Experimental Study on Compressive Strength of Permeable Concrete with Shredded Plastic and Plastic Pellets

Ms. Mrunali Mahesh Samshette[1], Prof. G N Shete[2]

[1] PG Student, Department of Civil Engineering, M.S. Bidve Engineering College, Latur

[2]Professor, Department of Civil Engineering, M.S. Bidve Engineering College, Latur

Abstract

This study examines the mechanical performance of permeable concrete incorporating shredded plastic fibers and plastic pellets as sustainable partial replacements for cement and coarse aggregates. The research aims to address two critical challenges: the growing environmental burden of plastic waste and the reduced mechanical strength typically associated with permeable concrete. Portland Pozzolana Cement (PPC) was partially replaced with shredded plastic at 0%, 1%, 2%, and 3%, while plastic pellets were used at similar percentages to replace coarse aggregates. Experimental tests were conducted to determine compressive and flexural strengths at 7, 14, and 28 days of curing. The results reveal that a 1% replacement level provides the highest enhancement in performance, achieving a compressive strength of 37.87 N/mm² and a flexural strength of 7.66 N/mm² at 28 days both superior to the control mix. Improvements at this level are attributed to the fiber-bridging effect, which enhances crack resistance and internal bonding. However, strength decreased significantly beyond 2% replacement due to poor adhesion and increased void formation. Overall, the findings demonstrate that limited incorporation of shredded plastic and plastic pellets can improve mechanical properties while maintaining permeability, offering an eco-efficient, resource-conserving solution suitable for low-load pavements and sustainable urban drainage systems.

Keywords: Permeable concrete, Shredded plastic, Plastic pellets, Compressive strength, Flexural strength, Sustainable construction

1. Introduction

Impermeable concrete constructions have largely replaced natural ground surfaces due to rapid urbanisation and haphazard development. This transition greatly inhibits precipitation penetration, resulting to frequent water stagnation, flash floods, and an increased demand on storm-water drainage systems. Particularly in metropolitan areas, conventional pavements contribute to falling water tables because they do not sustain groundwater recharge. Clogged drainage systems often aren't able to manage the extra runoff during monsoon seasons, which leads to environmental imbalance, traffic jams, and property damage. These difficulties highlight the pressing need for sustainable, environmentally friendly, and hydrological cycle-supporting alternative pavement materials. Permeable concrete, also referred to as pervious or porous concrete, has become a viable way to address these kinds of environmental problems. Permeable concrete, as opposed to conventional concrete, has interconnected gaps that let water flow through its structure, allowing it to seep into the ground and lowering surface runoff. Because it promotes groundwater recharge, lowers the danger of floods, and lessens reliance on man-made storm-water management infrastructure, it is essential to sustainable urban drainage systems. Permeable concrete is often used in low-traffic areas including parks, parking lots, pedestrian walkways, and low-volume roadways because of its high porosity. Due to the lack of fine particles, permeable concrete usually exhibits lesser mechanical strength than conventional concrete, despite its benefits in storm water management.

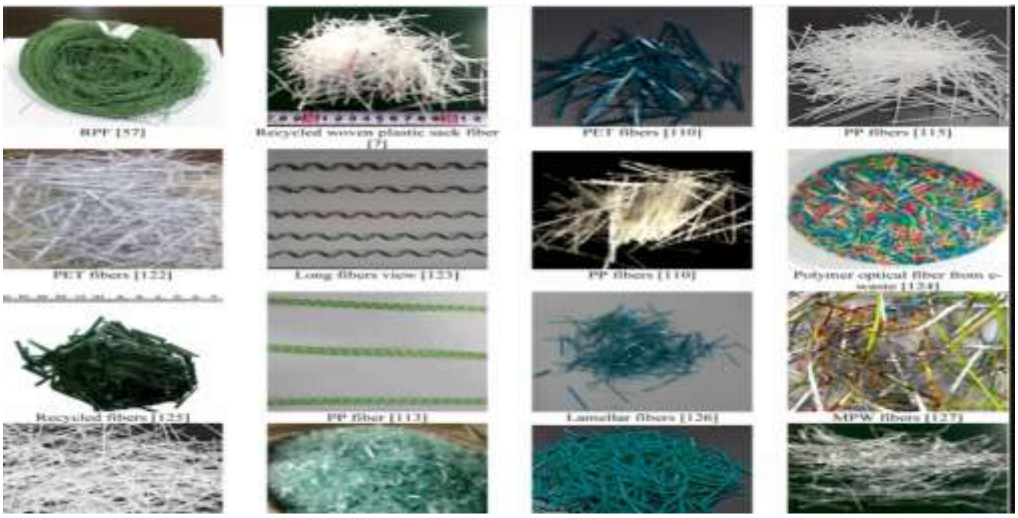

Figure 1. Different types of recycled plastic fibers used in concrete.

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*

Therefore, it is crucial to do research on enhancing its performance using novel and sustainable materials. Concurrently, the increasing production of plastic garbage has emerged as a worldwide environmental issue. Plastics are dangerous for soil, water, marine life, and human health since they are not biodegradable and may linger in the environment for hundreds of years. When plastic is disposed of by burning or landfilling, harmful compounds are released, which worsens air pollution and degrades soil. A viable strategy for achieving waste management and sustainable building objectives is the recycling of plastic waste into building materials. Incorporating plastic into concrete supports resource conservation by minimising the use of natural aggregates and reducing the amount of plastic that ends up in the environment. In this regard, plastic pellets and shreds of plastic fibre have drawn interest from researchers as possible additions and partial substitutes for conventional concrete. While plastic pellets may alter the density and permeability properties of the concrete mix when used as lightweight aggregate replacements, shredded plastic fibres, when used as a partial replacement for cement, may help enhance tensile behaviour owing to their fibrous nature. Strength may be adversely affected by an excessive use of plastic, therefore mechanical performance and sustainability must be balanced. The combined effects of using plastic pellets as a partial coarse aggregate replacement and shreds of plastic fibres as a partial cement replacement in permeable concrete are the main focus of this investigation. Determining the amended concrete's compressive strength and flexural/tensile strength at 7 and 28 days of curing is the main goal in order to experimentally assess its mechanical behaviour. The results of this study should help create ecologically friendly, lightweight, and sustainable paving materials for non-structural uses, encouraging the use of plastic waste and effective stormwater management.

2. Problem Statement

The widespread use of impermeable concrete surfaces brought on by increased urbanisation has resulted in significant stormwater runoff, decreased groundwater recharge, and frequent urban floods. Because it can let water in, permeable concrete has become a viable alternative. However, because of its high void structure and lack of fine particles, it has a poor mechanical strength, which prevents it from being widely used. A viable strategy for resource conservation and sustainable waste management is the incorporation of waste materials like shredded plastic and plastic pellets into permeable concrete. But unlike traditional cementitious and aggregate components, plastic elements often weaken the binding matrix, reduce density, and have a detrimental impact on compressive and flexural strength. Few studies have examined the combined effects of replacing aggregate with plastic pellets or cement with plastic fibres in permeable concrete, despite the fact that both have been investigated independently. Finding an appropriate composition that strikes a compromise between strength and water infiltration properties is crucial as the dual replacement may further affect porosity, permeability, and structural integrity. Determining the ideal proportion of plastic pellets and shreds that may provide satisfactory mechanical performance without sacrificing permeability is vital. By experimentally identifying a balanced, sustainable mix design for realistic non-structural pavement applications, this study seeks to close this gap.

3. 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.

4. Literature Review

Pervious or porous concrete, also referred to as permeable concrete, has drawn a lot of interest as a sustainable pavement material that may control surface runoff and encourage groundwater recharge. The use of recycled plastic materials to improve sustainability and lessen environmental pollution has been the subject of recent research. In their experimental investigation of the compressive strength of permeable concrete containing plastic pellets and shredded plastic fibre, Vijayakumar et al. (2022) found that although small amounts of plastic enhanced water penetration, they also decreased compressive strength over an ideal threshold. Similar patterns were seen by Supit and Priyono (2022) when they used recycled PET plastic waste as coarse aggregate in pervious concrete, observing better permeability but decreased density and strength. According to Ramesh (2023), using recycled plastic increased workability but required precise proportioning to preserve compressive strength. Chemically treated or mixed plastic fibres improve concrete ductility and decrease brittleness, as shown by Oddo et al. (2024) and El-Nadoury et al. (2022). Shredded PET might safely replace a portion of coarse aggregates without significantly reducing strength at lower replacement levels, according to Farah et al. (2024).

The mechanical and durability characteristics of permeable concrete when combined with plastic-based components have been emphasised in a number of different research. Cole et al. (2020) investigated the use of recycled rubber aggregates and waste plastic together, finding satisfactory compressive strength and improved permeability for light-duty pavements. When Rahul et al. (2024) examined the use of nano-silica and shredded plastics in pervious concrete, they found that improved particle packing increased the concrete's strength. E-waste and polypropylene-based plastic substitutes enhance sustainability while preserving structural integrity under mild loads, as shown by Dhanalakshmi et al. (2025) and Islam (2022). Further studies by Supit et al. (2022) and Hande et al. (2023) verified that the creation of eco-efficient concrete mixes is supported, waste recycling is encouraged, and the environmental effect is lessened when plastics are replaced with regulated alternatives. According to previous research, an ideal replacement level—usually between 1% and 2% plastic content—offers the optimum compromise between permeability and compressive strength, making it appropriate for parking lots, pedestrian walkways, and low-load pavements.

5. Methodology

The methodology adopted in this study involved systematic material selection, mix preparation, casting, curing, and mechanical testing to evaluate the performance of permeable concrete incorporating shredded plastic and plastic pellets. Portland Pozzolana Cement (PPC), shredded plastic fibers, plastic pellets, coarse aggregates (6.3–11.3 mm), and clean potable water were used. Shredded plastic served as a partial replacement for cement at 0%, 1%, 2%, and 3%, while plastic pellets partially replaced coarse aggregates at the same percentages.

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	IS 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.

6. 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	

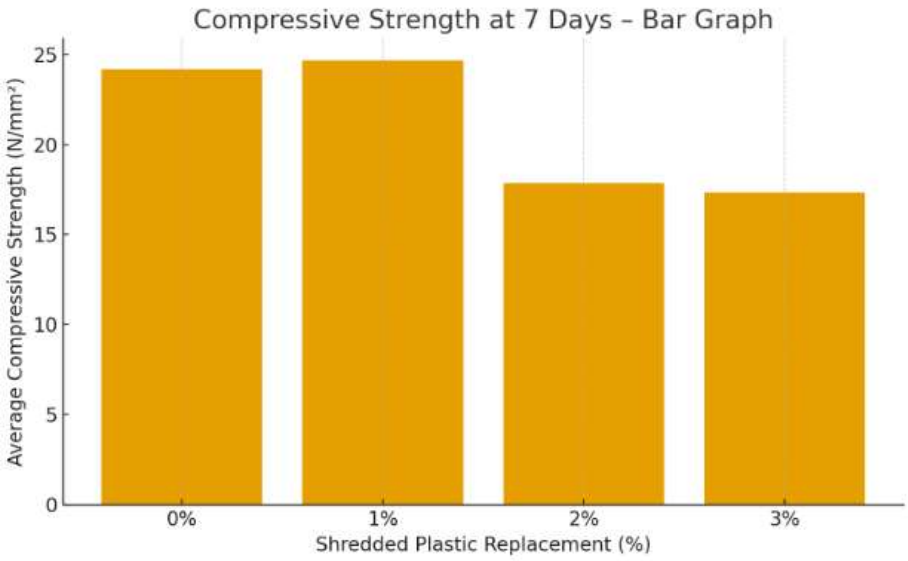

Figure 2: Average Compressive Strength of Concrete at 7 Days with Shredded Plastic Replacement

The graph illustrates the variation in compressive strength of permeable concrete at 7 days with different percentages of shredded plastic replacing cement. The control mix (0%) recorded a strength of 24.17 N/mm², which increased slightly to 24.67 N/mm² at 1% replacement, indicating that a small amount of shredded plastic can enhance early-age strength due to better crack-bridging and internal reinforcement. However, a sharp decline occurred at 2% and 3% replacement levels, where strengths dropped to 17.86 N/mm² and 17.33 N/mm² respectively. This reduction is attributed to poor bonding between plastic particles and cement paste, leading to void formation and weakened matrix integrity. Overall, 1% plastic addition provides optimum 7-day strength performance.

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	

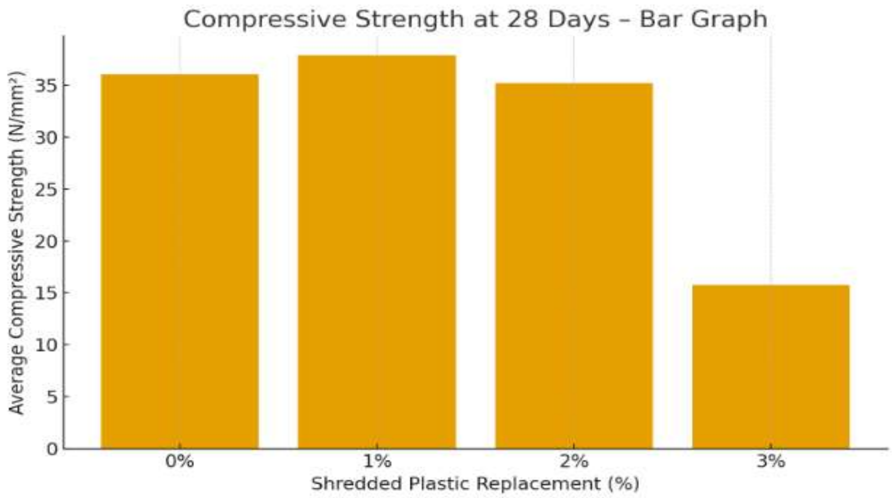

Figure 3: Average Compressive Strength of Concrete at 28 Days with Shredded Plastic Replacement

The graph presents the 28-day compressive strength of permeable concrete with varying percentages of shredded plastic used as a partial cement replacement. The control mix (0%) achieved a strength of 36.04 N/mm², while the 1% replacement showed the highest value at 37.87 N/mm², indicating improved long-term bonding and crack resistance due to the fiber-bridging action of shredded plastic. At 2% replacement, the strength slightly decreased to 35.21 N/mm², suggesting that higher plastic content begins to reduce cementitious bonding. A drastic drop occurred at 3%, where the compressive strength fell sharply to 15.76 N/mm² because excess plastic creates weak zones and voids within the matrix. Overall, 1% replacement remains the optimal proportion for maximizing 28-day compressive strength while promoting 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	

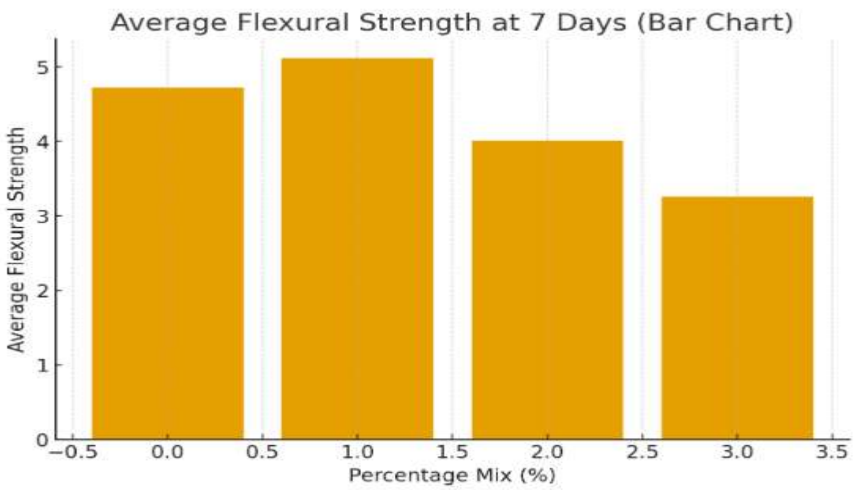

Figure 4: Average Flexural Strength of Concrete at 7 Days with Shredded Plastic Replacement

The graph illustrates the variation in average flexural strength at 7 days for concrete mixes containing different percentage levels of additives (0%, 1%, 2%, and 3%). The results show that the 1% mix achieves the highest flexural strength (5.12 MPa), indicating that this proportion provides optimal enhancement in early-age strength. At 0%, the strength is moderate (4.72 MPa), suggesting a baseline performance without additives. However, a noticeable decrease in flexural strength occurs at 2% (4.01 MPa) and further at 3% (3.26 MPa), indicating that higher additive proportions negatively affect the concrete's performance. Overall, the interpretation suggests that 1% additive improves strength, while excessive addition weakens the material's structural behavior.

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	

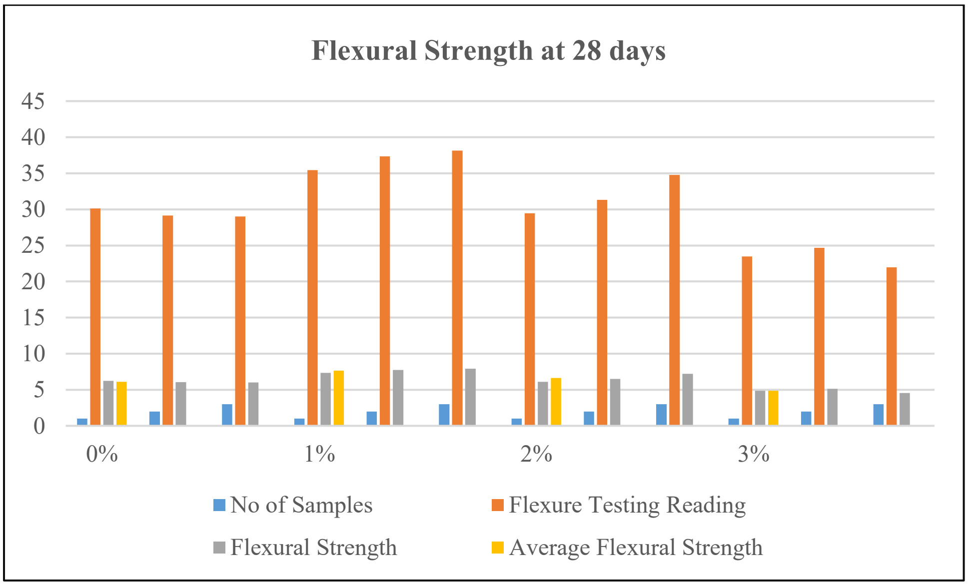

Figure 5: Average Flexural Strength of Concrete at 28 Days with Shredded Plastic Replacement

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	

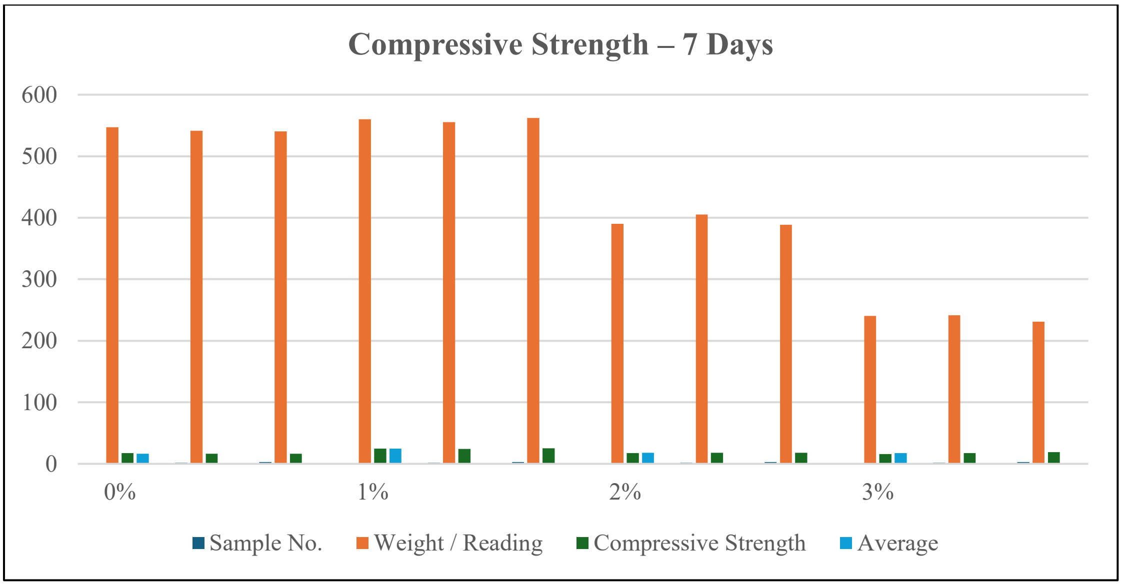

Figure 6: Compressive Strength – 7 Days

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	

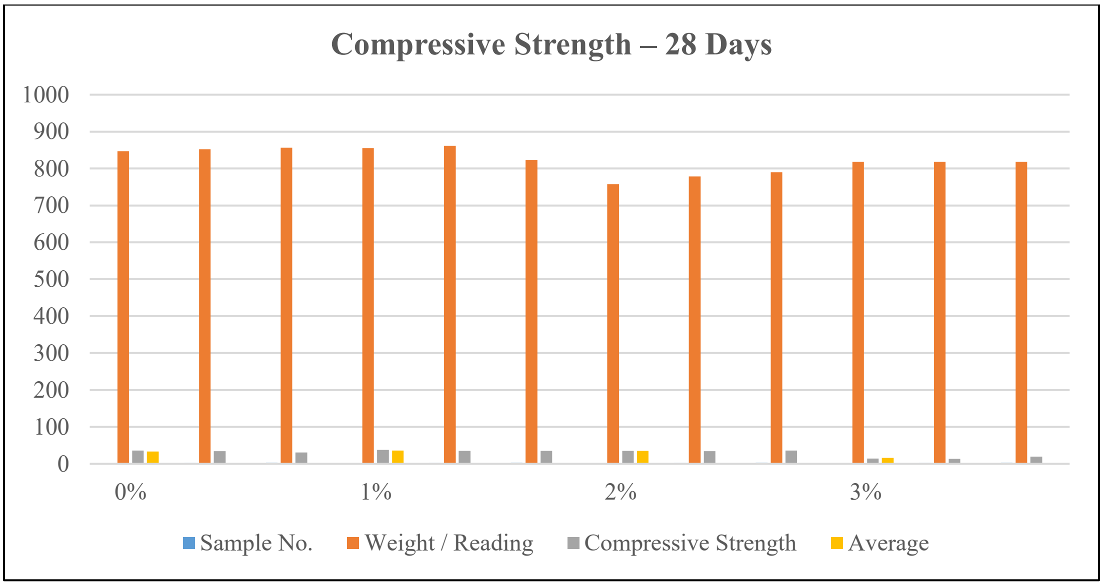

Figure 7: Compressive Strength – 28 Days

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	

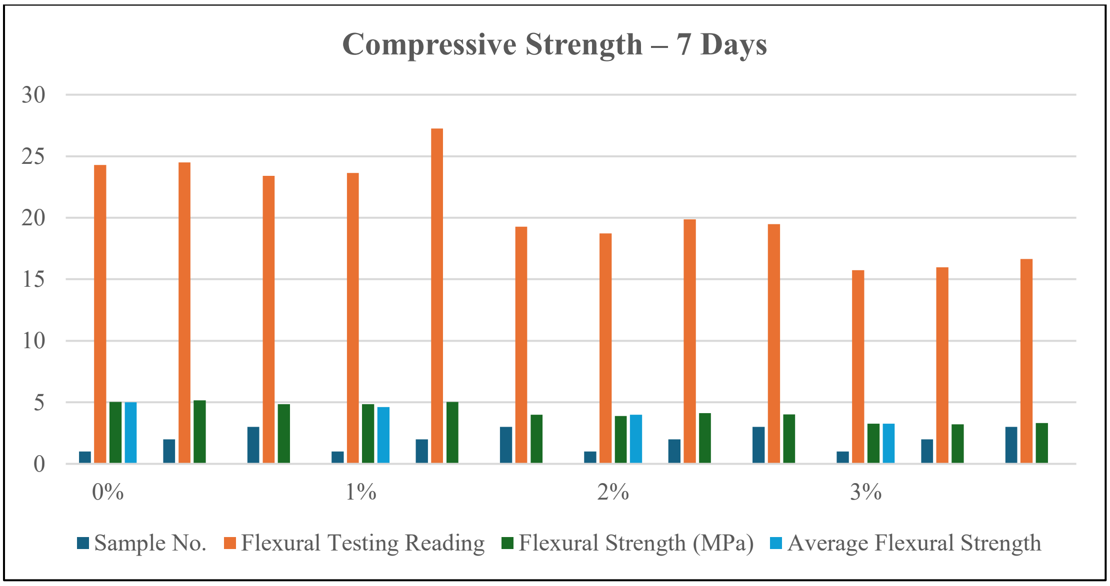

Figure 8: Compressive Strength – 7 Days

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	

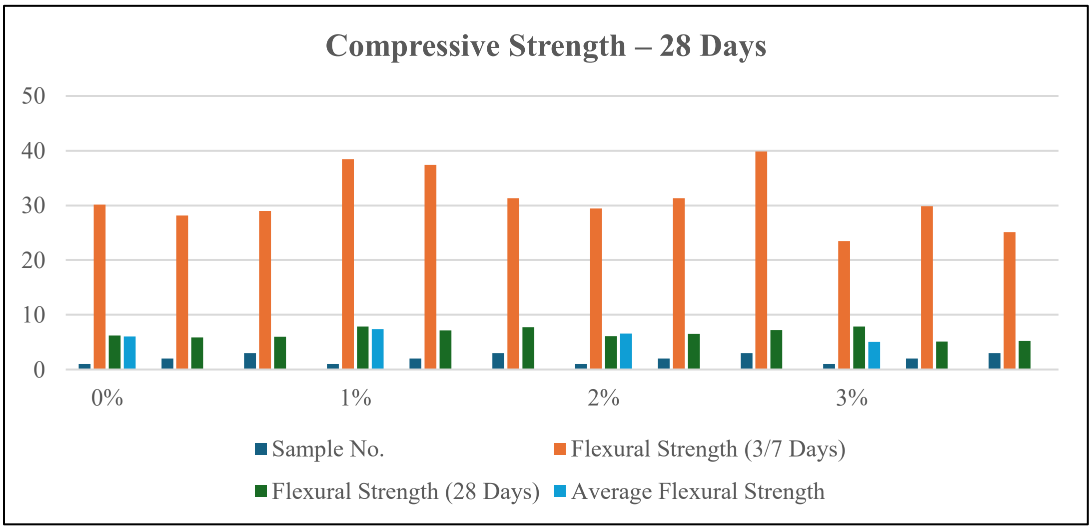

Figure 8: Compressive Strength – 28 Days

Conclusion

The experimental study demonstrates that incorporating shredded plastic and plastic pellets into permeable concrete offers a promising and sustainable alternative to traditional pavement materials. The results confirm that limited plastic additions, particularly at a 1% replacement level, significantly enhance both compressive and flexural strengths at 7 and 28 days. This improvement is primarily attributed to the fiber-bridging mechanism of shredded plastic, which helps control crack propagation and improves internal bonding within the concrete matrix. However, increasing plastic content beyond 2% leads to a noticeable decline in strength due to weak adhesion, increased porosity, and the formation of voids that reduce structural integrity. The inclusion of plastic pellets further helps maintain permeability, making the concrete suitable for water-sensitive applications, though their use must also be controlled to prevent strength reduction. Overall, the study establishes that a 1% replacement of cement with shredded plastic and a corresponding limited use of plastic pellets provide an optimal balance between strength, permeability, and sustainability. This optimized mix is ideal for low-traffic pavements, walkways, parking areas, and storm-water management systems. The research confirms the environmental and structural feasibility of utilizing waste plastics in permeable concrete, contributing meaningfully to sustainable construction and effective plastic waste recycling.

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