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Manufacturing of Sustainable Paver Blocks Using Mixed Plastic Waste as a Partial Replacement of Cement

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Abstract - Disposal of mixed plastic waste and the environmental burden of cement production are pressing challenges facing the construction industry. This study investigates the use of fine mixed plastic waste (MPW)—comprising high-density polyethylene (HDPE), low-density polyethylene (LDPE), and polyethylene terephthalate (PET)—as a partial replacement for cement in M40-grade concrete paver blocks. Five concrete mixes were prepared with 0%, 5%, 10%, 15%, and 20% cement replacement by mass (designated S1–S5), keeping aggregate and water proportions constant. Blocks were water-cured for 28 days and evaluated for full-block compressive strength and 24-hour water absorption per IS 15658:2021. Compressive strength remained stable across all mixes (37.56–38.00 N/mm²), reaching a peak of 38.00 N/mm² (+1.17% over control) at 10% replacement. Water absorption rose from 3.05% (control) to 5.07% (20% replacement), remaining within the 6% code limit. While material cost rose from ₹12.00 to ₹14.54 per block at ₹50/kg plastic, sensitivity analysis shows cost parity or savings with low-cost waste plastic. A 10% replacement level is optimal for general-purpose paving, whereas 15–20% suits light-load footpaths and landscaping.

Key Words: Mixed plastic waste, paver blocks, cement replacement, compressive strength, water absorption, sustainable construction.

1. INTRODUCTION

Rapid urbanization and infrastructure expansion have steadily increased the demand for precast paving products, while simultaneously generating large volumes of non-biodegradable municipal and industrial plastic waste. Mixed plastic waste (MPW)—particularly thin films, multi-layer packaging, and post-consumer blends of high-density polyethylene (HDPE), low-density polyethylene (LDPE), and polyethylene terephthalate (PET)—is difficult to process through conventional single-polymer recycling routes and frequently accumulates in landfills, storm drains, and water bodies.

Concurrently, Ordinary Portland Cement (OPC), the principal binder in concrete, is associated with intensive energy consumption and carbon dioxide emissions of approximately 0.8–0.9 tonne of CO_2 per tonne of cement produced. Reducing cement demand across mass-produced precast elements therefore offers substantial cumulative environmental benefits.

Concrete paver blocks represent an ideal medium for valorizing waste materials because they are produced as discrete, standardized units across pedestrian and vehicular load categories governed in India by IS 15658:2021. While most existing studies substitute fine or coarse aggregates with plastic or employ fully melt-bonded cementless systems, comparatively little work investigates fine, un-melted MPW particles as a partial replacement of cement itself. This study evaluates the effect of partial cement replacement (0%–20% by mass) with shredded MPW on the compressive strength, water absorption, and unit material cost of M40-grade concrete paver blocks.

2. LITERATURE REVIEW

Prior investigations have explored plastic incorporation in paver units through aggregate substitution and thermal binding routes. Sharma et al. (2025) compared eco-friendly paver tiles incorporating recycled marble, slag, glass powder, and plastics, demonstrating that mechanical performance depends strongly on replacement dosage and exhibits a clear optimum threshold [4]. Gholap et al. (2025) applied a TOPSIS multi-criteria decision framework to rank recycled HDPE, LDPE, and PET paver compositions across strength, cost, and environmental metrics [6].

Asif and Javed (2024) combined experimental testing with life-cycle assessment (LCA), reporting that 30% plastic inclusion retained approximately 20 MPa compressive strength while reducing production cost by nearly 52% [7]. Saraswat and Singh (2024) produced cementless paver blocks using melt-bonded LDPE with recycled concrete aggregates, achieving nearly 35 MPa strength [8]. Similarly, Debele et al. (2024) optimized LDPE–sand flexible paver tiles using Response Surface Methodology for light-traffic applications [10], whereas Choudhary et al. (2024) highlighted via bibliometric mapping that durability and standardized mix design remain key research priorities [9]. Unlike aggregate-replacement or melt-extrusion approaches, the present work

evaluates un-melted fine MPW as a direct partial substitute for cement.

3. MATERIALS AND METHODOLOGY

3.1 Materials

Ordinary Portland Cement (OPC 53 grade) conforming to IS 269:2015 was used as the primary binder. Manufactured sand (M-sand) conforming to Zone II of IS 383:2016 served as fine aggregate, and crushed stone of 10 mm nominal maximum size was used as coarse aggregate. Mixed plastic waste (HDPE and LDPE particles shredded up to 1.5 mm) was sourced from Shyam Industries, washed thoroughly to remove surface contaminants, oven-dried at 40–50°C for 24 hours, and sieved prior to batching. Potable water conforming to IS 456:2000 and rectangular plastic moulds of internal dimensions 200 × 100 × 60 mm were used throughout casting.

Table -1: Material Specifications

Material	Specification / Standard
Cement	OPC 53 Grade, IS 269:2015
Fine Aggregate	Manufactured Sand (M-sand), Zone II, IS 383:2016
Coarse Aggregate	Crushed aggregate, 10 mm nominal size
Mixed Plastic Waste	Shredded HDPE & LDPE particles (≤ 1.5 mm)
Water	Potable water, IS 456:2000
Moulds	Rectangular plastic moulds (200 × 100 × 60 mm)

3.2 Mix Proportions and Casting

The control concrete mix (S1) was proportioned for M40 grade in accordance with IS 10262:2019 [2]. Cement was partially replaced by MPW at 0%, 5%, 10%, 15%, and 20% by mass (designated S1 to S5), while fine aggregate, coarse aggregate, and mixing water were held constant across all batches as detailed in Table -2.

Table -2: Mix Proportions per Batch

Mix ID	MPW (%)	Cement (kg)	Plastic (kg)	Sand (kg)	CA (kg)	Water (L)
S1	0%	8.53	0.00	10.53	21.07	3.1–3.3
S2	5%	8.11	0.43	10.53	21.07	3.1–3.3
S3	10%	7.68	0.85	10.53	21.07	3.1–3.3
S4	15%	7.25	1.28	10.53	21.07	3.1–3.3
S5	20%	6.83	1.71	10.53	21.07	3.1–3.3

Dry constituents were blended uniformly before incorporating shredded plastic and gradually adding mixing water. Fresh concrete was placed into oiled moulds and compacted on a table vibrator to expel entrapped air. Specimens were demoulded after 24 hours, cured by full water immersion for 28 days, and tested at 57 days.

3.3 Testing Methods

Full-block compressive strength and 24-hour water absorption were determined on five specimens per mix in accordance with IS 15658:2021 [1]. Compressive strength Fc (N/mm²) was calculated using Eq. (1) with a thickness correction factor of 1.00 per IS 456:2000:

$$Fc = P / A \qquad (1)$$

where P is the maximum crushing load (N) and A is the loaded plan area (mm²). Water absorption (%) was obtained after 24 hours of immersion using Eq. (2):

$$\text{Water Absorption (\%)} = [(Ws - Wd) / Wd] \times 100 \qquad (2)$$

where Ws and Wd represent the saturated surface-dry mass and oven-dry mass (g), respectively.

4. RESULTS AND DISCUSSION

4.1 Compressive Strength

As summarized in Table -3, compressive strength remained remarkably consistent across all five mixes, ranging between 37.56 N/mm² and 38.00 N/mm² (a total spread of 0.44 N/mm², or 1.17%). None of the plastic-modified mixes exhibited strength degradation relative to the control mix S1. Strength increased marginally up to 10% replacement (S3), achieving the peak value of 38.00 N/mm², before tapering slightly at 15% and 20%.

Physically, at up to 10% dosage, fine non-absorbent plastic particles act as micro-fillers within inter-granular voids, improving particle packing density. Beyond 10%, because plastic particles are hydrophobic and do not participate in cement hydration, the growing number of weak polymer–paste interfacial transition zones slightly interrupts matrix continuity. Overall, replacing up to 20% cement with MPW preserves structural compressive strength.

4.2 Water Absorption and Combined Evaluation

In contrast to compressive strength, 24-hour water absorption increased steadily with plastic content from 3.05% in S1 to 5.07% in S5 (Table -3). Although the plastic particles themselves are hydrophobic, weak interfacial bonding at the plastic–cement paste boundary creates micro-fissures that serve as capillary pathways, reinforced by the lower total cement paste volume available to seal matrix pores. Nevertheless, every mix satisfied the IS 15658:2021 maximum permissible average water absorption limit of 6.0%, with S3 (10%) offering the best combined strength–durability balance.

Table -3: Compressive Strength, Water Absorption, and Cost Summary

Mix	Failure Load (kN)	Strength (N/mm²)	Change vs. S1	Water Abs. (%)	Cost/Block (₹)
S1 (0%)	954	37.56	—	3.05	12.00
S2 (5%)	948	37.63	+0.19%	3.83	12.63
S3 (10%)	955	38.00	+1.17%	4.18	13.26
S4 (15%)	950	37.96	+1.06%	4.97	13.90
S5 (20%)	953	37.80	+0.64%	5.07	14.54

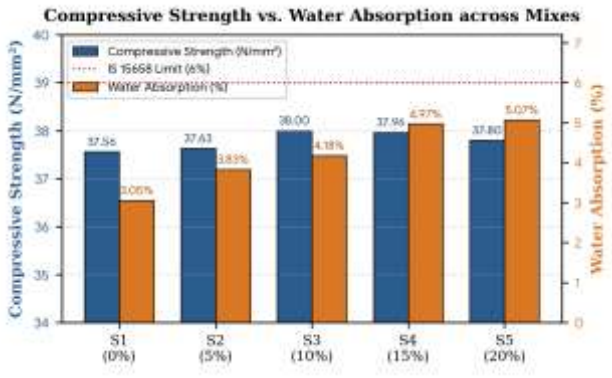

Fig -1: Variation of compressive strength and water absorption with plastic replacement percentage

4.3 Cost Analysis and Application Suitability

At prevailing commercial rates of ₹50/kg for processed plastic versus ₹7/kg for OPC, unit material cost rose from ₹12.00 (S1) to ₹14.54 (S5), representing a 21.2% increase at 20% replacement. However, sensitivity analysis demonstrates that when municipal or industrial waste plastic is sourced at ₹20/kg, the cost premium drops to 1.6%–6.3%, and with freely collected waste plastic, unit block cost decreases by up to 3.5% below the conventional control block. Each block sequesters 15 g to 59 g of plastic waste (15–59 kg per 1,000 blocks). Recommended field applications based on test performance are outlined in Table -4.

Table -4: Recommended Field Applications by Mix

Application Area	Recommended Mix	Technical Justification
Parking areas, bus stops & public plazas	S3 (10%)	Peak compressive strength (38.00 N/mm²) with comfortable absorption margin
Residential driveways & light streets	S2–S3 (5–10%)	Low capillary absorption (3.83–4.18%) and reliable load capacity
Footpaths, walkways & landscaping	S4–S5 (15–20%)	Light pedestrian load; maximizes plastic waste diversion within 6% limit

5. CONCLUSIONS

Fine mixed plastic waste (HDPE/LDPE) can be effectively utilized as a partial replacement for cement up to 20% by mass in M40-grade concrete paver blocks without compromising compressive strength. All plastic-modified mixes maintained compressive strengths between 37.63 and 38.00 N/mm², slightly outperforming the control mix (37.56 N/mm²) and peaking at 10% replacement. Water absorption increased progressively with plastic dosage due to micro-voids at the polymer–paste interface but remained below the IS 15658:2021 limit of 6.0% across all mixes (maximum 5.07% at 20% replacement). A 10% replacement level (S3) is recommended for general-purpose paving applications, while 15%–20% replacement (S4–S5) is viable for light-load pedestrian walkways and landscaping, offering a scalable pathway for sustainable plastic waste management.

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