathways for harmful substances like water, chlorides, and acids, leading to reinforcement corrosion and structural damage.
- To overcome these limitations, fiber-reinforced concrete (FRC) has been developed as an advanced construction material. The inclusion of fibers in concrete helps in controlling crack propagation, improving tensile strength, enhancing ductility, and increasing resistance to impact and fatigue loading. Fibers act as bridging elements across cracks, thereby delaying their growth and improving overall structural integrity.
- Among different types of fibers, steel fibers are widely used due to their high strength and stiffness. They significantly improve compressive strength, flexural strength, and toughness of concrete. However, steel fibers may increase the cost of construction and are susceptible to corrosion in aggressive environmental conditions, which can affect durability over time.
- In recent years, the use of recycled plastic fibers has gained attention as a sustainable alternative. Plastic waste, especially from materials such as polyethylene terephthalate (PET) bottles, poses a serious environmental challenge due to its non-biodegradable nature. Converting this waste into fibers for concrete reinforcement not only reduces environmental pollution but also contributes to sustainable construction practices

II. LITERATURE REVIEW

- A literature review is an essential part of any research work as it provides an understanding of previous studies, experimental findings, and advancements in the field of fiber-reinforced concrete and durability enhancement.
- Fiber-Reinforced Concrete (FRC) has been extensively studied for improving tensile strength, crack resistance, and durability of conventional concrete. Steel fibers and synthetic fibers such as plastic fibers have shown significant potential in enhancing performance under various environmental conditions.
- Recycled plastic fibers have recently gained attention due to their environmental benefits and ability to improve durability properties such as permeability resistance and crack control. The following studies provide a strong foundation for the present research:

1. **Romualdi, J. P., & Batson, G. B. (1963)** – ACI Journal, introduced the concept of crack control using randomly

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distributed steel fibers and demonstrated improved tensile strength.
2. **Shah, S. P., & Rangan, B. V. (1971)** – Journal of Structural Division (ASCE), studied fiber-reinforced concrete and reported increased ductility and toughness.
3. **Swamy, R. N., & Mangat, P. S. (1974)** – Cement and Concrete Research, observed improved flexural strength and energy absorption with steel fibers.
4. **Bentur, A., & Mindess, S. (1990)** – Cementitious Composites, provided a comprehensive review on fiber-reinforced cement materials and durability improvements.
5. **Banthia, N., & Trottier, J. F. (1995)** – ACI Materials Journal, studied synthetic fibers and reported reduction in plastic shrinkage cracking.
6. **Naaman, A. E. (2000)** – Construction and Building Materials, highlighted enhanced toughness and durability in fiber-reinforced concrete.
7. **Ochi, T., Okubo, S., & Fukui, K. (2007)** – Cement and Concrete Composites, investigated recycled PET fibers and reported improved tensile strength and crack resistance.
8. **Yazici, S., et al. (2007)** – Construction and Building Materials, studied fiber-reinforced concrete and observed improved mechanical performance.
9. **Siddique, R. (2008)** – Resources, Conservation and Recycling, studied utilization of waste materials in concrete and highlighted environmental benefits.
10. **Fraternali, F., et al. (2011)** – Composite Structures Journal, investigated recycled plastic fibers and found improved durability and crack resistance.
11. **Dawood, E. T., & Ramli, M. (2012)** – Construction and Building Materials, studied hybrid fiber concrete and reported enhanced durability performance.
12. **Rossi, P. (2004)** – Materials and Structures, investigated fatigue behavior and reported improved durability with fiber inclusion.
13. **Khaloo, A. R., & Afshari, M. (2005)** – Cement and Concrete Composites, studied steel fiber concrete and reported increased compressive strength.
14. **Afroughsabet, V., & Ozbakkaloglu, T. (2015)** – Construction and Building Materials, compared steel and synthetic fibers and found differences in durability performance.

III. PROBLEM STATEMENT

- The Concrete structures are continuously exposed to environmental conditions such as moisture, temperature variations, chemical attacks, and mechanical stresses, which lead to deterioration over time. The durability of concrete is therefore a major concern in modern construction practices.
- Conventional concrete, although strong in compression, is weak in tension and prone to cracking. These cracks allow the ingress of harmful substances such as water, chlorides, and acids, which accelerate the process of deterioration and reduce the service life of structures.
- Fiber-reinforced concrete has been introduced as a solution to improve crack resistance and durability. Steel fibers are widely used due to their high strength and ability to enhance mechanical properties. However, steel fibers have certain limitations such as high cost, increased weight, and susceptibility to corrosion in aggressive environments.

IV. OBJECTIVE AND SCOPE

- Objectives of this study are:

1. To investigate the effect of steel fiber and recycled plastic fiber on the durability properties of concrete.
2. To study the influence of fiber inclusion on compressive strength, tensile strength, and crack resistance of concrete.
3. To compare the performance of conventional concrete, steel fiber reinforced concrete (SFRC), and plastic fiber reinforced concrete (PFRC).
4. To determine the optimum fiber dosage that improves durability without adversely affecting workability.
5. To evaluate the resistance of fiber-reinforced concrete against water absorption, permeability, and chemical attack.
6. To assess the effectiveness of recycled plastic fibers as a sustainable alternative to steel fibers.

- The scope of this research is limited to laboratory-based experimental investigation of durability characteristics of concrete containing steel fibers and recycled plastic fibers. The study focuses on key parameters such as water absorption, permeability, crack resistance, and resistance to chemical attack. The results obtained are useful for understanding the comparative performance of both fiber types and their application in durable and sustainable construction practices.

V. METHODOLOGY

- The experimental investigation was carried out in the following stages:

1. **Material Selection** : Cement, fine aggregate, coarse aggregate, steel fibers, recycled plastic fibers, and water were selected as per IS codes. All materials were tested for properties such as specific gravity, grading, and water absorption before use.
2. **Mix Design :** M25 grade concrete mix was designed as per IS: 10262 guidelines. Control mix and fiber-reinforced mixes were prepared with different percentages of steel and plastic fibers to study their effect on strength and durability.
3. **Mixing and Casting:Materials** were mixed uniformly to achieve proper consistency. Fibers were added gradually to avoid clumping and ensure even distribution. Concrete was poured into molds in layers and compacted properly.
4. **Specimen Preparation**

- Cubes (150 mm × 150 mm × 150 mm) for compressive strength
- Cylinders (150 mm × 300 mm) for split tensile strength

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- Beams (100 mm × 100 mm × 500 mm) for flexural strength

5. **Curing:** Specimens were kept undisturbed for 24 hours and then cured in clean water for 7, 14, and 28 days to achieve required strength.
6. **Testing:** Tests such as compressive strength, split tensile strength, water absorption, and permeability were conducted as per standard procedures. Workability was also checked using slump test.
7. **Result Analysis:** The obtained results were analyzed and compared to evaluate the performance of steel fiber reinforced concrete and plastic fiber reinforced concrete. Graphs and tables were used for better comparison and interpretation of results..

VI. MATERIALS

Table 1: Materials used in the study

Name of Material	Source
Cement	Locally available OPC
Fine Aggregate	River sand
Coarse Aggregate	Crushed Stone
Fibers	Steel / Polypropylene fibers
Water	Potable water

A. Cement

➢ Ordinary Portland Cement (OPC) conforming to IS: 8112 was used in this study. The cement showed adequate strength, setting time, and fineness suitable for concrete production

Table 2: Physical and Mechanical Properties of Cement

S.No	Characteristics	Experimental Value	IS Code Requirement
1	Standard consistency	30%	—
2	Specific gravity	3.15	3.15
3	Initial setting time (min)	40	≥ 30
4	Final setting time (min)	180	≤ 600
5	Compressive strength (28 days)	50MPa	≥ 43 MPa

B. Aggregates

➢ Aggregates used in this study consisted of fine aggregate and coarse aggregate. All aggregates were tested and confirmed to meet IS specifications.

➢ Coarse aggregates were clean, hard, and free from impurities. Fine aggregates were well-graded river sand.

Table 3: Physical Properties of Aggregates

Aggregate Type	Specific Gravity	Water Absorption (%)	Fineness Modulus
Fine Aggregate	2.65	1.2	2.7
Coarse Aggregate	2.70	0.8	6.5

C. Fibers

➢ Two types of fibers were used in this study to improve durability and crack resistance: Steel fibers (to increase strength and toughness) Recycled plastic fibers (to improve durability and sustainability)

➢ Fibers were added in different proportions to study their effect on concrete performance.

Table 4: Properties of Fibers

Fiber Type	Length (mm)	Diameter (mm)	Aspect Ratio
Steel Fiber	30	0.5	60
Plastic Fiber	12	0.04	300

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- Fibers were added in different volume fractions to study their influence on mechanical performance of recycled aggregate concrete.

D. Water

- Clean and potable water free from harmful salts, oils, and organic matter was used for both mixing and curing of concrete specimens. The quality of water satisfied the requirements of IS: 456 for concrete production.

VII. MIX DESIGN

- The concrete mix was designed for M25 grade in accordance with IS: 10262 guidelines to achieve the desired strength, workability, and durability. A control mix and fiber-reinforced mixes were prepared for comparative study.
- The water-cement ratio was carefully selected to maintain a balance between strength and durability. All ingredients were proportioned by weight to ensure accuracy in the mix.

- Steel fibers and recycled plastic fibers were added in different proportions to evaluate their influence on the performance of concrete. The addition of fibers was done gradually during mixing to ensure uniform distribution and to avoid clumping.
- Proper mixing was carried out using standard procedures to achieve a homogeneous mixture. The prepared concrete was then used for casting specimens for further testing

Table 5: Mix Proportions

Mix Type	Cement (kg/m³)	Fine Aggregate (kg/m³)	Coarse Aggregate (kg/m³)	Water (kg/m³)	W/C Ratio	Fiber Type	Fiber Content (%)
M1	400	650	1200	180	0.45	None	0
M2	400	650	1200	180	0.45	Steel Fiber	0.5
M3	400	650	1200	180	0.45	Steel Fiber	1.0
M4	400	650	1200	180	0.45	Plastic Fiber	0.5
M5	400	650	1200	180	0.45	Plastic Fiber	1.0

- The mix design ensured that all specimens were prepared under similar conditions so that the effect of fibers on durability and strength could be accurately compared.
- This approach helped in evaluating the performance differences between steel fiber reinforced concrete and recycled plastic fiber reinforced concrete under controlled conditions.

VIII. RESULT & DISCUSSION

- The results obtained from experimental tests are presented and discussed to evaluate the performance of concrete with steel fibers and recycled plastic fibers.

➢ The compressive strength of concrete increases with the addition of fibers as compared to conventional concrete.

➢ Steel fiber reinforced concrete shows higher strength due to better bonding and resistance to crack formation.

➢ Plastic fiber reinforced concrete shows moderate improvement in strength but performs well in durability aspects.

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➢ Water absorption decreases with the addition of fibers, indicating improved resistance to moisture penetration.
➢ Permeability is reduced in fiber-reinforced concrete, which enhances durability and resistance to chemical attack.
➢ Steel fibers are more effective in improving strength properties, while plastic fibers are more effective in improving durability and sustainability.

Table 6: Test Results of Concrete

Mix ID	Fiber Type	Fiber Content (%)	Compressive Strength (MPa)	Water Absorption (%)	Permeability
M1	Control Mix	0%	32	5.2	High
M2	Steel Fiber	0.5%	36	4.5	Medium
M3	Steel Fiber	1.0%	39	4.0	Low
M4	Plastic Fiber	0.5%	34	4.3	Medium
M5	Plastic Fiber	1.0%	36	3.8	Low

IX. CONCLUSION

➢ Based on the experimental investigation, the following conclusions are drawn:

1. It is observed that the addition of fibers improves the overall performance of concrete in terms of strength and durability.
2. Steel fiber reinforced concrete shows higher compressive strength and better crack resistance as compared to conventional concrete.
3. Recycled plastic fiber reinforced concrete shows improvement in durability properties such as reduced water absorption and permeability.
4. The use of plastic fibers helps in utilizing waste materials, making the concrete more eco-friendly and sustainable.
5. Both steel fibers and plastic fibers enhance the properties of concrete, but their performance varies depending on the parameter considered.
6. Steel fibers are more effective for strength improvement, whereas plastic fibers are more beneficial for durability and environmental aspects.
7. It can be concluded that recycled plastic fibers can be used as a suitable alternative in applications where durability and sustainability are important.

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