

# An Eco-Smart Approach: Pervious Concrete Blocks with Partial Replacement by Plastic Aggregates

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**Abstract—** The paper addresses the dual environmental challenges of urban waterlogging and the accumulation of non-biodegradable plastic waste. This study investigates the feasibility of developing sustainable pervious concrete by partially replacing natural coarse aggregates with waste plastic aggregates at varying levels of 5%, 10%, 15%, and 20%. Experimental specimens, cast as 150 mm x 150 mm x 150 mm cubes using 10 mm aggregates and a water-cement ratio of 0.35, were subjected to rigorous testing for compressive strength, permeability, and workability after 14 days of curing. The results indicate that while increasing the plastic content leads to a reduction in compressive strength and a slight decrease in permeability due to modifications to the void structure, a replacement level of up to 10% offers an optimum balance, maintaining sufficient structural integrity for light-load applications. Ultimately, this research demonstrates that integrating plastic waste into pervious concrete not only aids in groundwater recharge by effectively reducing surface runoff but also provides a viable waste management solution for sustainable infrastructure development.

**Keywords—** Pervious Concrete, Plastic Aggregates, Compressive Strength, Permeability, Sustainable Construction, Groundwater Recharge.

## I. INTRODUCTION

**Environmental Context and Problem Statement** Rapid urbanization has led to the extensive use of conventional concrete, which is inherently dense and impervious. This impermeability prevents the natural infiltration of rainwater, leading to severe urban issues such as waterlogging, increased surface runoff, and a significant reduction in groundwater recharge<sup>2222</sup>. To mitigate these challenges, pervious concrete has emerged as a viable solution. Characterized by its interconnected voids, pervious concrete allows water to pass directly through its structure and infiltrate the ground, making it an ideal material for flatwork applications such as pavements, parking lots, and walkways<sup>3333</sup>. Simultaneously, the accumulation of non-biodegradable plastic waste has become a critical global environmental issue<sup>4444</sup>. Integrating waste plastic into construction materials offers a promising pathway to reduce environmental pollution while conserving scarce natural resources.

### Methodology and Experimental Approach

This study specifically focuses on the development of pervious concrete by utilizing waste plastic aggregates as a partial replacement for natural coarse aggregates. The experimental program involves the preparation of concrete mixes where natural aggregates are replaced with plastic aggregates at varying levels of 5%, 10%, 15%, and 20%<sup>7</sup>. To evaluate the

performance of these mixes, standard concrete cubes of size 150 mm x 150 mm x 150 mm were cast and cured<sup>88</sup>. The research methodology includes a comprehensive analysis of key engineering properties, specifically testing the specimens for compressive strength, workability, and permeability to understand how the inclusion of plastic affects the concrete's structural and hydraulic performance.

**Objectives and Sustainable Impact** The primary aim of this project is to promote sustainable and eco-friendly construction practices by combining effective plastic waste management with improved water conservation strategies<sup>10</sup>. By successfully incorporating waste plastic, the study aims to design a material that is not only lightweight and permeable but also environmentally responsible. The anticipated results intend to demonstrate that pervious concrete with plastic aggregates can serve as a cost-effective solution for future infrastructure, balancing the need for structural integrity in light-load applications with the imperative to reduce the ecological footprint of the construction industry.

## II. PROBLEM STATEMENT

Rapid urbanization and infrastructure development have led to the extensive use of conventional concrete, which is inherently dense and impervious. This impermeability obstructs the natural infiltration of rainwater into the ground, resulting in

severe urban issues such as frequent waterlogging, increased surface runoff, and the depletion of groundwater tables.

Simultaneously, the global accumulation of non-biodegradable plastic waste presents a critical environmental crisis. The disposal of waste plastic in landfills not only occupies vast land areas but also poses long-term ecological threats due to its persistence in the environment. Furthermore, the construction industry consumes massive quantities of natural aggregates, leading to the depletion of finite natural resources.

There is an urgent need to address these interconnected challenges by developing sustainable construction materials that mitigate stormwater runoff while utilizing waste materials. However, a significant technical challenge remains: integrating lightweight waste plastic into pervious concrete often compromises mechanical strength. Therefore, this study addresses the problem of finding an optimum mix design that successfully utilizes waste plastic as a partial replacement for coarse aggregates to create an eco-friendly pervious concrete, balancing the conflicting requirements of adequate compressive strength and effective permeability for light-load applications

### III. LITERATURE REVIEW

Pervious concrete is widely recognized for its ability to reduce stormwater runoff and promote groundwater recharge. Alshareedah and Nassiri (2021) reviewed the physical and mechanical properties of pervious concrete, emphasizing that its interconnected voids, while beneficial for permeability, significantly reduce mechanical strength compared to conventional concrete. They noted that aggregate size, shape, and texture are critical factors influencing this balance, and approximate mix designs are essential to achieve porosity between 15% and 35%. Supporting this, Shah and Pitroda (2014) investigated the hardened properties of pervious concrete. They concluded that using smaller gravel sizes (9.375 mm) and lower water-cement ratios improves the compressive strength, making the material suitable for non-structural applications such as pavements and parking lots.

The global crisis of non-biodegradable plastic waste has prompted an investigation into its use as a construction material. Siddique, Khatib, and Kaur (2008) provided a comprehensive review of utilizing recycled plastics, such as polyethylene and polypropylene, in concrete. They reported that substituting natural aggregates with plastic reduces the density and compressive strength of the mix, but enhances its lightweight characteristics, toughness, and impact resistance. Mohamedsalih et al. (2024) further validated these findings,

highlighting that limited substitution (up to 2.5–5%) yields eco-friendly and workable concrete, whereas higher replacement levels significantly reduce mechanical strength.

Several researchers have determined optimum replacement levels for plastic aggregates. Ismail and Al-Hashmi (2008) focused on replacing sand with waste plastic, conducting over 250 tests. Their results indicated that a 10–15% replacement level offers the best balance between strength and workability, with plastic particles helping to arrest the propagation of microcracks.

Regarding the replacement of coarse aggregate, Lopez et al. (2019) experimented with recycled High-Density Polyethylene (HDPE) in pervious concrete. They observed that increasing the HDPE content significantly improved permeability but reduced compressive strength due to weaker bonding between the plastic and the cement paste. They concluded that a 10% replacement level is optimal for maintaining structural integrity in pavement applications. Similarly, Manjunath (2016) investigated the use of E-plastic waste, finding that a 10% replacement provided strength comparable to that of conventional concrete, while replacements exceeding 20% resulted in a notable reduction in strength.

More recent studies have explored broader applications. Tota-Maharaj et al. (2022) emphasized the use of waste plastics in low-carbon concrete pavements, recommending a 5–10% substitution to maintain durability. Pushing the boundaries further, Sathvik S. et al. (2024) explored the use of 100% plastic replacement for lightweight applications, achieving a concrete that was 12% lighter while maintaining adequate strength for non-structural purposes, thereby demonstrating the potential for significant ecological impact reduction.

### IV. RESEARCH GAP

The research gap addressed by this project lies in the specific application and mix design of plastic aggregates in pervious concrete. While previous studies, such as those by Ismail and Al-Hashmi (2008) and Tota-Maharaj et al. (2022), have extensively explored the use of waste plastic as a replacement for fine aggregates (sand) in conventional concrete, there is limited research focused on replacing coarse aggregates in a "no-fines" pervious concrete mix. Furthermore, existing research on coarse aggregate replacement, such as the study by Lopez et al. (2019), often relies on chemical admixtures, like acrylic polymers, to enhance bonding. This project fills a critical gap by evaluating the mechanical performance of plastic aggregates in a simplified, low-cost mix (water-cement ratio of 0.35) that does not require the use of plasticizers or

bonding agents. Additionally, while some recent studies have advocated for 100% plastic replacement in lightweight applications, this research focuses on optimizing partial replacement levels (5% to 20%) to identify a precise balance that retains sufficient structural integrity for light-load pavements while maximizing permeability and waste utilization.

## V. METHODOLOGY

### Material Collection

- Cement: OPC 53 grade conforming to IS 12269:20132.
- Coarse Aggregate: Natural crushed stone of 10 mm size, clean and angular.
- Plastic Aggregate: Waste plastic aggregates processed to a 10 mm size, used as a partial replacement for coarse aggregates44.
- Water: Potable water used for both mixing and curing.

### Mix Design & Preparation

- A standard mix design for M20 grade concrete was adapted6.
- The Water-Cement Ratio was fixed at 0.35 for all mixes.
- Variables: Plastic aggregates replaced natural coarse aggregates at 0% (Control), 5%, 10%, 15%, and 20% levels by volume8888.
- No plasticizers were used; materials were dry mixed first, followed by water addition.

### Casting and Curing

- Specimens were cast in \$150 mm \times 150 mm \times 150 mm\$ steel cube moulds10.
- The mix was placed in two layers and lightly tamped with a rod (no vibration) to preserve the porous structure 11.
- After 24 hours, specimens were demoulded and subjected to water curing for 7, 14, and 28 days using wet gunny bags 12.

### Testing

- Material Tests: Specific gravity, sieve analysis, aggregate impact value, and crushing strength 13.
- Specimen Tests: Compressive strength (using CTM) and Permeability (Constant Head Method) 14

## VI. RESULTS AND DISCUSSION

### 1. Aggregate Properties

Tests on the aggregates confirmed their suitability for construction:

- Aggregate Impact Value (AIV): The mean AIV was 10.62%, which is well below the 30% limit for wearing surfaces, indicating the aggregates are tough.
- Aggregate Crushing Value (ACV): The ACV was 19.51%, indicating sufficient strength for structural use (below the 30% limit).

### 2. Compressive Strength (14 Days)

The compressive strength test results indicate a clear trend where strength decreases as the percentage of plastic replacement increases.

Table 1. Compressive Strength

Plastic Replacement (%)	Peak Load (kN)	Compressive Strength (MPa)
0% (Control)	152.3	6.76
5%	94.2	4.19
10%	97.4	4.33

The strength dropped from 6.76 MPa (Control) to roughly 4.19–4.33 MPa with the inclusion of plastic. While this is a reduction, the strength remains acceptable for light-load applications, such as walkways and parking lots.

### 3. Permeability

The permeability was tested using the constant head method. The results show that permeability decreases as plastic content increases.

Table 2. Permeability

Plastic Replacement (%)	Volume (m3)	Time (s)	Permeability Coefficient (k) (m/s)
0%	0.0005	30	$5.56 \times 10^{-4}$
5%	0.0004	30	$4.44 \times 10^{-4}$
10%	0.0003	30	$3.33 \times 10^{-4}$

## VII. CONCLUSIONS

**Feasibility:** The project successfully demonstrates that waste plastic can be utilized as a partial replacement for coarse aggregates in pervious concrete.

**Optimum Replacement:** A replacement level of up to 10% is identified as the optimal replacement level. At this level, the concrete maintains a balance, exhibiting acceptable

compressive strength for non-structural use while not significantly compromising its drainage capability.

Performance Trade-off: Increasing plastic content leads to a decrease in both compressive strength and permeability. The reduction in strength limits the application to light-load structures, such as eco-pavements and pathways.

Sustainability: This "Eco-Smart" approach offers a dual benefit: it provides a viable disposal method for non-biodegradable plastic waste and creates a material that aids in groundwater recharge and stormwater management.

## REFERENCES

1. Vachasiddha, L. P., Tandon, S. A., & Kumar, R. (2024). Recycling wastes to develop permeable blocks. *Indian Journal of Engineering & Materials Sciences*, 31(6), 773–782.
2. Yang, Z., et al. (2020). Development of permeable bricks using ceramic waste, fly ash, and clay. *Journal of Cleaner Production*, 254, 120167
3. Liu, Y., et al. (2016). Lightweight geopolymer blocks from fly ash for wastewater reuse. *Materials Letters*, 185, 370–375.
4. Nishigaki, M. (1997). Recycling bottom ash slag and ceramic gravel for permeable bricks. *Studies in Environmental Science*, 71(C), 31–35.
5. Lin, C. F., et al. (2006). Permeable bricks from bottom ash and sludge: A sustainable approach. *Waste Management*, 26(9), 970–975.
6. Wu, M. H., et al. (2016). Performance of permeable concrete using recycled aggregates. *Construction and Building Materials*, 111, 618–625.
7. Zong, L., et al. (2014). Recycled aggregate permeable concrete for pavement applications. *Journal of Cleaner Production*, 70, 175–182.
8. Monrose, J., et al. (2020). Permeable pavement systems incorporating recycled plastics. *International Journal of Pavement Engineering*, 21(14), 1823–1835.
9. Rahman, M. A., et al. (2015). Utilization of waste plastic in pervious concrete blocks. *Journal of Cleaner Production*, 90, 183–191.
10. Toghroli, A., et al. (2020). Evaluation of plastic waste in construction materials. *Construction and Building Materials*, 252, 119–126.