

Experimental study on compressive strength of permeable concrete with shredded plastic and plastic pellets

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Abstract—This study investigates the mechanical behavior of permeable concrete incorporating shredded plastic fibers and plastic pellets as sustainable replacements for cement and coarse aggregates. The increasing challenge of plastic waste disposal and the environmental consequences of impermeable pavements necessitate eco-friendly alternatives. Portland Pozzolana Cement (PPC) was partially replaced with shredded plastic at 0%, 1%, 2%, and 3%, while plastic pellets were used at similar percentages as partial aggregate replacements. Experimental tests were conducted to evaluate compressive and flexural strengths at 7, 14, and 28 days of curing. The results demonstrated that 1% shredded plastic replacement exhibited the highest compressive strength (37.87 N/mm²) and flexural strength (7.66 N/mm²), surpassing the control mix. Strength declined beyond 2% due to poor bonding and increased voids. The findings reveal that minimal plastic addition enhances strength through improved crack resistance and internal reinforcement while maintaining permeability. Thus, 1% shredded plastic and plastic pellet inclusion provide an optimal balance between strength, porosity, and sustainability, promoting eco-efficient permeable concrete for low-load pavements and drainage-sensitive infrastructures.

Index Terms—Permeable concrete, Shredded plastic, Plastic pellets, Compressive strength, Flexural strength, Sustainable construction

I. INTRODUCTION

Rapid urbanization and unplanned construction activities have significantly reduced natural ground surfaces, replacing them with impermeable concrete structures. This transformation severely hampers rainwater infiltration, leading to frequent water stagnation, flash floods, and an increased burden on storm-water drainage systems. Conventional pavements do not support groundwater recharge, contributing to declining water tables, especially in urban regions. During monsoon seasons, clogged drainage networks often fail to handle the excess runoff, resulting in property damage, traffic disruption, and environmental imbalance. These challenges emphasize the urgent need for alternative pavement materials that are eco-friendly, sustainable, and capable of supporting natural hydrological cycles. Permeable concrete, also known as pervious or porous concrete, has emerged as an effective solution to mitigate such environmental issues. Unlike traditional concrete, permeable concrete contains interconnected voids that allow water to pass through its structure, enabling infiltration into the ground and reducing surface runoff. It plays a vital role in sustainable urban drainage systems by supporting groundwater recharge, minimizing flooding risks, and reducing the dependence on artificial storm-water management infrastructure. Due to its high porosity, permeable concrete is widely used in low-traffic applications such as pedestrian pathways, parking lots, footpaths, parks, and low-volume roads. Although advantageous in managing storm water, permeable concrete typically shows lower mechanical strength compared to conventional concrete due to the absence of fine aggregates.

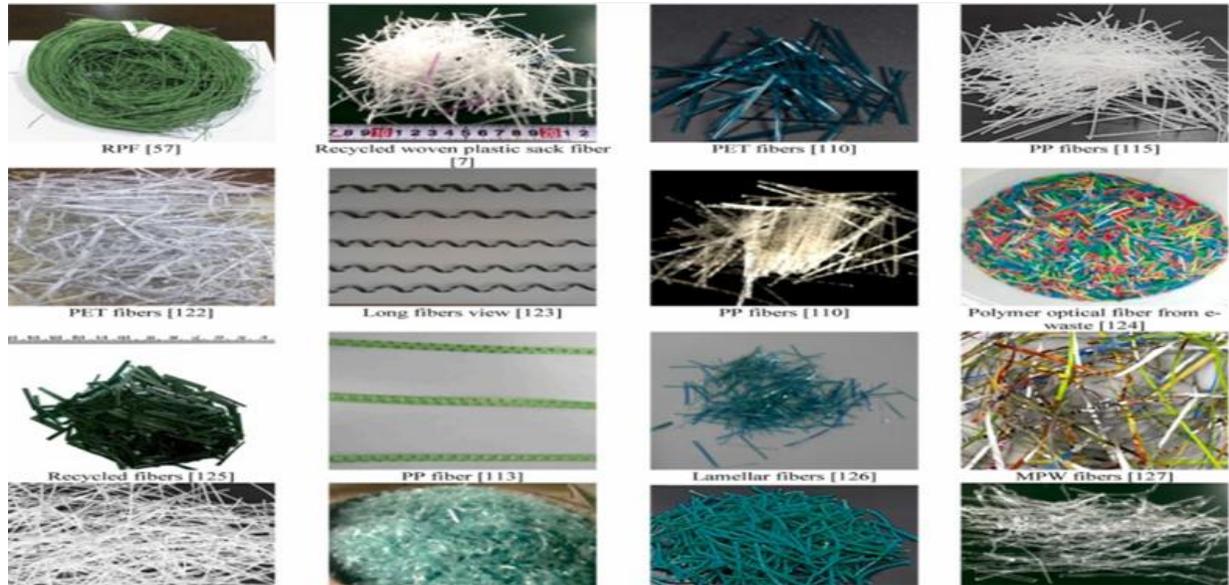


Figure 1. Different types of recycled plastic fibers used in concrete.

Source: Siddique, R., Khatib, J., & Kaur, I. (2008)
 The figure presents various recycled plastic fibers such as PET, PP, RPF, and MPW used in concrete production. These fibers vary in shape, texture, and composition, enhancing tensile strength, reducing

cracking, and promoting eco-friendly construction by reusing non-biodegradable plastic waste in sustainable concrete applications.



Plastic pellets



Shredded plastic

Hence, research on improving its performance using innovative and sustainable materials is essential. Simultaneously, the growing generation of plastic waste has become a global environmental concern. Plastics are non-biodegradable, persist in nature for hundreds of years, and pose serious threats to soil, water, marine life, and human health. Disposing of plastic through landfilling or burning releases toxic substances, contributing to land degradation and air pollution. Recycling plastic waste into construction materials offers a promising approach to addressing

both waste management and sustainable construction goals. Incorporating plastic into concrete not only reduces plastic accumulation in the environment but also minimizes the consumption of natural aggregates, supporting resource conservation. In this context, shredded plastic fibers and plastic pellets have gained research attention as potential additives and partial replacement materials in concrete production. Shredded plastic fibers, when used as a partial replacement for cement, may contribute to improved tensile behavior due to their fibrous nature, while

plastic pellets, when used as lightweight aggregate substitutes, can modify the density and permeability characteristics of the concrete mix. However, excessive plastic content may negatively impact strength, requiring a balanced optimization between sustainability and mechanical performance. This study focuses on the combined effect of shredded plastic fibers as partial cement replacement and plastic pellets as partial coarse aggregate replacement in permeable concrete. The primary objective is to experimentally evaluate the mechanical behavior of the modified concrete by determining its compressive strength and flexural/tensile strength at 7 and 28 days of curing. The outcomes of this research are expected to contribute toward developing sustainable, lightweight, and environmentally responsible pavement materials suitable for non-structural applications, promoting both plastic waste utilization and efficient storm-water management.

II. PROBLEM STATEMENT

Increasing urbanization has led to extensive use of impermeable concrete surfaces, resulting in severe storm-water runoff, reduced groundwater recharge, and frequent urban flooding. Permeable concrete has emerged as a sustainable alternative due to its ability to allow water infiltration, yet its widespread adoption is restricted by low mechanical strength, primarily because of its high-void structure and absence of fine aggregates. The introduction of waste materials such as shredded plastic and plastic pellets into permeable concrete presents a promising approach for sustainable waste management and resource conservation. However, plastic materials behave differently from conventional cementitious and aggregate components, often weakening the bond matrix, reducing density, and negatively affecting compressive and flexural strength. Although several studies have separately explored either cement replacement using plastic fibers or aggregate replacement using plastic pellets, limited research is available on their combined influence in permeable concrete. The dual replacement may further impact porosity, permeability, and structural integrity, making it essential to identify a suitable composition that balances both strength and water infiltration characteristics. There is a critical need to evaluate the optimum percentage of shredded plastic and plastic pellets that can deliver acceptable

mechanical performance without compromising permeability. This research aims to address this gap by experimentally determining a balanced, sustainable mix design for practical non-structural pavement applications.

III. AIM AND OBJECTIVES

Aim of this study to develop sustainable permeable concrete using shredded plastic and plastic pellets while evaluating strength performance.

Objectives

1. Assess compressive strength of permeable concrete with plastic additives.
2. Evaluate tensile/flexural strength at 7, 14, and 28 days.
3. Analyze impact of shredded plastic and plastic pellets on mechanical behavior.
4. Determine optimum mix for permeability and strength balance.

IV. LITERATURE REVIEW

Permeable concrete, also known as pervious or porous concrete, has gained significant attention as a sustainable pavement material capable of managing surface runoff while promoting groundwater recharge. Recent studies have examined the incorporation of recycled plastic materials to enhance sustainability and reduce environmental pollution. Vijayakumar et al. (2022) conducted an Experimental study on compressive strength of permeable concrete with shredded plastic fiber and plastic pellets, concluding that limited quantities of plastic improved water infiltration but reduced compressive strength beyond an optimal threshold. Supit and Priyono (2022) observed similar trends when using recycled PET plastic waste as coarse aggregate in pervious concrete, noting reduced density and strength but improved permeability. Ramesh (2023) reported that substituting recycled plastic improved workability but required careful proportioning to maintain compressive strength. Oddo et al. (2024) and El-Nadoury et al. (2022) demonstrated that chemically treated or blended plastic fibers enhance concrete ductility and reduce brittleness. Farah et al. (2024) confirmed that shredded PET could safely replace part of coarse aggregates without major strength loss at lower substitution levels.

Several other studies have highlighted the mechanical and durability behavior of permeable concrete when integrated with plastic-based materials. Cole et al. (2020) explored the combined use of waste plastic and recycled rubber aggregates, reporting enhanced permeability and acceptable compressive strength for light-duty pavements. Rahul et al. (2024) analyzed nano-silica and shredded plastics in pervious concrete, showing strength improvement due to better particle packing. Dhanalakshmi et al. (2025) and Islam (2022) demonstrated that e-waste and polypropylene-based plastic replacements improve sustainability while maintaining structural integrity under moderate loading. Additional research by Hande et al. (2023) and Supit et al. (2022) confirmed that controlled substitution of plastics reduces environmental impact, promotes waste recycling, and supports the development of eco-efficient concrete mixes. Overall, prior investigations reveal that an optimal replacement level—typically around 1% to 2% plastic content—offers the best balance between compressive strength and permeability, making it suitable for low-load pavements, parking lots, and pedestrian pathways.

V. METHODOLOGY

5.1 Material Collection

The materials used in this research include:

- Portland Pozzolana Cement (PPC) conforming to IS 1489 (Part-1).
- Shredded plastic fibers passing 4.75 mm sieve and retained on 2.36 mm.
- Plastic pellets of approximately 2.36 mm diameter.
- Coarse aggregates ranging between 6.3 mm to 11.3 mm.
- Clean potable water for mixing and curing.

5.2 Mix Design

- A binder-to-aggregate ratio of 1:6 was adopted for porous concrete preparation.
- The binder includes cement and shredded plastic fiber (partial cement replacement).
- The aggregate includes natural coarse aggregate and plastic pellets (partial aggregate replacement).

5.3 Percentage Replacement Strategy Two types of replacements were carried out:

Material Replaced	Replacement Material	Percentage Variations
Cement	Shredded plastic fiber	0%, 1%, 2%, 3%
Coarse aggregate	Plastic pellets	0%, 1%, 2%, 3% (as per sample mix requirement)

4.4 Mixing Procedure

1. Dry Mixing:
 - Cement and coarse aggregate were first mixed uniformly.
 - Shredded plastic fibers were added slowly to ensure even distribution and avoid ball formation.
2. Addition of Plastic Pellets:
 - Plastic pellets were introduced as partial replacement of coarse aggregate and mixed thoroughly.
3. Water Addition:
 - Water was added gradually while mixing to achieve a uniform concrete mix with workable consistency.
4. Manual mixing was carried out for approximately 3–4 minutes to ensure homogeneity.

5.5 Casting of Specimens

- Compressive Strength Test Specimens Cube moulds of 150 × 150 × 150 mm were used.
- Flexural/Tensile Strength Test Specimens Beam or cylindrical specimens were cast as per standard size for flexural testing. Each mix percentage consisted of 3 samples to ensure accuracy in results.

5.6 Curing Process

1. After casting, specimens were kept undisturbed for 24 hours at room temperature.
2. The samples were demoulded and placed in a water curing tank.
3. Curing was carried out for 7, 14, and 28 days to analyze strength development at different ages.

5.7 Testing of Specimens After curing, the specimens were tested for:

Test Type	Equipment Used	Test Standard	Curing Days
Compressive Strength	Compression Testing Machine (CTM)	IS 516	7, 14, 28 days
Flexural/Tensile Strength	Flexural/UTM Testing Machine	ARE 516 / ASTM standards	7, 14, 28 days

The load was applied gradually until the specimen failed and strength values were recorded.

5.8 Result Recording & Analysis

- The load at failure was noted for all samples.
- Average compressive and flexural strength values were calculated from 3 samples per mix.

- Results were analyzed to study:
 - Effect of shredded plastic on cement replacement.
 - Effect of plastic pellets on aggregate replacement.
 - Strength behavior over different curing periods.

V. RESULT AND DISCUSSION

The results and discussion align with the study's objective of enhancing permeable concrete strength using shredded plastic and plastic pellets. Findings confirm that 1% plastic replacement optimizes compressive and flexural performance, validating the concept that limited plastic integration can improve durability, sustainability, and permeability for eco-friendly pavement applications.

Replacement Of Cement by Shredded Plastic

Table 1: Compressive Strength at 7 days

Different % Mix	No of Samples	Compression Testing Reading	Compressive Strength	Average Compressive Strength
0%	1	548.12	24.36	24.17
	2	542.36	24.10	
	3	541.36	24.06	
1%	1	555.20	24.67	24.67
	2	542.35	24.15	
	3	548.12	25.20	
2%	1	390.25	17.34	17.86
	2	405.12	18.03	
	3	388.68	18.21	
3%	1	240.20	10.67	17.33
	2	231.26	10.27	
	3	260.65	11.58	

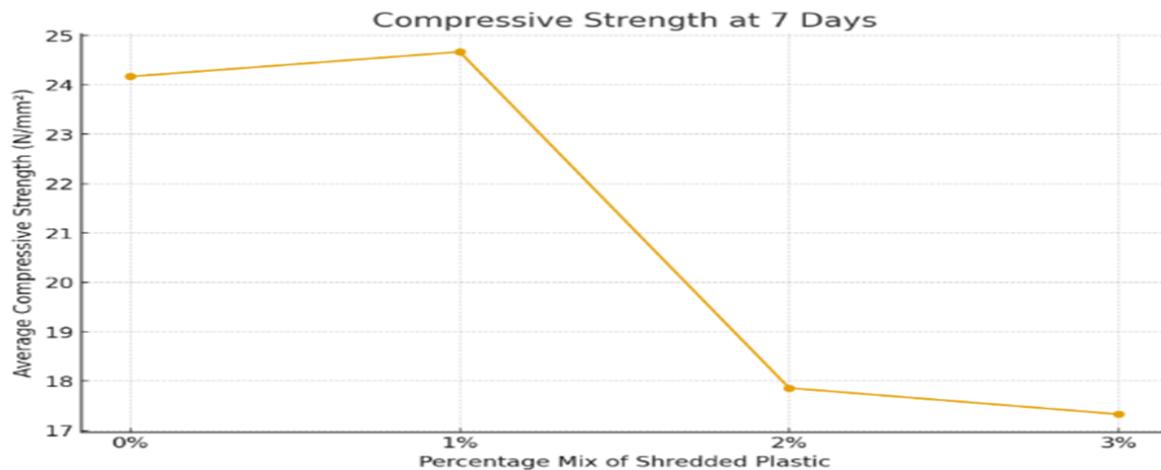


Figure 2: Average Compressive Strength of Concrete at 7 Days with Shredded Plastic Replacement

The graph illustrates the variation in average compressive strength of concrete at 7 days with different percentages of shredded plastic used as a partial replacement for cement (0%, 1%, 2%, and 3%). The results indicate that the control mix (0% plastic) achieved a strength of 24.17 N/mm². Interestingly, replacing 1% of cement with shredded plastic showed a slight increase in strength to 24.67 N/mm², suggesting that a small amount of shredded plastic may contribute to better internal bonding and

improved crack resistance due to fiber bridging. However, a significant reduction in compressive strength is observed when the replacement level increases to 2% and 3%, where strength drops to 17.86 N/mm² and 17.33 N/mm², respectively. This decline occurs because excessive plastic particles reduce the cementitious bonding area, weaken the matrix, and create voids. Therefore, 1% shredded plastic is found to be the optimum replacement level, maintaining strength while promoting waste utilization.

Table 2: Compressive Strength at 28 days

Different % Mix	No of Samples	Compression Testing Reading	Compressive Strength	Average Compressive Strength
0%	1	849.21	37.74	36.04
	2	852.14	35.64	
	3	856.41	34.74	
1%	1	855.11	38.06	37.87
	2	881.30	38.01	
	3	823.31	35.59	
2%	1	797.25	35.43	35.21
	2	745.31	33.12	
	3	781.33	35.10	
3%	1	302.31	17.43	15.76
	2	318.45	15.43	
	3	308.68	14.43	

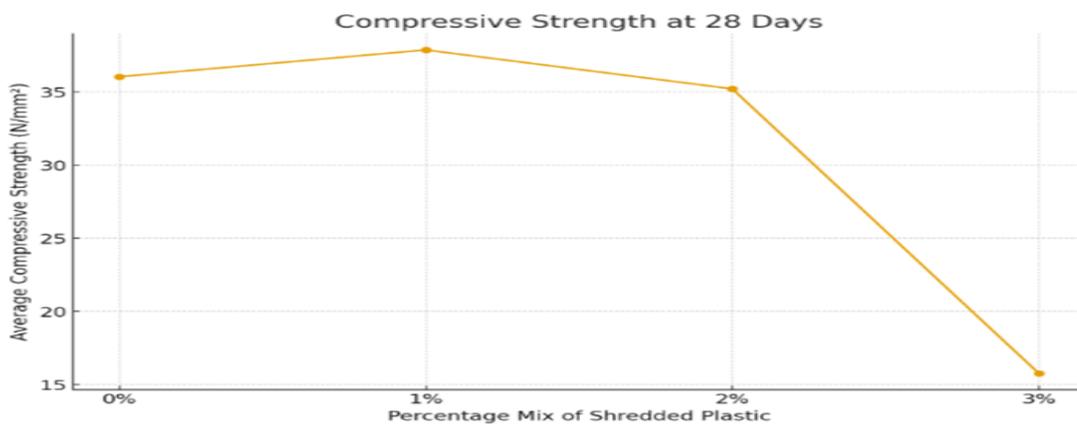


Figure 3: Average Compressive Strength of Concrete at 28 Days with Shredded Plastic Replacement

The graph illustrates the variation in 28-day compressive strength of concrete incorporating different percentages of shredded plastic (0%, 1%, 2%, and 3%) as a partial replacement for cement. The control mix (0% plastic) achieved a strength of 36.04 N/mm², which is within the expected range for

permeable concrete. When 1% shredded plastic was added, the compressive strength increased to 37.87 N/mm², making it the highest strength among all mixes. This increase indicates that a small percentage of plastic fibers helps in better crack control and contributes to internal reinforcement due to the fiber-

bridging effect. At 2% plastic replacement, the compressive strength slightly decreased to 35.21 N/mm², showing that the cementitious bonding started weakening as plastic percentage increased. The strength dropped drastically at 3% replacement to 15.76 N/mm², proving that excessive plastic reduces

the bonding area and creates weak zones within the concrete matrix. Thus, 1% shredded plastic is identified as the optimum replacement level for achieving maximum compressive strength at 28 days, balancing strength and sustainability.

Table 3: Flexural Strength at 7 days

Different % Mix	No of Samples	Flexure Testing Reading	Flexural Strength	Average Flexural Strength
0%	1	22.31	4.62	4.72
	2	22.90	4.74	
	3	23.23	4.81	
1%	1	23.35	4.84	5.12
	2	25.21	5.23	
	3	25.55	5.29	
2%	1	18.73	3.88	4.01
	2	19.86	4.12	
	3	19.34	4.03	
3%	1	15.73	3.26	3.26
	2	15.47	3.21	
	3	16.05	3.32	

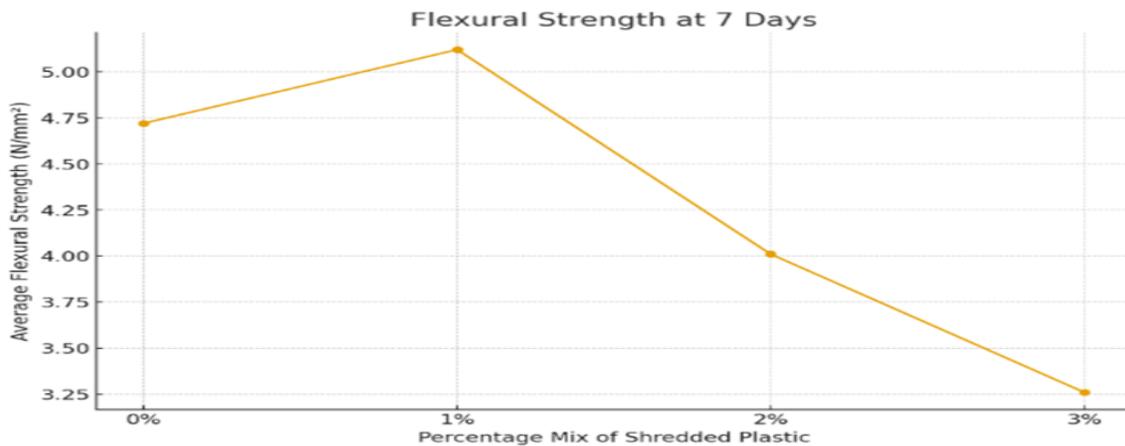


Figure 4: Average Flexural Strength of Concrete at 7 Days with Shredded Plastic Replacement

The graph shows the variation in average flexural strength of concrete at 7 days with different percentages of shredded plastic as partial cement replacement. The control mix (0%) recorded an average flexural strength of 4.72 N/mm², while the 1% plastic replacement showed a notable increase to 5.12 N/mm², indicating an improvement in the material's tensile resistance. This enhancement at 1% is attributed to the uniform distribution of fine plastic fibers that bridge micro-cracks, delaying crack

propagation and improving the ductility of the concrete. However, as the plastic percentage increased beyond 1%, the flexural strength began to decrease. At 2%, the strength reduced to 4.01 N/mm², and at 3%, it further dropped to 3.26 N/mm², reflecting a loss in interfacial bonding between plastic and cement paste. The reduction at higher levels is due to poor adhesion and increased voids. Thus, 1% shredded plastic gives the optimum flexural performance at 7 days, balancing strength and flexibility.

Table 4: Flexural Strength at 28 days

Different % Mix	No of Samples	Flexure Testing Reading	Flexural Strength	Average Flexural Strength
0%	1	30.1	6.24	6.09
	2	29.16	6.04	
	3	29.0	6.01	
1%	1	35.43	7.34	7.66
	2	37.36	7.75	
	3	38.13	7.90	
2%	1	29.45	6.11	6.61
	2	31.33	6.51	
	3	34.76	7.21	
3%	1	23.48	4.87	4.85
	2	24.68	5.12	
	3	21.98	4.56	

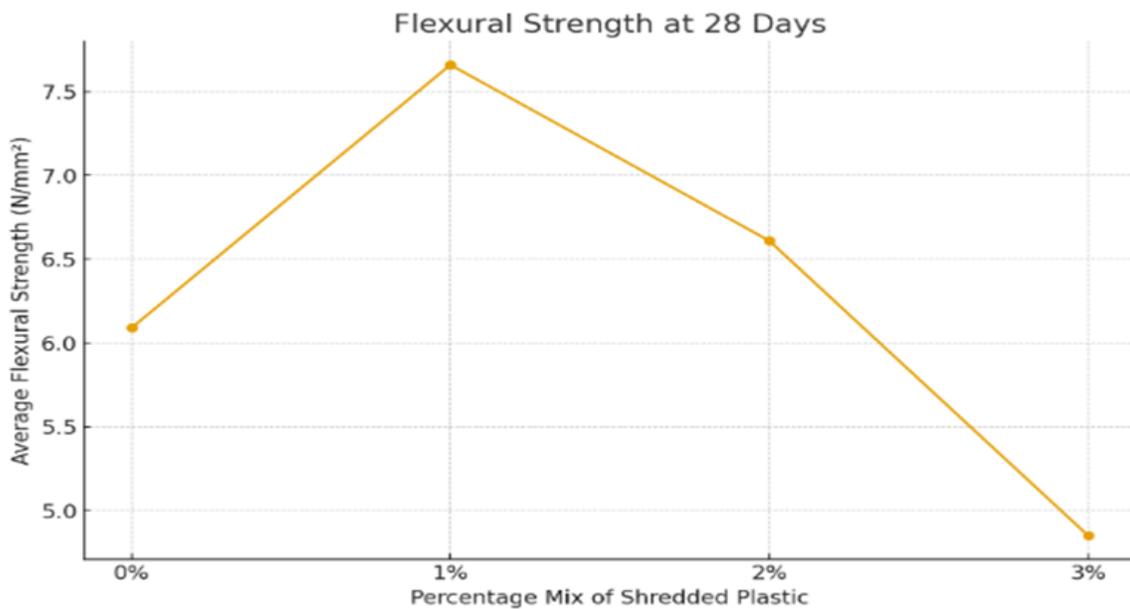


Figure 5: Average Flexural Strength of Concrete at 28 Days with Shredded Plastic Replacement

The graph illustrates the variation in 28-day flexural strength of concrete when different percentages of shredded plastic were used as a partial replacement for cement. The control mix (0%) recorded an average flexural strength of 6.09 N/mm², which increased significantly to 7.66 N/mm² at 1% plastic replacement. This indicates that a small percentage of shredded plastic fibers improves the ductility and crack resistance of concrete due to their fiber-bridging effect, which helps in transferring stress across micro-cracks. When the replacement level increased to 2%, the flexural strength decreased slightly to 6.61 N/mm²,

suggesting that higher plastic content begins to weaken the cement matrix. At 3%, the strength dropped drastically to 4.85 N/mm², showing that excess plastic reduces bonding efficiency and increases internal voids. Therefore, 1% shredded plastic is the most effective proportion for enhancing the flexural strength of concrete, achieving both improved performance and sustainable waste utilization.

Table 5: Compressive Strength – 7 Days

per.	Sample No.	Weight / Reading	Compressive Strength	Average
0%	1	547.12	17.22	16.55
	2	541.36	16.22	
	3	540.3	16.22	
1%	1	560.36	24.67	24.67
	2	555.3	24.15	
	3	562.25	25.2	
2%	1	390.25	17.36	17.86
	2	405.12	18.03	
	3	388.68	18.21	
3%	1	240.2	15.83	17.33
	2	241.26	17.34	
	3	231.26	19.24	

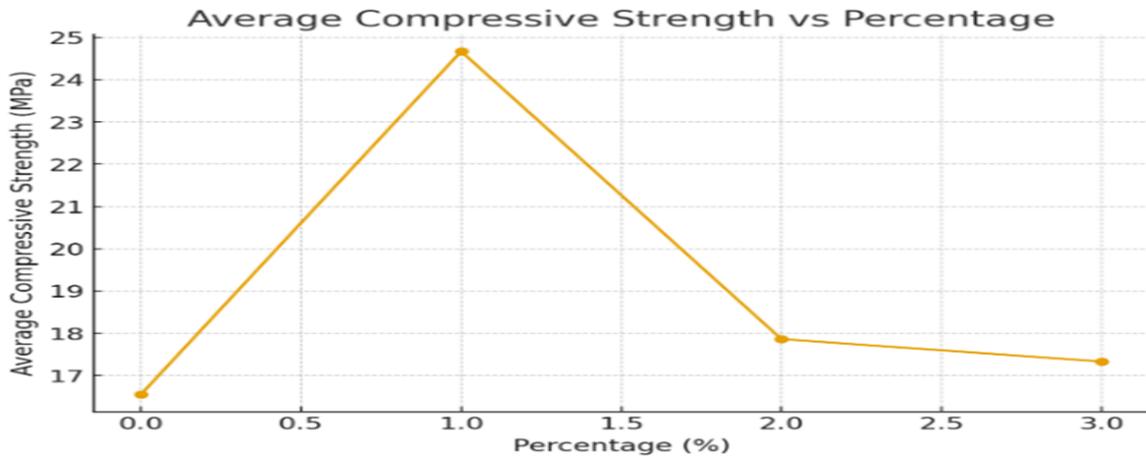


Figure 6: Compressive Strength – 7 Days

Table 6: Compressive Strength – 28 Days

per.	Sample No.	Weight / Reading	Compressive Strength	Average
0%	1	847.21	35.69	33.65
	2	852.16	34.61	
	3	856.41	30.72	
1%	1	855.11	37.66	36.02
	2	861.3	35.01	
	3	823.31	35.01	
2%	1	757.26	35.43	35.21
	2	778.65	34.32	
	3	789.33	35.87	
3%	1	818.72	14.33	15.76
	2	818.32	13.54	
	3	818.69	19.41	

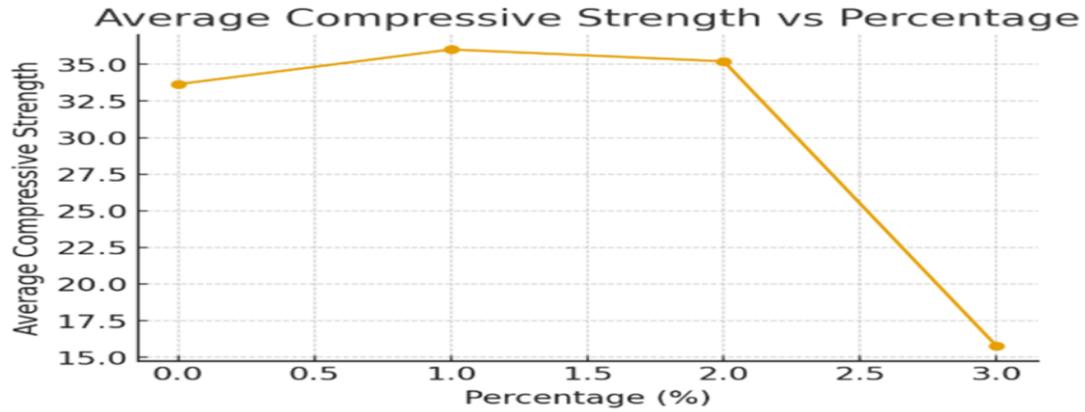


Figure 7: Compressive Strength – 7 Days

Table 7: Flexural Strength – 7 Days

per.	Sample No.	Flexural Testing Reading	Flexural Strength (MPa)	Average Flexural Strength
0%	1	24.3	5.04	5.01
	2	24.49	5.16	
	3	23.4	4.85	
1%	1	23.65	4.86	4.62
	2	27.25	5.02	
	3	19.27	3.99	
2%	1	18.73	3.88	4
	2	19.86	4.11	
	3	19.49	4.01	
3%	1	15.73	3.26	3.26
	2	15.97	3.2	
	3	16.65	3.32	

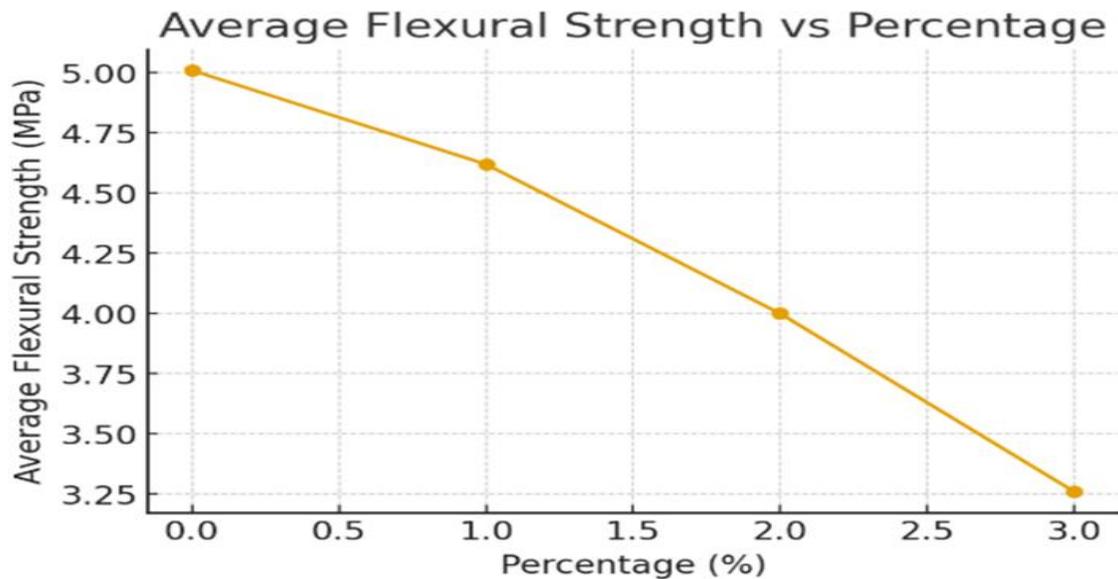


Figure 8: Compressive Strength – 7 Days

Table 8: Flexural Strength 28 Days

per.	Sample No.	Flexural Strength (3/7 Days)	Flexural Strength (28 Days)	Average Flexural Strength
0%	1	30.16	6.22	6.02
	2	28.16	5.84	
	3	29	6.01	
1%	1	38.43	7.84	7.4
	2	37.42	7.17	
	3	31.3	7.73	
2%	1	29.45	6.1	6.59
	2	31.33	6.49	
	3	39.85	7.2	
3%	1	23.48	7.86	5.04
	2	29.84	5.08	
	3	25.12	5.21	

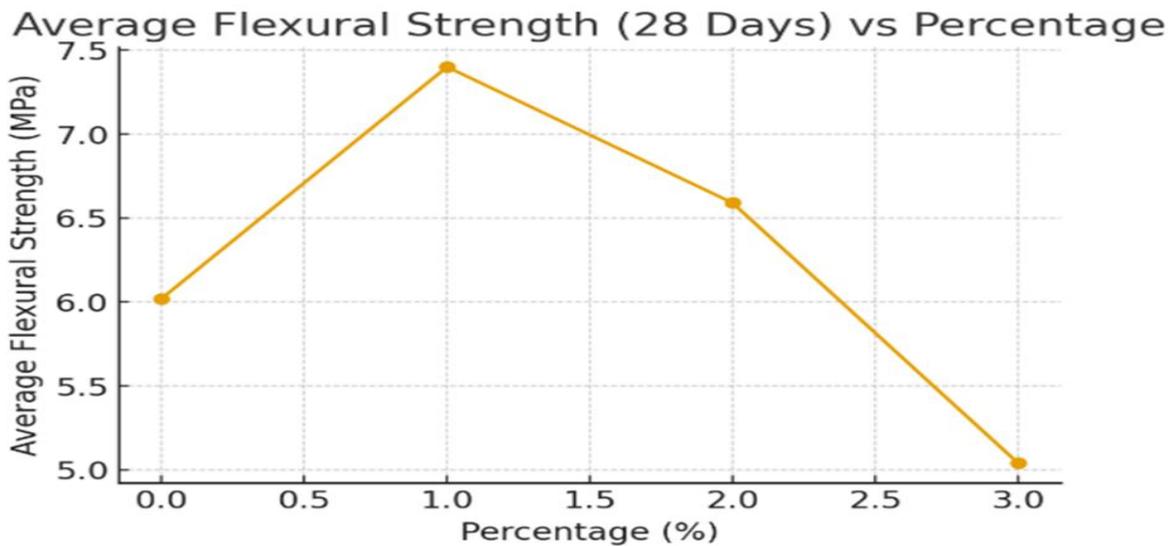


Figure 8: Compressive Strength – 28 Days

VI. CONCLUSION

The experimental investigation confirms that incorporating shredded plastic and plastic pellets into permeable concrete can significantly contribute to sustainable construction and effective waste management. Results indicate that partial replacement of cement with shredded plastic up to 1% enhances both compressive and flexural strength, attributed to the fiber-bridging effect that improves internal bonding and resists crack propagation. However, increasing the replacement beyond 2% leads to reduced strength due to poor adhesion and void formation. Similarly, plastic pellets as aggregate

replacements help maintain permeability but must be used within optimum limits to prevent weakening of the matrix. The combination of these recycled materials not only minimizes plastic pollution but also conserves natural resources used in conventional concrete. The study establishes that 1% replacement level achieves the best balance between mechanical strength and permeability, making it suitable for low-traffic pavements, parking areas, and pedestrian walkways. Overall, the research validates the feasibility of using waste plastics in permeable concrete as an eco-friendly, cost-effective, and durable alternative that supports sustainable urban development and water management systems.

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