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Eco-Concrete Innovation: Strength Performance Analysis of Waste Plastic Fiber Mixtures

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Abstract

Concrete is a primary material in construction, impacting structural integrity through its strength characteristics. With increasing global development, the demand for concrete rises, alongside concerns about its environmental footprint and native properties like brittleness. Moreover, the rapid increase of plastic waste, particularly Polyethylene Terephthalate (PET), poses a substantial environmental challenge. Because of this, waste plastic fibers derived from PET were employed in this study to modify concrete. The addition of these fibers is anticipated to enhance concrete's toughness, reduce cracking, and provide a sustainable avenue for waste recycling. Many tests were performed on the concrete mixtures once prepared. Based on the material properties and the aim to evaluate mechanical strength, 100mm x 100mm x 100mm cubes were used to measure compressive and split tensile strength; also, 100mm x 100mm x 450mm beams were used to measure flexural strength. Before mechanical testing, each of the samples, adding waste plastic fiber at varying percentages (0%, 0.12%, 0.24%, and 0.36%), was cured for 7, 14, and 28 days. Study on the investigation of the effect of these waste plastic fibers in concrete mixtures for the specified curing times and percentages discovered that their addition increased compressive strength (up to 29.99 MPa, a 19.3% increase with

0.36% fiber), improved flexural strength (up to 6.65 MPa, a 10.46% increase with 0.24% fiber), and also showed improvements in split tensile strength. In summary, waste plastic fibers can effectively enhance concrete's mechanical performance, offering a sustainable construction solution by reusing PET waste and improving material properties.

Keywords
Waste Plastic Fiber, Concrete Strength, PET Waste, Sustainable Construction.

1. Introduction
Concrete's widespread use is hampered by its intrinsic brittleness and low tensile strength, which often leads to early-age cracking and reduced long-term durability (Qu et al. 2024). While conventional steel reinforcement mitigates this, its high embodied carbon and susceptibility to corrosion conflict with the global push towards net zero construction (Mi, Rengaraju, and Ai-Tabbaa 2025). Concurrently, the environmental crisis of plastic waste, with its detrimental impacts on ecosystems and landfill sustainability, demands urgent and innovative recycling solutions (Fayshal 2024). Meanwhile, plastic waste, particularly polyethylene terephthalate (PET) from bottles, contributes to environmental degradation, with 67% of Asian plastic bottles landfilled and only 8% recycled (Fadhil and Yaseen 2015; Watkins et al. 2012). Recycling PET into fibers for concrete offers a dual benefit, it reduces plastic waste and enhances concrete's properties. Studies show that PET fibers improve tensile strength, toughness, and crack resistance while maintaining workability at optimal levels(Siddique, Khatib, and Kaur 2008). The integration of recycled polyethylene terephthalate (PET) fibers into concrete presents a compelling strategy to address both challenges simultaneously, aligning with the principles of a circular economy (Haba et al. 2025). In fiber-reinforced concrete (FRC), these fibers act as a micro-reinforcement system, bridging incipient cracks to enhance toughness, ductility, and post-cracking resistance (Da Silva Neto et al. 2025; Pham 2025). Research shows PET fibers can increase flexural strength by up to 26% and impact resistance by 340% compared to plain concrete(Al-Hadithi, Al-Ejbari, and Jameel 2013). Adding 1% PET fibers by volume, for example, boosts rupture strength by 24.105% (Nibudey et al. 2013). The rough surface of PET fibers improves bonding with the cement matrix, reducing crack sizes and enhancing durability. This makes PET fiber concrete ideal for precast panels, pavements, and lightweight structures where toughness and sustainability matter (Fraternali et al. 2013). Despite these benefits, challenges remain. The behavior of plastic fiber concrete varies depending on the plastic type, fiber size, shape, and amount added. Too many fibers can reduce workability or cause uneven mixing. The impact on compressive and flexural strength also differs across studies, making it hard to predict outcomes (Irwan et al. 2013). Limited lab-based research exists on how waste plastic fibers affect concrete's mechanical strength, especially compressive and flexural performance. More detailed studies are needed to understand how these fibers work in real concrete mixes and whether they can improve performance without harming workability or durability. Through rigorous laboratory tests on compressive, tensile, and flexural strengths, this study aims to:

- Evaluate the effect of waste PET fiber content (0%, 0.12%, 0.24%, and 0.36% by volume) on the compressive, flexural, and split tensile strengths of concrete.
- Identify the optimal fiber content for enhanced mechanical performance.
- To compare the experimental findings of this study with established results from existing literature.

This study supports sustainable construction by developing plastic fiber concrete, a practical solution that enhances material properties and reduces plastic waste.

2. Materials and Methodology
2.1 Materials
The experimental program utilized Portland Composite Cement (PCC) with a minimum compressive strength of 42.5 MPa at 28 days as the binder (Seven Rings Cement (CEM II/B-M) | SEVEN RINGS CEMENT n.d.). Fine aggregate consisted of Sylhet sand and coarse aggregate comprised 20 mm stone chips, both complying with ASTM C33 standards (Ahmed 2016; Sadiqul Islam and Gupta 2016). The properties of the coarse, and fine aggregates used in the concrete mix were tested in the lab and listed in Table 1

Table 1 Properties of aggregates

Properties	Test Results (Fine Aggregate)	Test Results (Coarse Aggregate)	Unit
Fineness Modulus(FM)	2.64	4.25	-
Specific gravity	2.63	2.51	-
Absorption capacity	2.02	0.6	%
Unit weight	1612	1662	kg/m^3

Figure 1 show that the grain size distribution curves of both stone and sand are well graded and evenly spread, which helps improve the strength of the concrete.

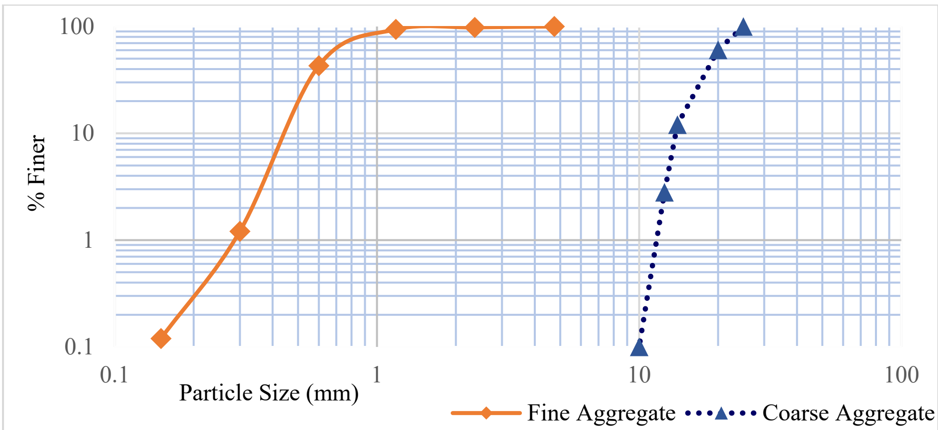

Figure 1 Grain size distribution curve

Waste plastic fibers were sourced from locally collected PET bottles, shredded into 20 mm lengths. The fibers were washed and dried to remove contaminants, ensuring compatibility with the cement matrix (Rahman and Alam 2020). Clean drinking water from Southern University Bangladesh's supply was used for mixing to maintain quality and avoid impurities that could affect cement hydration (Taherkhani 2014) (Figure2).

Figure 2 Left: Waste plastic bottles; Middle: Handmade cutting machine; Right: Drying process of cleaned plastic fibers.

The basic physical properties of the plastic fibers are listed in **Table 2**.

Table 2 Properties of the plastic fibers used in this study.

Type of fiber	Average Length (mm)	Average Width (mm)	Aspect Ratio (L/W)	Unit weight (Kg/m^3)
Waste plastic fiber (PET)	20	1.63	12.27	1140

2.2 Fresh Concrete Design & Curing

Concrete mixes were designed per ACI 328 guidelines to achieve a target strength of 25 MPa, using a mix ratio of 1: 1.81: 2.87 (Cement: Fine Aggregate: Coarse Aggregate). **Table 3** shows the quantities of materials used in the concrete mix.

Table 3 Mix proportions for plain concrete.

Mix Constituents	Cement (kg/m^3)	Sand (kg/m^3)	Coarse Aggregate(kg/m^3)	w/c ratio	Water (kg/m^3)	14-Day compressive strength results of trial concrete mixes (MPa)
Design Concrete (25MPa)	370	670.65	1064	0.5	195	14.97

[Note: Base mix Proportions for plain concrete without plastic fiber]

Four mixes were prepared: a control mix (CC) without fibers and three WPF mixes (WFC-A, WFC-B, WFC-C) with fiber content by volume. The fiber concretes were labeled WFC followed by their respective fiber volume fractions. The various fiber concrete mixes tested are provided in **Tables 4**

Table 4 Various concrete mixes with waste plastic fiber.

Sl. No	Mix ID	Type of Concrete Mix	Fiber Proportions (in %)	Weight (kg) of Plastic Fibers Incorporated per 1 m³ of Concrete Mix
1	CC	Conventional concrete	0	0
2	WFC-A	Plastic fiber—homogenous	0.12	1.36
3	WFC-B	Plastic fiber—homogenous	0.24	2.74
4	WFC-C	Plastic fiber—homogenous	0.36	4.10

Figure 3 Fresh concrete mixing, cube and beam casting, demolding and curing process.

Specimens included 100 mm cubes for compressive and split tensile strength tests and 100 mm x 100 mm x 450 mm beams for flexural strength tests. Concrete materials for, measured according to the proportions listed in **Table 4**. Fibers were dry-mixed with aggregates for 3 to 5 minutes before adding water to ensure uniform dispersion and prevent segregation (Irwan et al. 2013). Specimens were cast in steel (cubes) and wooden (beams) molds, compacted using a tamping rod, and cured in water at room temperature for 7, 14, and 28 days (shown in **Figure 3**). All tests followed standard protocols to ensure reproducibility.

3. Results and Discussion

3.1 Compressive Strength

Compressive strength tests revealed significant improvements with WPF incorporation. At 7 days, the control mix (CC) achieved 15.71 MPa, while WFC-A, WFC-B, and WFC-C recorded 17.70 MPa, 17.97 MPa, and 19.11 MPa, respectively. By 14 days, strengths increased to 22.22 MPa (CC), 22.46 MPa (WFC-A), 22.83 MPa (WFC-B), and 25.84 MPa (WFC-C). At 28 days, WFC-C peaked at 29.99 MPa, a 19.3% increase over CC (25.13 MPa), as shown in **Figure 4**. A similar increasing trend was observed in another study(Hasan 2012), where high-grade concrete showed at least a 20% strength increase compared to conventional concrete. The enhancement is attributed to fibers improving internal cohesion and load distribution within the concrete matrix (Hasan 2012; Khaleel et al. 2024).

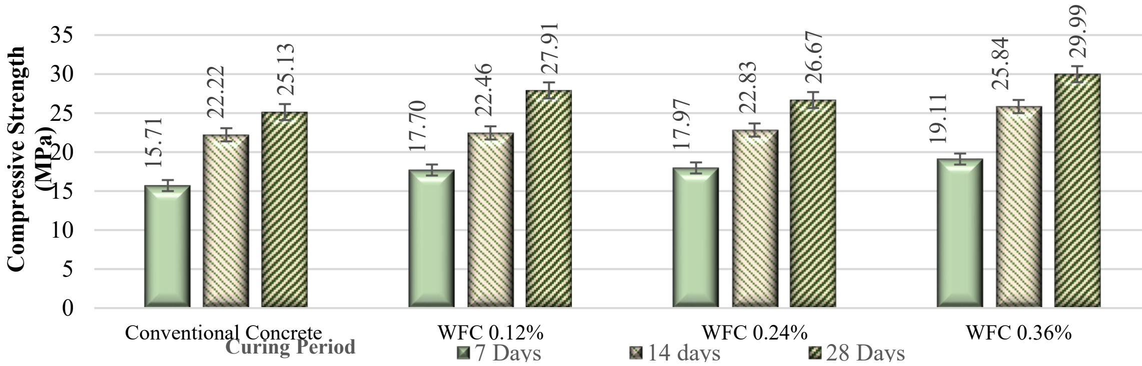

Figure 4. Compressive strength of cubes at 7, 14 and 28 days.

3.2 Flexural Strength

Flexural strength, indicative of bending resistance, showed notable improvements with WPF**.** At 7 days, CC recorded 4.64 MPa, while WFC-A, WFC-B, and WFC-C achieved 4.72 MPa, 4.74 MPa, and 4.74 MPa, respectively. By 14 days, strengths increased to 5.95 MPa (CC), 5.98 MPa (WFC-A), 6.08 MPa (WFC-B), and 6.21 MPa (WFC-C). At 28 days, WFC-B peaked at 6.65 MPa, a 10.46% increase over CC (6.02 MPa), as shown in **Figure 5** In previous studies, 1% fiber content increased flexural strength by 17.32% (aspect ratio 35) and 24.105% (aspect ratio 50) over control concrete (Nibudey et al. 2013). The optimal performance at 0.24% WPF is due to effective crack-bridging and enhanced post-crack behavior (Al-Hadithi et al. 2013; Fraternali et al. 2013).

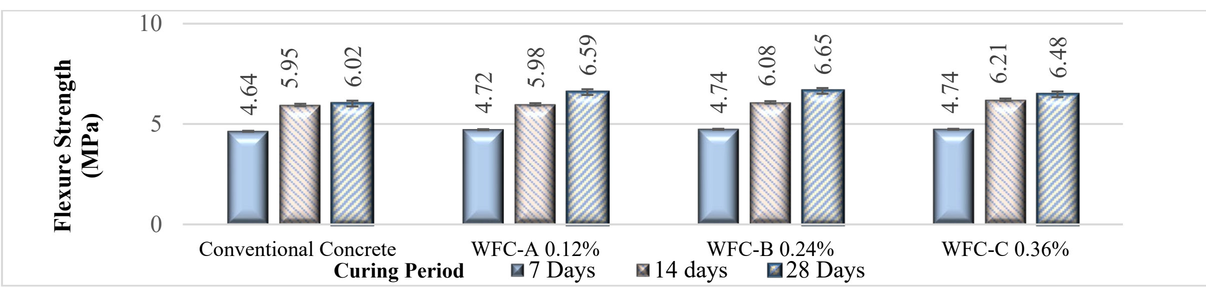

Figure 5.. Flexural strength of beams at 7, 14 and 28 days.

3.3 Tensile Strength

Tensile strength exhibited the most significant enhancement. At 7 days, CC recorded 2.78 MPa,while WFC-A, WFC-B, and WFC-C achieved 3.58 MPa, 4.02 MPa, and 3.46 MPa, respectively. By 14 days, strengths increased to 3.88 MPa (CC), 4.95 MPa (WFC-A), 5.21 MPa (WFC-B), and 4.02 MPa (WFC-C). At 28 days, WFC-0.24% peaked at 6.18 MPa, a 43% increase over CC (4.32 MPa), as shown in Table 3. According to previous research, split tensile strength increased by 54.4% at 28 days compared to conventional concrete (Ananthi, Eniyan, and Venkatesh 2017). The fibers act as crack arresters, distributing stress and enhancing tensile resistance (Saikia & Brito, 2014).

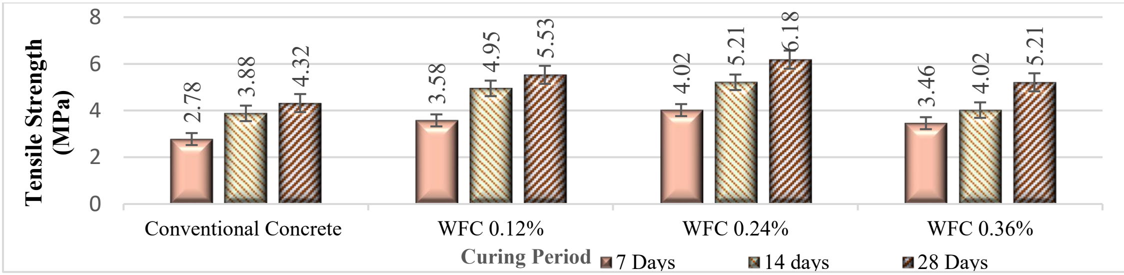

Figure 6. Tensile strength of beams at 7, 14 and 28 days.

3.4 Relationship Analysis

The relationship between compressive and tensile strengths is non-linear. At 0% WPF, compressive strength was 25.13 MPa and tensile strength was 4.32 MPa. At 0.12% WPF, both increased to 27.91 MPa and 5.53 MPa, respectively. The peak tensile strength occurred at 0.24% WPF (6.18MPa) with a compressive strength of 26.67 MPa, indicating optimal fiber content for tensile enhancement (**Figure 6- Figure 8**). At 0.36% WPF, compressive strength peaked at 29.99 MPa, but tensile strength decreased to 5.21 MPa, likely due to fiber clustering (Saikia and Brito 2014). Similarly, flexural strength peaked at 0.24% WPF (6.65 MPa) with a compressive strength of 26.67 MPa, but decreased to 6.48 MPa at 0.36% WPF (**Figure 3-e**). These trends suggest that 0.24% WPF optimizes tensile and flexural performance due to effective fiber bridging (Nibudey et al. 2013).

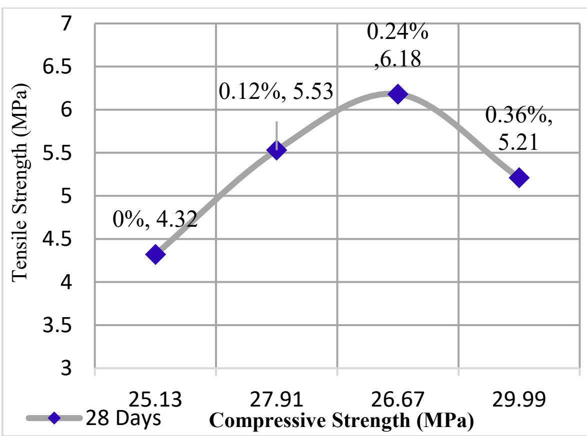

Figure 7. Relations between Compressive and Tensile strengths.

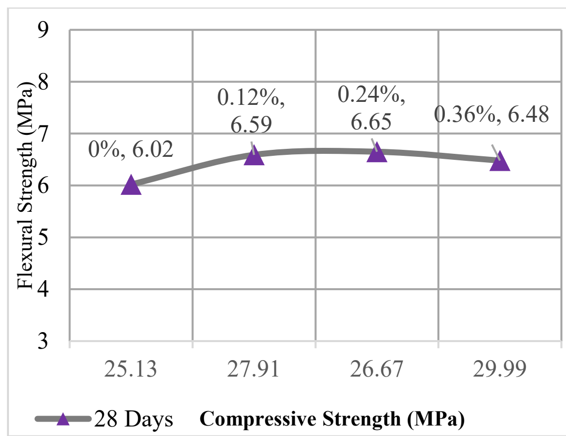

Figure 8. Relations between Compressive and Flexural strengths.

3.5 Discussion

The incorporation of WPF significantly enhances concrete's mechanical properties. Compressive strength improvements are attributed to enhanced internal cohesion and load distribution, with WFC-0.36% achieving a 19.3% increase at 28 days. Flexural and tensile strengths peak at 0.24% WPF, with increases of 10.46% and 43%, respectively, due to effective crack-bridging and stress distribution (Al-Hadithi et al. 2013; Foti 2019). Higher fiber content (0.36%) slightly reduces tensile and flexural gains, likely due to clustering and reduced matrix continuity.

4. Conclusion

The incorporation of waste plastic fibers (WPF) into 25 MPa grade concrete has been demonstrated to significantly enhance its mechanical properties, a finding with considerable implications for sustainable construction practices. Analysis of the hardened concrete at 28 days revealed that the optimal fiber content for maximizing tensile and flexural performance was 0.24% WPF. This concentration resulted in a peak flexural strength of 6.65 MPa, representing a 10.46% increase over the control mix, and more notably, yielded a tensile strength of 6.18 MPa, which constitutes a substantial 43% improvement over the reference concrete. Conversely, the maximum compressive strength was achieved at a slightly higher fiber content of 0.36% WPF, registering 29.99 MPa which is an increase of 19.3%

compared to the control's 25.13 MPa. These quantitative improvements collectively validate WPF modified concrete as a durable and high-performance material, simultaneously addressing the environmental concerns associated with PET waste and carbon emissions in the construction sector.

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Saiful Islam Talukder is a driven undergraduate student majoring in civil engineering at Southern University Bangladesh. With a strong passion for the field, he stays actively involved in the Southern University Career Club, participating in events that build skills and networks for future professionals. His research curiosities center on structural design, environmental impacts, and sustainable materials, where he explores ways to create greener, more resilient buildings. Always willing to learn, Saiful balances academics with hands-on initiatives, setting his sights on innovative solutions for real world challenges.

Tania Sultana is an enthusiastic undergraduate student pursuing civil engineering at Southern University Bangladesh. Brimming with motivation, she actively contributes to the Southern University Career Club, engaging in workshops and networking events that sharpen her professional edge. Her research passions revolve around civil engineering management, environmental conservation, and sustainable materials, aiming to develop efficient, eco-friendly infrastructure that tackles modern challenges. Tania gain on blending theory with practical projects, always pushing for innovative ideas that promote a greener future.

Md Shifatul Islam Sizol is a dedicated and motivated Civil Engineering graduate from Southern University Bangladesh. With a strong academic foundation and a passion for structural design, construction management, and environmental engineering, he aims to contribute to sustainable and modern infrastructure development. He is committed to continuous learning, professional growth, and applying engineering principles to real-world solutions.

Arka Prava Das is a lecturer at Southern University in Bangladesh, passionate about civil engineering. He graduated with a bachelor's from Chittagong University of Engineering and Technology (CUET), where he researched coconut fiber reinforced concrete for sustainable builds. He later earned a master's in geotechnical engineering from Japan's University of Tsukuba, studying dry granular flows via experiments and the Discrete Element Method (DEM). Blending structural and geotechnical fields, Arka focuses on innovation in materials and disaster mitigation. His publications cover granular flow impacts (6th World Landslide Forum 2023, GeoKanto 2022), coconut fiber strength (ICRICE 2020), and upcoming studies on slag/fly ash cement replacements and fly ash geopolymer concrete (ICACE 2024).