Development of Permeable Concrete Blocks Using Recycled Plastic and Waste Concrete Aggregates

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***Abstract*—Urbanization and rapid infrastructure development have significantly altered natural hydrological cycles by increasing impervious surfaces, reducing infiltration, and escalating flood risks. Conventional concrete pavements hinder natural water percolation, leading to surface runoff and groundwater depletion. Permeable concrete presents an eco-sustainable alternative that combines strength, durability, and high porosity, enabling stormwater infiltration. This study focuses on developing permeable concrete blocks utilizing recycled plastic waste and waste concrete aggregates as partial replacements for natural coarse aggregates. The project explores the mechanical, physical, and hydraulic properties of the designed mixes to determine an optimal proportion that ensures sufficient compressive strength and permeability. The research also addresses waste management challenges, contributing to circular economy principles, low-carbon construction, and green infrastructure. The expected results will demonstrate that up to 20–25% replacement of coarse aggregates by recycled plastic and waste concrete can produce functional permeable blocks suitable for pavements and walkways, reducing environmental impact and promoting sustainable construction practices.**

I. INTRODUCTION

Urban growth and population expansion have resulted in increased construction activities, thereby generating a large quantity of construction and demolition (C&D) waste, including concrete, bricks, and metals. Simultaneously, the global accumulation of plastic waste, particularly single-use plastic, has reached alarming levels, with only 9–12% effectively recycled. In conventional pavements, impervious surfaces prevent infiltration, leading to surface waterlogging, flash floods, and reduced groundwater recharge. In addition, impermeable pavements exacerbate urban heat island (UHI) effects due to higher surface temperatures.

Permeable pavements, also known as pervious or porous pavements, allow water to infiltrate through interconnected voids, storing and gradually releasing it into the sub-base or groundwater. The system generally consists of three layers: paver surface, sub-base, and subgrade, each designed for structural support and infiltration performance.

The use of recycled plastic as a partial coarse aggregate not only minimizes plastic waste but also improves concrete’s ductility and reduces self-weight. Similarly, recycled concrete aggregates (RCA) from demolished structures can replace natural aggregates, reducing environmental degradation due to quarrying. By integrating these wastes, permeable concrete becomes a multi-beneficial material—reducing pollution, conserving resources, and enabling sustainable stormwater management.

II. LITERATURE REVIEW

1.Bhogayata & Shah (2019) proved that reusing PET plastic and RCA not only achieves desirable strength and infiltration rates but also helps in reducing landfill waste and conserving natural aggregates.
Similarly, Al-Gharbawi et al.

2. (2021) demonstrated that the optimized mix design (10% PET, 100% RCA) enhances water permeability and supports urban stormwater management.
Overall, both works highlight that integrating construction and plastic waste into permeable pavements promotes sustainable infrastructure development and aligns with green building practices.

3. Gupta et al. (2022) found that using 50% RCA and 5% PET provided an ideal balance between strength and permeability, enhancing stormwater management potential. Al-Nini et al.

4. (2023) used HDPE plastic and RCA, achieving lightweight, highly permeable concrete suitable for pedestrian pavements and SUDS applications.
Together, these studies confirm that combining recycled aggregates and plastic waste can effectively reduce environmental impact while maintaining adequate structural and hydraulic performance for non-structural infrastructure.

5. Manan et al. (2021) found that a mix with 50% RCA and 5% PET achieved a good balance between strength (15.5 MPa) and permeability (0.85 cm/s), showing practical potential for sustainable paving.
Singh et al.

6. (2021) explored mechanical and microstructural properties, revealing that although plastic slightly weakens the bond between cement and aggregates, mixes like 60% RCA and 15% PET still perform well for light-traffic pavements.

7. Gupta et al. (2020) utilized LDPE strips and RCA, achieving 12 MPa strength and high permeability, making the mix ideal for car parks and footpaths while solving flimsy plastic disposal issues.

8. Faiz et al. (2022) used polypropylene (PP) fibers with 100% RCA, which improved flexural and tensile strength and maintained excellent permeability (>0.9 cm/s), enhancing durability for permeable pavements.

9. Listi et al. (2020) introduced E-waste plastic with RCA, producing lightweight, highly permeable (1.2 cm/s) blocks suitable for gardens, rooftops, and pedestrian areas, effectively addressing dual waste streams. Al-Gharbawi et al.

10. (2022) optimized permeable concrete paving blocks (PCPBs) using 100% RCA and 15% PET, achieving 18 MPa strength and 0.5 cm/s permeability, meeting standards for light-vehicle pavements.
Together, these studies confirm that combining E-waste or PET with RCA enhances sustainability and functionality in urban construction materials.

11. Patel, V., & Mehta, R. (2020). Journal of Environmental Engineering and Science, L.D. College of Engineering, Ahmedabad, India.
Used shredded LDPE plastic waste (8%) in permeable paver blocks, achieving 16 MPa strength and 0.9 cm/s permeability, showing good drainage and flexibility.

12. Khan, S., et al. (2021). Materials Today: Proceedings, Aligarh Muslim University, India.
Added PET bottle waste (5–15%) to paver blocks; 10% PET gave the best results with 18 MPa strength and 0.7 cm/s permeability, suitable for green pavements.

13. Dutta, A., & Basu, P. (2019). International Journal of Civil and Environmental Engineering, Jadavpur University, Kolkata.
Used PP plastic chips (7%) in interlocking blocks, achieving 15 MPa strength and 0.75 cm/s permeability, improving durability and reducing water absorption.

14. Reddy, P. R., et al. (2022). Construction and Building Materials, NIT Warangal, India.
Used HDPE flakes (10%) as fine aggregate replacement, resulting in 17.2 MPa strength and 1.0 cm/s permeability, suitable for stormwater drainage.

15. Kumar, A., & Sinha, M. (2023). Sustainability in Infrastructure Engineering, IIT Delhi, India.
Combined C&D waste with PET flakes, achieving 19 MPa strength and 0.65 cm/s permeability, promoting eco-friendly and sustainable pavements.

III METHODOLOGY

3.1 Materials
Cement: Ordinary Portland Cement (OPC 43 Grade).
Coarse Aggregates: Natural crushed stone (10–20 mm) and recycled concrete aggregates (RCA).
Recycled Plastic: Shredded HDPE or PET particles (10–15 mm).
Water: Potable water conforming to IS 456:2000.
Admixtures (if needed): Superplasticizers to maintain workability.

3.2 Mix Proportions

Mix ID	Plastic Replacement (%)	RCA Replacement (%)	Cement: Aggregate Ratio	Target Voids (%)
M1	0	0	01:04	15
M2	10	20	01:04	18
M3	20	30	01:04	20
M4	30	40	01:04	22

Table No 1

3.3 Casting and Curing

Specimens (150×150×150 mm) cast for compressive strength and cylindrical samples for permeability tests. Curing in water for 28 days at room temperature.

Testing performed as per IS 15658:2006 and ASTM C1701 for permeability.

3.4 Tests Conducted

1.Compressive strength test on block

Purpose:To determine the load-carrying capacity of the permeable concrete block and evaluate its suitability for pavement applications. It measures the ability of the block to withstand axial loads without failure.

Apparatus:

- •Compression Testing Machine (CTM)
- •Cube moulds (150 × 150 × 150 mm)
- •Tamping rod and steel float

Procedure:

1 Cast concrete cubes as per IS 516:1959.

2 After 24 hours, remove specimens and cure them in clean water for 7, 14, and 28 days.

3 Wipe excess water and place the cube centrally on the compression testing machine

4 Apply a uniform load at a rate of 140 kg/cm² per minute until failure.

5 Record the maximum load applied.

Formula:

$f_c = \frac{P}{A}$

= Compressive strength (N/mm²)

= Maximum load at failure (N)

= Cross-sectional area of specimen (mm²)

Interpretation:

- For permeable paver blocks, the compressive strength typically ranges between 10–25 MPa depending on application (footpath or parking).
- Higher strength indicates better load-bearing capacity, but excessive density may reduce permeability.

2. Permeability Test (Falling Head Method)

Purpose:

To measure the rate at which water passes through the interconnected voids in the permeable concrete specimen. It represents the hydraulic conductivity of the block.

Apparatus:

- Permeameter with standpipe
- Stop-watch
- Water reservoir and measuring cylinder

Procedure:

1 Saturate the specimen before testing to remove entrapped air.

2 Fix the specimen in the permeameter cell ensuring no leakage.

3 Fill the standpipe with water to an initial head.

4 Allow water to flow through the specimen until it reaches final head.

5 Record the time taken for the drop from to.

6 Repeat the test at least three times for accuracy.

Formula:

$k = \frac{aL}{A t} \ln{\frac{h_1}{h_2}}$

= Coefficient of permeability (cm/s)

= Cross-sectional area of standpipe (cm²)

= Cross-sectional area of specimen (cm²)

= Length/thickness of specimen (cm)

= Time (s)

= Initial and final head of water (cm)

Interpretation:

- Typical permeability for good-quality permeable concrete ranges from 2–10 mm/s.
- Higher values indicate better drainage ability, but excessively high permeability may reduce strength.

3. Water Absorption Test

Purpose:

To determine the amount of water absorbed by the concrete block, which helps to understand its porosity and durability. Excessive absorption may lead to deterioration during freeze–thaw or wet–dry cycles.

Apparatus:

•Weighing balance (accuracy ±0.1 g)

•Water tank

Procedure:

1 Dry the specimen in an oven at 105°C for 24 hours and record dry weight
2 Immerse it completely in water for 24 hours.
3 Remove, wipe surface water, and record wet weight.
4 Calculate water absorption using the formula below.

Formula:

$$\text{Water Absorption (\%)} = \frac{W_2 - W_1}{W_1} \times 100$$

Interpretation:

- For permeable concrete, typical water absorption is between 5–15%.
- Higher absorption signifies more void content and better permeability, but excessive absorption may compromise durability.

4. Density and Porosity Test

Purpose:

To determine the mass per unit volume and percentage of voids within the concrete. These parameters influence both strength and permeability.

Apparatus:

Weighing balance

Water tank and pycnometer

Vernier caliper

Procedure:

1. Measure the oven-dry weight of specimen.
2. Immerse it in water until fully saturated and record saturated weight.
3. Determine the apparent volume by displacement method.
4. Calculate bulk density and apparent porosity.

Formulae:

$$\text{Bulk Density} = \frac{W_d}{V}$$

$$\text{Porosity (\%)} = \frac{W_s - W_d}{V \times \rho_w} \times 100$$

Where = Density of water (1000 kg/m³)

Interpretation:

- Typical density for permeable concrete: 1800–2200 kg/m³
- Porosity: 15–30% (suitable for stormwater infiltration).
- •High porosity improves drainage but may reduce compressive strength.

5. Visual Surface Inspection (Clogging and Pore Distribution)

Purpose:

To examine surface characteristics, pore continuity, and potential clogging due to fine particles. This test helps assess long-term performance in the field.

Procedure:

1. After curing, inspect the specimen visually or under a magnifying glass.
2. Record observations for pore size uniformity, surface cracks, and visible clogging.
3. Pour water on the surface and observe infiltration speed and distribution.
4. Optionally, use image analysis software to measure pore connectivity.

Interpretation:

- Uniformly distributed pores → good permeability and even drainage.
- Clogging or paste blocking indicates improper mix or segregation.
- Cracks may signify shrinkage or inadequate curing.

3.5 Data Analysis

Strength and permeability plotted against replacement ratios.

Optimum mix chosen where acceptable compressive strength (>10 MPa) and permeability (>2 mm/s) coexist.

Statistical correlation between porosity, density, and permeability established.

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