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Experimental Investigation and Performance Evaluation of Concrete Incorporating Waste Plastic Fibres for Enhanced Mechanical Strength and Durability

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Abstract: Concrete remains the most extensively utilized construction material worldwide, with its performance influenced by mix composition, proportioning, and production practices. Although conventional concrete exhibits excellent compressive strength, its tensile capacity is relatively low, often necessitating the incorporation of fibres to improve structural performance. Fibre-reinforced concrete (FRC), developed through the addition of short, discrete fibres, has been shown to enhance tensile and flexural strength, control crack propagation, reduce shrinkage, and improve resistance to impact, abrasion, and permeability. Despite these benefits, fibre inclusion typically reduces workability, particularly at higher aspect ratios and fibre volumes, thereby requiring adjustments such as the use of superplasticizers or smaller aggregate sizes.

The present study focuses on the sustainable utilization of waste plastic derived from discarded flush doors as fibre reinforcement in concrete. The plastic waste was processed into fibres of 5 mm width and varying lengths to obtain aspect ratios of 30 and 50. Fibre volume fractions of 0.25%, 0.50%, and 0.75% were incorporated to investigate their impact on the fresh and hardened properties of concrete. This research aims to establish an eco-friendly approach to recycling plastic waste while evaluating its feasibility as a functional additive in concrete.

Experimental findings indicate that an increase in fibre content and aspect ratio leads to a noticeable reduction in workability. However, waste plastic fibres exhibited potential in improving selected mechanical properties, demonstrating their viability as a sustainable reinforcement material. The study provides valuable insights into the performance behaviour of waste plastic fibre-reinforced concrete and its prospects for structural and environmental applications.

Index Terms **- Fibre-Reinforced Concrete (FRC), Waste Plastic Fibres, Mechanical Properties, Durability, Recycled Plastic, Aspect Ratio**

1. Introduction

Concrete is the backbone of modern infrastructure and remains one of the most commonly used construction materials due to its adaptability, durability, and relatively low cost. Although concrete performs exceptionally well in compression, its tensile strength is comparatively poor, which often leads to early crack formation and reduced service life. To overcome these drawbacks, different types of fibres such as steel, glass, synthetic polymers, and natural fibres are incorporated into concrete. The addition of fibres transforms conventional concrete into fibre-reinforced concrete (FRC), improving crack control, ductility, impact resistance, energy absorption, and overall mechanical behaviour.

Parallel to the growing demand for high-performance concretes, the increasing generation of plastic waste has emerged as a critical environmental challenge. Plastics are non-biodegradable and accumulate rapidly in landfills and open environments. One potential method to reduce this waste burden is to recycle plastic into value-added construction materials. Using waste plastic as fibres in concrete is a promising approach that supports both sustainable waste management and material performance enhancement. Discarded flush doors which contain durable, tough plastic sheets provide a consistent and readily available waste source for fibre production.

1.2 Types of Fiber

A variety of fibres have been used to improve the performance of concrete. Steel and polypropylene fibres are among the most frequently used, while several non-metallic fibres such as carbon, glass, synthetic polymers, asbestos substitutes, natural fibers, and cellulose-based fibres have also been successfully incorporated in specialized concretes. These fibres enhance several important properties of concrete, including tensile strength, flexural behavior, toughness, impact resistance, fatigue performance, and overall durability. The selection of fiber type depends on the intended application, mechanical requirements, cost, and environmental considerations.

1.3 Factors affecting the properties of Fibre reinforced concrete (FRC)

The performance of fibre-reinforced concrete is significantly influenced by the quantity, geometry, and distribution of fibres within the mix.

1.Fibre Content: Increasing fibre dosage generally enhances crack resistance and post-cracking strength, but an excessively high content may reduce workability and lead to segregation or poor surface finishing.

2.Aspect Ratio: The aspect ratio (length/diameter) plays a major role in fibre effectiveness. Fibres with very low aspect ratios may not significantly alter mechanical behaviour, whereas extremely long fibres may result in entanglement or “balling,” making mixing difficult.

3.Orientation and Distribution: Uniform dispersion and random orientation of fibres tend to provide improved isotropic performance. Poor dispersion can lead to weak zones within the concrete matrix.

4.Workability: The inclusion of fibres generally reduces the flowability of concrete due to increased surface area and internal friction. To overcome this, smaller aggregates (typically less than 10 mm) and super plasticizers are often employed to maintain suitable workability.1.3. Raw Materials in Geopolymer Concrete

1.4 Waste Plastic Fibre Reinforced Concrete

The amount and variety of plastic waste generated in the world is alarming and is causing a huge impact on the environment. Since the plastic does not degenerate easily, alternate ways to dispose of plastic is necessary. Using the plastic as a concrete ingredient is quickly gaining popularity. When the plastic is added to the concrete, the way its behavior changes and whether it is beneficial to the concrete has been a topic of interest. Researchers have used a variety of plastics such as pet bottles, bottle caps, waste pots, buckets, polythene bags, cement bag wastes, etc. Many of them have cut the plastic into strips (fibres) for their investigations. The section below showcases the study of such surveys in detail.

2. METHODOLOGY

This chapter outlines the materials and experimental procedures adopted to evaluate concrete incorporating waste plastic fibres through a structured laboratory program focusing on fresh, mechanical, and durability performance. Conventional M30 grade concrete served as the control mix, while fibres were produced from discarded flush door plastic sheets and cut into strips with different aspect ratios. Multiple mixes were prepared by varying fibre content while maintaining constant mix proportions. Standard methods were followed for material characterization, mix design, casting, curing, and testing. Workability, compressive strength, split tensile strength, flexural strength, and selected durability properties were evaluated to ensure consistency and accuracy.

2.1 MATERIALS PROPERTIES

2.1.1 Cement

Cement is a cohesive and adhesive material capable of binding solid particles together to form a compact and durable mass. In this study, Ordinary Portland Cement (OPC) 43 grade was used as the primary binder. OPC, first named by Joseph Aspdin in 1824, is commonly employed in general concrete construction where exposure to sulfates in soil or groundwater is minimal. For the present project, OPC 43 grade cement was procured locally from Raipur. The physical properties of cement, as per IS 8112:1989, were determined through laboratory tests, and the experimental results are summarized in the following section.

Table 4.1 Properties of cement

S.N	Experiment of the Cement	Results
1	Fineness (Kg/m^2)	300
2	Soundness (mm)	1
3	Specific Gravity	3.15
4	Standard Consistency %	31.2%
5	Initial Setting Time in minutes	28.5
6	Final setting time in minutes	435

2.1.2 Natural Fine Aggregates:

Sand was used in this study as the primary fine aggregate, passing through a 4.75 mm IS sieve. The particle size of sand significantly affects the workability and strength of concrete; sand that is too fine or too coarse is unsuitable. Crushed sand with angular particles and rough surfaces generally provides better workability than naturally rounded river sand. For this project, sand was collected from the Mahanadi River. Based on sieve analysis, the sand was classified as Zone III according to IS 383:2016. Sand is a granular material composed of mineral particles, and its physical properties such as specific gravity, bulk density, and fineness modulus were determined to ensure suitability for concrete production.

Table 4.2Properties of Fine aggregate

S.N	Experiment of the Natural Sand	Result
1	Specific gravity of the fine aggregate	2.54
2	Water absorption of fine aggregate	0.7
3	Fineness modulus	2.90
4	Bulk density of fine aggregate Kg/cum	1670

2.2.3 Coarse Aggregate

Natural coarse aggregate was used as the primary structural skeleton of concrete. Crushed stone aggregates with a maximum size of 20 mm were employed in this study. The aggregates were angular in shape, clean, and free from clay, silt, or organic impurities, ensuring good interlocking and bonding with the cement matrix. Coarse aggregates provide strength, reduce shrinkage, and improve the durability of concrete. The physical properties of the coarse aggregates, such as specific gravity, water absorption, and bulk density, were determined according to relevant IS standards to ensure their suitability for M30 grade concrete

Table 4.3 Properties of coarse aggregate

S.N	*Properties*	*Value*
1	Specific Gravity	2.75
2	Water Absorption	0.15%
3	Crushing Value	22%
4	Impact Value	15%

2.2.4 Waste Plastic Fibres

Plastics, being lightweight, chemically inert, and non-corrosive, can improve certain properties of concrete when used as reinforcement. In this study, waste plastic sheets obtained from discarded flush doors were used as fibres. A single brand of plastic sheets, manufactured in Coimbatore, Tamil Nadu and widely supplied across South India, was selected to maintain consistency in all experiments. According to supplier reports, 10–15% of the production is typically damaged or rejected during transportation and installation. These rejected sheets were collected, cleaned, and manually cut into strips to serve as reinforcing fibres in the concrete mixes. The fibres were introduced in varying aspect ratios and percentages to study their effect on workability, mechanical strength, and durability of concrete.

Table 4.4 Physical properties of the plastic fibres

S.N	*Properties*	*Value*
1	Thickness	0.7 mm
2	Density	1.152 g/cm^3
3	Width of fiber	5 mm
4	Length	Cut as per aspect Ratio

2.2.5 Mix Design

The mix proportioning was performed for M30 grade concrete in accordance with IS 10262:2019, considering a moderate exposure condition and a desired slump of 100 mm.

Table 4.5 Mix Calculations per Unit Volume (1 m³ Concrete)

Component	Formula	Volume (m^3)
Cement	(366.80 / 3.15) × (1 / 1000)	0.116
Water	(157.72 / 1.00) × (1 / 1000)	0.157
Super plasticizer (1% of cement)	(3.668 / 1.08) × (1 / 1000)	0.0033

Table 4.6 Mix Proportion of materials

S.N	Materials	Quantity by mass
1	Cement	366.80 kg/m^3
2	Fine Aggregate (Zone II)	662.83 kg/m^3
3	Coarse Aggregate	1244.33 kg/m^3
4	Water	157.72 kg/m^3
5	Superplasticizer	3.668 kg/m^3
6	Water Cement Ratio	0.43

2.3 Preparation of Sample

A tilting-type power concrete mixer and a table-top vibrator were employed for the preparation of concrete specimens, as shown in Figures 1and 2, which is considered essential for achieving proper dispersion in fibre-reinforced concrete. The weighed quantities of dry materials were first introduced into the concrete mixer and dry-mixed for one minute. The fibres were then added along with the dry constituents to ensure uniform distribution. Subsequently, 80% of the total mixing water was added and the mixture was blended for two minutes. The calculated dosage of superplasticizer was then introduced and mixed thoroughly. The remaining 20% of water was used to rinse the superplasticizer container and was added to the mixer. Mixing was continued for an additional one minute until a homogeneous mix was obtained. The fresh concrete was then placed into greased moulds in three layers, with each layer compacted using a table-top vibrator. Compaction was carried out for a minimum duration of two minutes to ensure adequate densification.

Figures 1

Figures 2

3. Results and Discussions

This chapter presents and discusses the experimental results obtained from the investigation on fibre-reinforced concrete incorporating waste plastic fibres. The results include workability, mechanical strength, and durability characteristics of various concrete mixes with different fibre contents and aspect ratios. The performance of fibre-reinforced concrete is compared with that of conventional concrete to evaluate the influence of waste plastic fibres on the overall behavior of concrete.

Table 3.1 Slump test values

Fiber %	Slump Values	
	Aspect Ratio 30	Aspect Ratio 50
0	100	100
0.25	85	83
0.50	80	76
0.75	76	72

Table 3.2Compaction factor values

Fiber %	Compaction Factor	
	Aspect Ratio 30	Aspect Ratio 50
0	0.96	0.96
0.25	0.93	0.92
0.50	0.81	0.89
0.75	0.88	0.87

Table 3.3 Compressive strength of concrete with Waste Plastic Fibers

Fibre Content (% by volume)	7 Days		14 Days		28 Days	
	Compressive strength (MPa)	% change in strength	Compressive strength (MPa)	% change in strength	Compressive strength (MPa)	% change in strength
C0	24.5	0.00	30.7	0.00	37.25	0.00
FRC 0.25	26.3	7.35	33.1	7.82	40.12	7.70
FRC 0.50	27.25	11.22	34.2	11.40	41.65	11.81
FRC 0.75	26.21	6.98	33.02	7.56	40.11	7.68

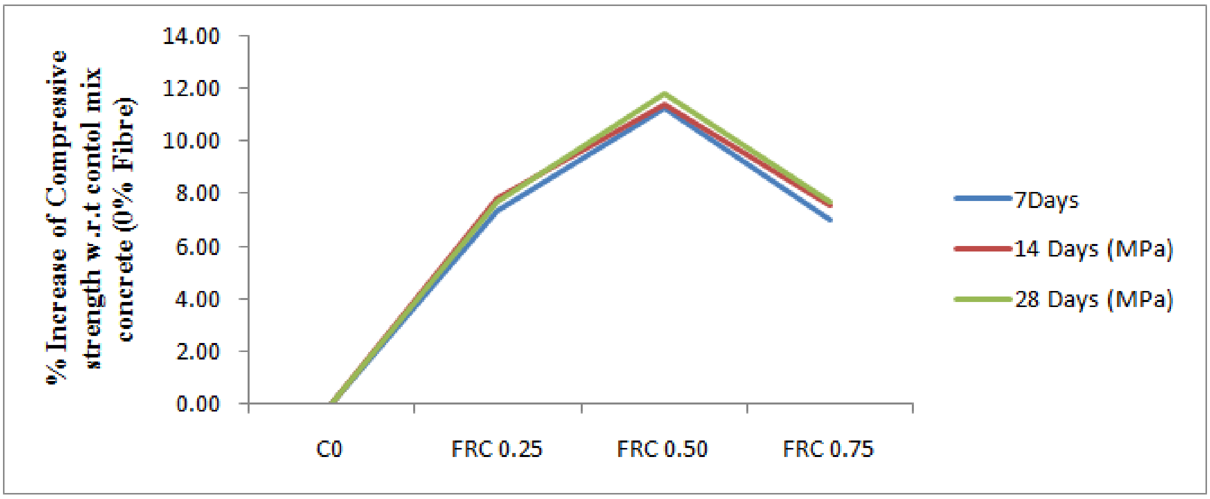
Table 3.4 Split tensile strength of concrete with Waste Plastic Fibers (Aspect Ratio = 30)

Fibre Content (% by volume)	7 Days (MPa)		14 Days (MPa)		28 Days (MPa)	
	Split Tensile strength (MPa)	% change in strength	Split Tensile strength (MPa)	% change in strength	Split Tensile strength (MPa)	% change in strength
C0	2.51	0.00	3.01	0.00	3.81	0.00
FRC 0.25	2.67	6.37	3.21	6.64	4.086	7.24
FRC 0.50	2.82	12.35	3.41	13.29	4.26	11.81
FRC 0.75	2.71	7.97	3.26	8.31	4.11	7.87

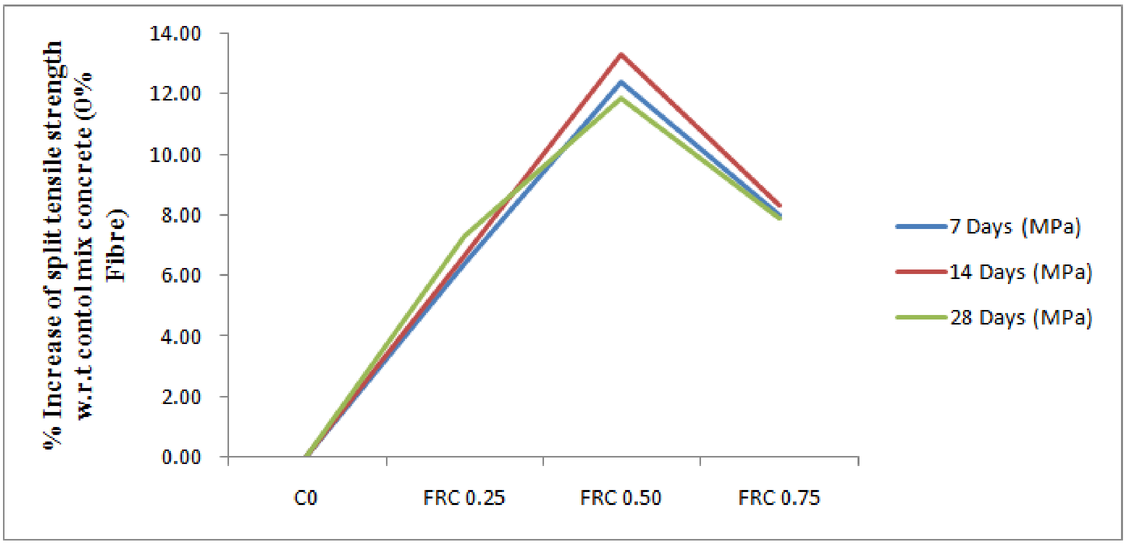
Table 3.5 Flexural strength of concrete with Waste Plastic Fibers

Fibre Content (% by volume)	7 Days (MPa)		14 Days (MPa)		28 Days (MPa)	
	Flexural strength (MPa)	% change in strength	Flexural strength (MPa)	% change in strength	Flexural strength (MPa)	% change in strength
C0	3.31	0.00	4.21	0.00	4.92	0.00
FRC 0.25	3.57	7.85	4.52	7.36	5.23	6.30
FRC 0.50	3.72	12.39	4.72	12.11	5.57	13.21
FRC 0.75	3.59	8.46	4.53	7.60	5.24	6.50

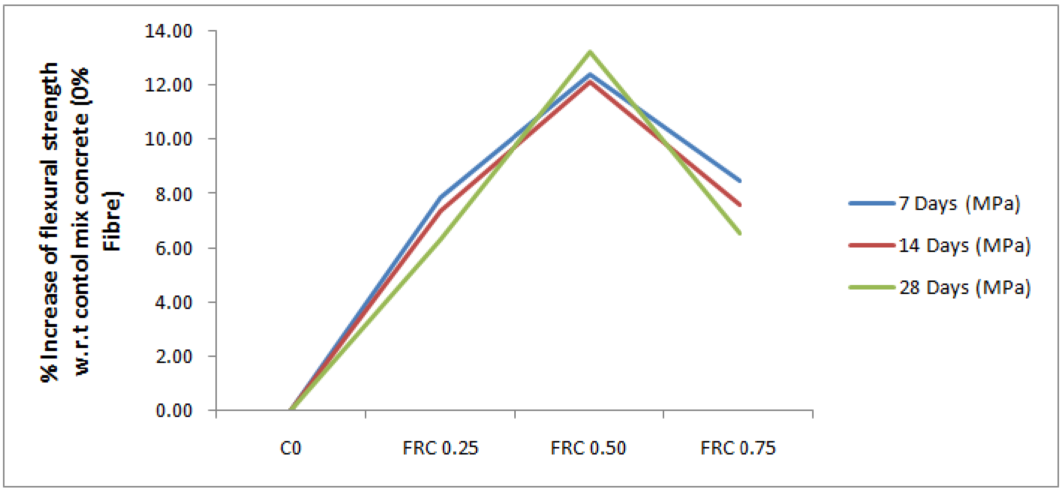
3.2 Graphical Representation



Graph 3.1:- % Increase of Compressive strength w.r.t control mix concrete (0% Fibre)



Graph3.2:- % Increase of split tensile strength w.r.t control mix concrete (0% Fibre)



Graph 3.3:- % Increase of flexural strength w.r.t control mix concrete (0% Fibre)

4. CONCLUSION

The experimental investigation was carried out to evaluate the mechanical performance and durability characteristics of concrete incorporating waste plastic fibres as a partial reinforcement material. Based on the results obtained from fresh, hardened, and durability tests, the following conclusions are drawn:

1. The slump test was conducted to evaluate the workability of concrete mixes incorporating waste plastic fibres with different fibre volume fractions 0.25%, 0.50%, and 0.75% and aspect ratios (30 and 50). The results indicate a consistent reduction in slump value with an increase in fibre content and aspect ratio.

2. The compaction factor test was carried out to assess the workability of concrete mixes incorporating waste plastic fibres with varying fibre volume fractions (0.25%, 0.50%, and 0.75%) and aspect ratios (30 and 50). The test results showed a gradual decrease in the compaction factor with an increase in fibre content and aspect ratio.

3.The percentage change in compressive strength by adding of Waste Plastic Fibers (Aspect ratio = 30) .25% , 0.5 % and 0.75 % by volume was +7.35, +11.22, +6.98 respectively after 7 days, +7.82 , +11.40, +7.56 respectively after 14 days & +7.70, +11.81, +7.68respectively after 28 days compared with the control mix concrete.

6.The percentage change in split tensile strength by adding of Waste Plastic Fibers (Aspect ratio = 30) .25% , 0.5 % and 0.75 % by volume was +6.37, +12.35, +7.97 respectively after 7 days, +6.64 , +13.29, +8.31 respectively after 14 days & +7.24, +11.81, +7.87 respectively after 28 days compared with the control mix concrete.

8.The percentage change in flexural strength by adding of Waste Plastic Fibers (Aspect ratio = 30) .25% , 0.5 % and 0.75 % by volume was +7.85, +12.39, +8.46 respectively after 7 days, +7.36 , +12.11, +7.60 respectively after 14 days & +6.30, +13.21, +6.50 respectively after 28 days compared with the control mix concrete.

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