

Effect of Material Proportions on Cement-Based Composites Incorporating Waste Foundry Sand and Recycled Plastic: A One-Factor-at-a-Time Investigation

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Abstract - Rapid depletion of natural aggregates and the unsustainable accumulation of industrial and post-consumer waste motivate the search for cement-based composites that exploit residual streams. This work evaluates the individual influence of cement, waste foundry sand (WFS) and recycled plastic (a PET/HDPE blend) on the engineering properties of mortar composites using the One-Factor-at-a-Time (OFAT) method. Nine 50-mm cube mixes were cast across three series (cement 350–450 g, plastic 35–135 g, WFS 415–615 g) at a constant water-to-cement ratio and tested after 7 d and 28 d of moist curing for bulk density, water absorption, porosity (ASTM C642) and compressive strength (ASTM C109/C109M). At 28 d, plastic content emerged as the dominant variable: increasing plastic from 35 g to 135 g (3.7–13.5 wt %) reduced compressive strength by 41 % (24.25 → 14.26 MPa) and bulk density by 10 % (1864 → 1671 kg m⁻³), while raising porosity from 26.0 % to 27.2 %. Cement and WFS variation produced second-order effects, indicating an optimum cement content of ~ 400 g and confirming the void-filling action of WFS. Based on compressive-strength benchmarking, the lowest-plastic mix (B1) exceeded the minimum strength values specified for ASTM C55 concrete building brick and ASTM C90 load-bearing concrete masonry units, but it remained below the requirements for ASTM C902/C1272 paving applications. Therefore, the material is more appropriately positioned for non-structural or low-load lightweight applications such as partition blocks, landscape elements and utility masonry units, subject to further product-scale durability testing.

Keywords: *OFAT methodology; cement-based composite; waste foundry sand; recycled plastic; PET/HDPE; compressive strength; sustainable construction*

1. INTRODUCTION

Cementitious composites, including concrete, mortar and masonry blocks, remain among the most widely used construction materials because of their availability, relatively low cost and satisfactory mechanical performance. However, their continued production places significant pressure on natural aggregate resources and contributes substantially to environmental emissions, particularly through cement clinker production, which is responsible for a notable share of global anthropogenic CO₂ emissions [1], [2]. At the same time, large quantities of industrial and post-consumer wastes are generated every year, including spent waste foundry sand (WFS) from metal-casting industries and discarded plastic waste from domestic and commercial sources. Global WFS generation has been reported at more than 100 Mt yr⁻¹, while less than 10% of post-consumer plastic waste is effectively recycled into secondary raw materials [3], [4]. Therefore, incorporating these waste streams into cement-based composites

offers a practical route to reduce the consumption of virgin raw materials, divert waste from landfills and support circular-economy-based construction practices.

Recent studies have demonstrated the potential of using different waste materials in construction products. Geopolymeric binders incorporating fly ash and brick waste have shown environmental advantages by reducing mineral-resource demand compared with conventional fired-clay products [5], [6]. Similarly, plastic-modified blocks and bricks produced with sand, clay or fly ash have been reported to reduce density and improve certain functional properties, although excessive plastic content generally weakens the bond between the plastic particles and the cementitious or mineral matrix, leading to lower compressive strength [7], [8]. Waste foundry sand has also been investigated as a partial replacement for natural fine aggregate in cementitious materials, where its fine particle size and angular morphology can contribute to filler action and improved particle packing when used within suitable limits [3]. However, the combined use of WFS and recycled plastic in cement-based composites remains less extensively studied, particularly when the objective is to identify the individual role of each constituent.

The available literature also shows considerable variation in the reported optimum replacement levels for plastic and WFS. Some studies have reported acceptable mechanical performance at low combined replacement levels, while others have used substantially higher plastic or foundry-sand contents with varying effects on strength, density and water absorption [10]–[13]. This variation is partly due to differences in plastic type, particle size, binder system, aggregate grading, curing condition and testing method. In addition, many previous investigations varied more than one constituent at the same time, making it difficult to clearly determine whether the observed performance changes were mainly caused by cement dosage, recycled plastic content or WFS content. As a result, simple mix-design guidance for preliminary development of WFS–plastic cement-based composites is still limited.

The One-Factor-at-a-Time (OFAT) method provides a simple and transparent experimental approach for isolating the apparent influence of individual mix constituents. In this method, one factor is varied while the remaining factors are kept constant, allowing direct observation of the response trend associated with that specific variable. Although OFAT does not capture interaction effects among variables and is less statistically powerful than factorial, Taguchi or response surface designs, it remains useful for preliminary screening when the material system is not yet fully understood [14]. For waste-integrated cementitious composites, such a screening approach can help identify the most influential constituent before moving toward more advanced optimization studies.

In this study, an OFAT approach was applied to a cement-based composite system incorporating Portland-limestone cement, WFS sourced from a regional ferrous-casting plant and shredded post-consumer PET/HDPE plastic. The main objectives were to: (i) evaluate the individual influence of cement content, recycled plastic content and WFS content on bulk density, water absorption, porosity and compressive strength; (ii) identify the constituent showing the strongest apparent influence on 7-day and 28-day performance; and (iii) benchmark the best-performing mix against selected ASTM masonry strength requirements to identify possible application areas. The novelty of the work lies in providing a preliminary single-factor screening of a cement–WFS–recycled plastic composite system, allowing the apparent influence of each constituent to be examined separately before future interaction-based optimization.

2. MATERIALS AND METHODS

2.1 Materials

Ordinary Portland-limestone cement (CEM II/A-LL 42.5N, Raysut Cement Co., Oman), conforming to BS EN 197-1:2011, was used as the binder. Waste foundry sand was supplied by Dunes Oman LLC; the as-received material was air-dried for 24 h and screened to remove agglomerates, yielding a fine, angular fraction predominantly between 0.30 and 0.60 mm with a dominant size around 0.425 mm. Recycled plastic a mixed PET/HDPE post-consumer stream from International Plastics LLC was processed in a single-shaft shredder (Fig. 3a) and graded by a mechanical sieve shaker (Fig. 3b). Sieve analysis (Fig. 1) returned 99.6 % passing 10 mm, 57.6 % passing 5 mm and 11.2 % passing 2 mm, giving an estimated d50 of approximately 4 mm; manual caliper

measurement of twenty randomly selected pieces gave a mean length of 0.82 cm and width of 0.82 cm, reflecting the irregular flaky morphology of the larger fraction. Tap water was used both for mixing and for moist curing. Specifications of the three constituents are summarised in Table 1.

Table 1. Specifications of the materials used in the cement-based composites.

Property	Cement (PLC)	Recycled plastic	Waste foundry sand
Designation	CEM II/A-LL 42.5N	PET / HDPE blend	Spent moulding sand
Standard	BS EN 197-1:2011	—	—
Source	Raysut Cement, Oman	International Plastics LLC	Dunes Oman LLC
Particle size	< 75 μm	1–10 mm ($d_{50} \approx 4$ mm)	0.30–0.60 mm
Shape	Fine powder	Irregular, flaky	Angular
Specific gravity / density range	~ 3.15	0.9–1.2	2.4–2.6
Water absorption	Low	Negligible	Moderate
Role in matrix	Binder	Lightweight inclusion	Fine-aggregate replacement

2.2 Mix design

Nine mortar mixes were proportioned according to an OFAT scheme with three series (Table 2). The reference mix (A2 \equiv B2 \equiv C2) contained 400 g cement, 85 g plastic and 515 g WFS, with a water-to-cement ratio fixed at 0.50 across all mixes. In Series A the cement mass was varied (350, 400, 450 g) at constant plastic and WFS; in Series B the plastic mass was varied (35, 85, 135 g) at constant cement and WFS; and in Series C the WFS mass was varied (415, 515, 615 g) at constant cement and plastic. Total batch mass therefore changed between series, but the substituted constituent was the only varied factor within each series.

The selected variation ranges were guided by replacement levels reported in previous studies on cementitious composites incorporating plastic and foundry-sand wastes. The cement range of 350–450 g (~ 37–43 % of the total dry mass) brackets the binder dosages typically adopted for 50-mm mortar cubes in similar mix-optimisation studies. The plastic range of 35–135 g (3.7–13.5 wt %) was set within the lower band of plastic replacement levels investigated in the literature: Mohammed [12] employed 30 wt % plastic in sand bricks, Ngayakamo [11] examined 10–60 wt % plastic-sand mixtures, and Rajesh and Raju [13] reported the best mechanical performance at low (≈ 5 %) combined replacement. Higher plastic dosages were avoided in this study so as to preserve the prospect of meeting the load-bearing requirement of ASTM C90 (13.1 MPa). The WFS range of 415–615 g (~ 46–56 % of the total dry mass) corresponds to the partial fine-aggregate replacement levels reported by Rajan et al. [10] and Rajesh and Raju [13]. The chosen ranges therefore allow each constituent to be evaluated within an industrially realistic window while remaining consistent with previously reported mix proportions.

Table 2. OFAT mix-design matrix. The reference mix is repeated as A2, B2 and C2 to allow common 7 d / 28 d benchmarks across the three series.

Mix ID	Series (varied factor)	Cement (g)	Plastic (g)	WFS (g)	Total (g)
A1	A — cement	350	85	515	950
A2 / B2 / C2*	Reference	400	85	515	1000
A3	A — cement	450	85	515	1050
B1	B — plastic	400	35	515	950
B3	B — plastic	400	135	515	1050

C1	C — WFS	400	85	415	900
C3	C — WFS	400	85	615	1100

*Note: A2, B2 and C2 represent the same reference composition containing 400 g cement, 85 g recycled plastic and 515 g WFS. The reference mix is repeated only to provide a common comparison point within each OFAT series.

2.3 Specimen preparation and curing

The dry constituents (cement, WFS and shredded plastic) were first mixed thoroughly for 2 min before progressive addition of water and a further 3 min of mixing. The fresh mortar was placed in two layers in $50 \times 50 \times 50$ mm³ steel cube moulds and compacted on a vibrating table for 30 s per layer to expel entrapped air. Specimens were demoulded after 24 h and submerged in tap water at ambient laboratory temperature (≈ 27 °C) for either 7 or 28 d before testing. A sequence of the mixing and casting operations is shown in Fig. 2; the compression-testing apparatus is shown in Fig. 3c. No formal workability test was conducted in the present study. However, because recycled plastic particles are lightweight, irregular and hydrophobic, changes in plastic dosage may influence fresh mix consistency, compaction efficiency and entrapped air content. This limitation should be considered when interpreting the density, porosity and strength trends, particularly for mixes with higher plastic content.

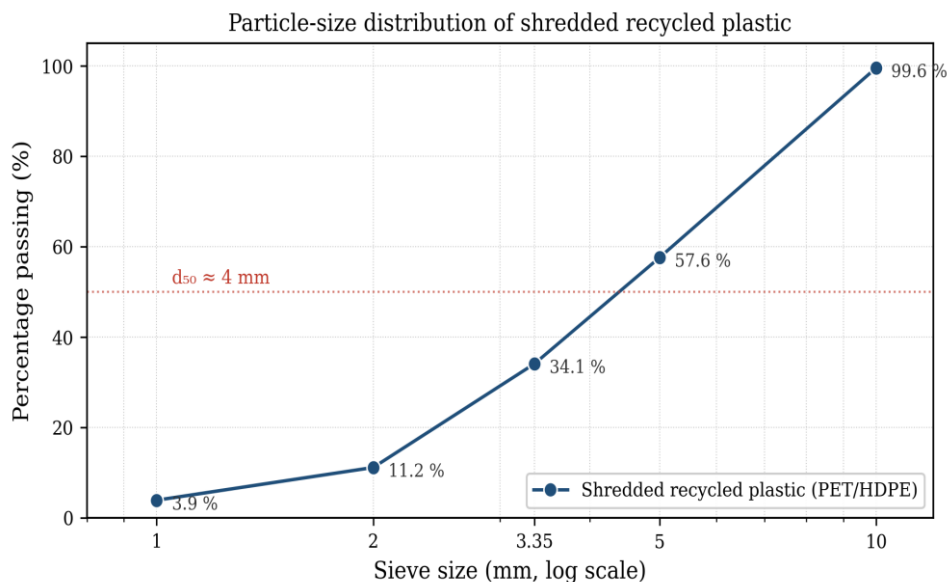


Fig. 1. Particle-size distribution of the shredded recycled plastic obtained by mechanical sieve analysis.

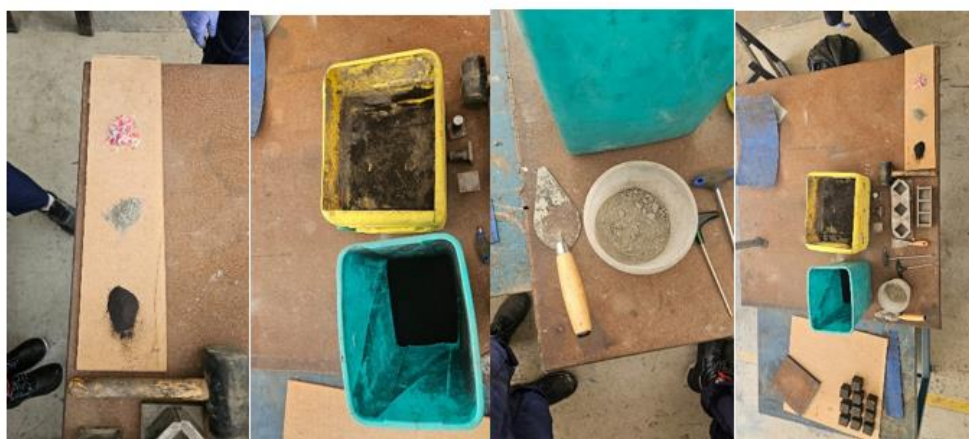


Fig. 2. Sequence of mixing, weighing and casting operations for the cement-based composite specimens.



Fig. 3. Equipment used in this study: (a) single-shaft plastic shredder; (b) mechanical sieve shaker for gradation analysis; (c) compression-testing machine.

2.4 Test methods

2.4.1 Bulk density

Bulk (experimental) density ρ_e was obtained from the dry mass m_d of each cube divided by its geometric volume V ($= 125 \text{ cm}^3$):

$$\rho_e = m_d / V \quad (1)$$

2.4.2 Water absorption

After oven-drying to constant mass, specimens were re-immersed for 24 h. Surface-dry wet mass m_w was recorded and water absorption WA computed from ASTM C642:

$$WA = (m_w - m_d) / m_d \times 100 (\%) \quad (2)$$

2.4.3 Theoretical density and porosity

Theoretical density ρ_t was estimated from the rule of mixtures using the mass fraction w_i and absolute density ρ_i of each constituent (cement 3150, WFS 2500, plastic 1000 kg m^{-3}):

$$1 / \rho_t = w_c / \rho_c + w_{WFS} / \rho_{WFS} + w_p / \rho_p \quad (3)$$

Porosity P, taken as an indirect measure of void content, follows from the relative density deficit:

$$P = (\rho_t - \rho_e) / \rho_t \times 100 (\%) \quad (4)$$

2.4.4 Compressive strength

Cubes were tested in a hydraulic compression-testing machine of 2000 kN capacity at a loading rate of approximately 0.25 MPa s^{-1} in accordance with ASTM C109/C109M. Three specimens per mix were tested at each curing age and the mean reported. The full set of standards followed during testing is summarised in Table 3.

Table 3. Test methods and reference standards.

Test / parameter	Standard	Description
Bulk density	ASTM C642	Bulk density and void characteristics of hardened concrete
Water absorption	ASTM C642	Saturation–desorption methodology for permeability assessment
Porosity	ASTM C642	Calculated from theoretical and bulk density
Compressive strength	ASTM C109/C109M	Compressive strength of 50 mm cement mortar cubes
Sieve analysis	ASTM C136/C136M	Particle-size distribution of fine and coarse aggregates
Cement specification	BS EN 197-1:2011	Portland-limestone cement composition and conformity

3. Results and Discussion

The complete experimental dataset is collected in Table 4 and discussed property-by-property below, followed by an inter-property analysis and a comparison with literature and standards.

Table 4. Bulk density, water absorption, porosity and compressive strength of the nine OFAT mixes after 7 d and 28 d of moist curing.

Mix	Water absorption (%)		Porosity (%)		Density (kg m ⁻³)		Compressive strength (MPa)	
	7 d	28 d	7 d	28 d	7 d	28 d	7 d	28 d
A1	11.85	11.4	27.03	26.2	1681	1705	14.63	18.56
A2	11.96	11.2	27	26.1	1687	1715	16.56	19.85
A3	14.67	11.93	32.69	28.45	1600	1692	12.71	18.29
B1	12.15	11.5	27.03	26	1867	1864	17.53	24.25
B2	11.96	11.3	27	26.15	1687	1703	16.56	18.96
B3	13.33	11.75	28.03	27.2	1593	1671	13.17	14.26
C1	11.39	10.95	28.62	27.1	1664	1680	16.8	18.08
C2	11.96	11.2	27	26.05	1687	1705	16.56	19
C3	12.77	10.11	31.44	27.26	1604	1715	16.59	18.99

3.1 Bulk density

The 28 d bulk density of the composites ranged from 1671 kg m⁻³ (B3, highest plastic) to 1864 kg m⁻³ (B1, lowest plastic), spanning 12 % around the reference value of 1700–1715 kg m⁻³. Within Series B, density decreased monotonically with increasing plastic content, consistent with the lower specific gravity of PET/HDPE (0.9–1.2) relative to cement (3.15) and WFS (2.4–2.6); plastic acts as a lightweight inclusion that effectively reduces the average particle density of the matrix. Series A and C showed only modest variation: cement variation (350 → 450 g) altered density by less than 1 %, and WFS variation (415 → 615 g) by less than 2 %, suggesting that within the ranges studied the binder and the fine-aggregate fraction contribute comparably to bulk density once compaction is established. Almost all mixes gained density between 7 d and 28 d, reflecting continuing hydration and pore-water consumption.

3.2 Water absorption

Twenty-eight-day water absorption fell within a narrow band of 10.1–11.9 %, with C3 the lowest (10.11 %) and A3 the highest (11.93 %). All mixes gained moisture resistance with extended curing, confirming that ongoing C–S–H gel formation refines the pore network. The relatively high absorption observed at 7 d in A3 (14.67 %) is

attributable to incomplete hydration of the higher cement dosage at early age — water demand for hydration was not yet fully satisfied — and was largely eliminated by 28 d. Variation with plastic content (Series B) was non-monotonic: B1 (35 g plastic) absorbed 11.5 %, the reference 11.3 %, and B3 (135 g plastic) 11.75 %. This reflects two opposing effects of plastic: PET/HDPE itself is hydrophobic and non-absorbent, but increased plastic content disturbs particle packing and creates additional interfacial voids that take up water through capillarity.

3.3 Porosity

Calculated porosity at 28 d ranged from 26.0 % (B1) to 28.45 % (A3), broadly mirroring the water-absorption ranking but with a wider spread. Series B again showed a clear trend: porosity increased from 26.0 % (B1) to 27.2 % (B3) as the plastic dose tripled, supporting the interpretation that excess plastic disrupts the cement–aggregate interlock. The unusually high 7 d porosity of A3 (32.7 %) and C3 (31.4 %) both at the upper end of their respective dose ranges points to inhomogeneous compaction at higher solids loadings, an effect that diminishes by 28 d as continued hydration partially heals the void network.

3.4 Compressive strength

Compressive strength was the property most sensitive to mix composition. At 28 d, strength ranged over a factor of 1.7×, from 14.26 MPa (B3) to 24.25 MPa (B1). The plastic series exhibited a strong, monotonic decrease in strength with plastic content: 24.25 MPa at 35 g, 18.96 MPa at 85 g, and 14.26 MPa at 135 g, corresponding to a strength penalty of approximately 100 kPa per gram of plastic added (linear fit, $R^2 \approx 0.999$). In parallel, all three Series-B mixes also gained strength between 7 d and 28 d, but the magnitude of this gain reduced markedly as plastic content increased from +6.72 MPa ($\approx 38\%$) in B1, to +2.40 MPa ($\approx 14\%$) in B2, and only +1.09 MPa ($\approx 8\%$) in B3 indicating that higher plastic dosages not only depress absolute strength but also restrict the late-age strength development normally driven by continued cement hydration. The mechanism is twofold: plastic particles offer poor adhesion to the cementitious matrix because of their hydrophobic, smooth surfaces, and their flaky geometry creates stress-concentration sites that initiate cracking under load. Cement variation (Series A) revealed an optimum at 400 g, with both 350 g (A1, 18.56 MPa) and 450 g (A3, 18.29 MPa) under-performing the reference. The drop at 450 g is initially counter-intuitive but is consistent with the elevated 7 d porosity of A3 and is attributed to the fixed water-to-cement ratio leaving insufficient mixing water at the higher binder dose, producing localised dry zones that did not heal at extended ages. WFS variation (Series C) had a comparatively minor effect on strength (18.08–19.00 MPa at 28 d), confirming that within the explored window WFS acts mainly as an inert void-filler rather than a reactive component. The series-by-series response of 28 d compressive strength to each varied factor is summarised in Fig. 4, while the detailed evolution of strength, bulk density and porosity within the dominant plastic series is shown in Fig. 5.

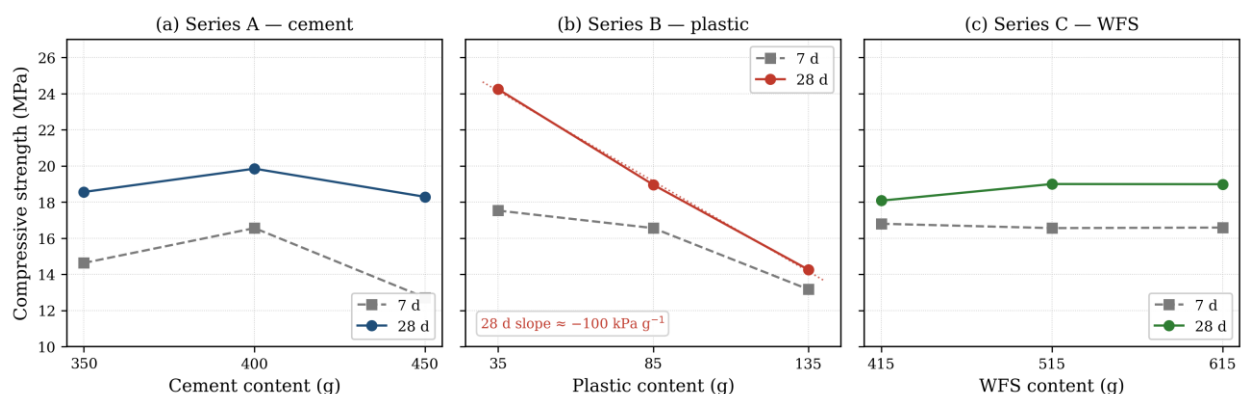


Fig. 4. OFAT effect of (a) cement, (b) plastic and (c) WFS content on the 7 d and 28 d compressive strength of the mortar composites. Series B shows a near-linear reduction of strength with plastic content (28 d slope ≈ -100 kPa g^{-1} , $R^2 \approx 0.999$), indicating that plastic content had the strongest apparent influence within the investigated OFAT range. Cement exhibited an optimum near 400 g, while WFS produced only minor strength variation within the studied dosage window.

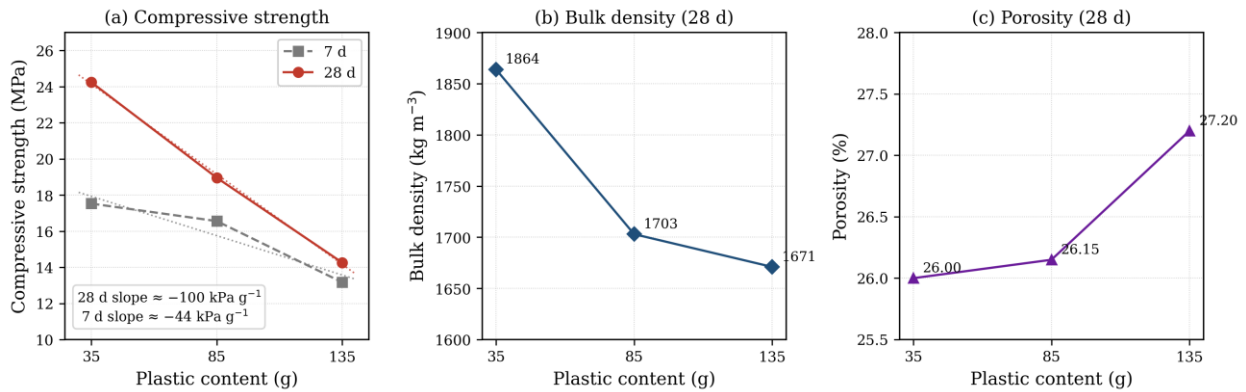


Fig. 5. Influence of plastic content (Series B) on (a) compressive strength at 7 d and 28 d with linear trendlines, (b) bulk density at 28 d, and (c) calculated porosity at 28 d. Strength and density decrease monotonically with plastic content while porosity rises; the 7 d to 28 d gain in strength also diminishes with plastic content, indicating that plastic dosage interferes with late-age hydration as well as with absolute strength.

3.5 Inter-property relationships

Across the dataset, 28 d compressive strength correlated positively with bulk density and negatively with both porosity and water absorption, in line with classical expectations for cementitious materials. Mix B1 sat at the favourable extreme of all four indicators simultaneously – highest density, lowest porosity, lowest water absorption among the high-strength mixes, and highest strength identifying low plastic content as the single most influential lever among the variables tested. Conversely, B3 occupied the opposite corner. The reference mix sat near the centre of the strength–density envelope, validating the choice of $A2 \equiv B2 \equiv C2$ as a baseline. Although the observed relationships between strength, density, porosity and water absorption are consistent with the expected behaviour of cementitious materials, they should be interpreted as trend-based correlations rather than statistically validated predictive relationships. The limited number of OFAT data points restricts the development of a robust regression model. A larger factorial dataset would be required to quantify interaction effects and establish statistically significant property–performance relationships.

3.6 Comparison with the literature

The 24.25 MPa attained by mix B1 is benchmarked against four representative studies on plastic- and WFS-modified cementitious systems (Table 5). The B1 strength sits within $\pm 17\%$ of all four reported optima, despite the differing replacement levels and constituents, and is closest to the plastic-sand brick of Mohammed [12] (23.7 MPa at 30% plastic). The agreement is encouraging given that B1 incorporates both a lightweight (plastic) and a granular (WFS) waste at the same time, and confirms the OFAT-derived dose recommendation of low plastic content for strength-critical applications.

Table 5. Comparison of the 28 d strength of mix B1 with selected literature data on cementitious composites incorporating recycled plastic and/or waste foundry sand.

Reference	System	Reported optimum (28 d)	Comparison with B1 (24.25 MPa)
Rajan et al. [10]	Plastic + foundry sand + coarse aggregate	40 % plastic + 40 % FS + 20 % coarse: 27 MPa; absorption < 5 %	B1 within 10 %
Ngayakamo [11]	Plastic + natural sand	23.84 MPa at 10 % plastic; 27.24 MPa at 60 %	B1 close to PSP-R10
Mohammed [12]	Plastic + sand brick	30 : 70 plastic-sand: 23.7 MPa; absorption 2.5 %	B1 marginally higher

Rajesh & Raju [13]	Recycled plastic + used FS	5 % combined replacement: 29.09 MPa	B1 about 17 % lower
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It should be noted that direct comparison with literature values is only approximate because previous studies differ in binder type, plastic type, plastic particle size, aggregate grading, curing regime, specimen geometry and testing method. Therefore, Table 5 is intended to position the present results within a broad performance range rather than to establish a direct equivalence among materials.

3.7 Compliance with ASTM masonry standards

A strength-based benchmark comparison of B1 with selected ASTM masonry-product specifications is summarised in Table 6. The 28-day cube compressive strength of B1 exceeds the minimum strength values specified in ASTM C129 for non-load-bearing concrete masonry units, ASTM C90 for load-bearing concrete masonry units and ASTM C55 for concrete building brick. However, this comparison should be interpreted cautiously because the present study tested 50 mm cube specimens rather than full-size masonry units manufactured and tested according to the complete requirements of each product standard. B1 did not meet the higher strength requirements associated with ASTM C902 pedestrian paving brick or ASTM C1272 heavy vehicular paving brick. Therefore, the composite is better positioned for non-structural and low-load masonry applications such as partition blocks, landscape blocks, lightweight utility blocks and low-load boundary wall units, pending further product-scale durability and dimensional compliance testing. Table 6. Compliance of mix B1 (24.25 MPa) with ASTM strength requirements for masonry products.

Standard	Application	Strength req. (MPa)	Conformity of B1 (24.25 MPa)
ASTM C129	Non-load-bearing CMU	4.14	Greatly exceeded
ASTM C90	Load-bearing CMU	13.1	Satisfied
ASTM C55	Concrete building brick	17.2	Satisfied
ASTM C902	Pedestrian/light-traffic paving brick	55.2	Not satisfied
ASTM C1272	Heavy vehicular paving brick	55–69	Not satisfied

4. CONCLUSIONS

An OFAT-based experimental investigation was conducted on cement-based composites incorporating waste foundry sand (WFS) and recycled PET/HDPE plastic in order to evaluate the influence of constituent proportions on density, water absorption, porosity, and compressive strength. Based on the experimental findings, the following conclusions can be drawn:

- Plastic content was identified as the most influential parameter affecting composite performance. Increasing plastic content from 35 g to 135 g significantly reduced compressive strength and bulk density while increasing porosity, primarily due to weak interfacial bonding and increased void formation within the cementitious matrix.
- Cement variation showed the existence of an optimum binder content around 400 g under the fixed water-to-cement ratio used in this study. Both lower and higher cement dosages resulted in reduced strength performance, indicating the importance of balancing binder content and water demand.
- Variation in WFS content produced comparatively smaller changes in mechanical and physical properties, suggesting that WFS mainly acts as a fine filler material within the investigated range.
- Among all mixes, B1 (400 g cement, 35 g plastic and 515 g WFS) exhibited the best overall performance, achieving a 28-day compressive strength of 24.25 MPa. Based on strength benchmarking, this value exceeds the minimum compressive-strength levels specified for selected non-load-bearing and load-bearing masonry units; however, full compliance requires testing of actual product-scale units according to the relevant ASTM procedures.

The study demonstrates the feasibility of incorporating industrial and post-consumer waste materials into cementitious composites for sustainable construction applications. The present investigation has several limitations that should be considered when interpreting the findings. First, the OFAT framework is useful for preliminary screening but does not capture interaction effects among cement content, recycled plastic dosage, WFS content and water demand. Second, although three specimens were tested for each mix, the results are mainly reported as mean values without standard deviation, coefficient of variation or statistical significance analysis. Third, the study was limited to 7-day and 28-day laboratory performance and did not evaluate longer-term durability indicators such as wet–dry cycling, sulphate resistance, chloride exposure, abrasion resistance, permeability or 56/90-day strength development. Fourth, the recycled PET/HDPE blend and WFS were not fully characterized in terms of chemical composition, surface chemistry, contaminant content or environmental leaching behaviour. Finally, the ASTM comparison should be regarded as a strength-based benchmark only, since full product compliance requires testing of actual masonry or paving units under the relevant standard procedures.

Future research should employ factorial, Taguchi or response surface methodology designs to quantify interaction effects and optimize the mix composition more robustly. Additional experimental work should include fresh-state workability assessment, flexural strength, splitting tensile strength, abrasion resistance, permeability, wet–dry durability and long-term strength development at 56 and 90 days. Microstructural characterization using SEM, XRD and FTIR is recommended to verify the bonding mechanism between plastic particles and the cementitious matrix. Chemical and environmental assessment of WFS, including XRF and leaching tests, should also be performed to confirm safe construction use. Finally, full-size blocks or bricks should be manufactured and tested according to the relevant ASTM product standards before practical field application.

From an application perspective, the present material should be considered as a candidate for low-load and non-structural masonry products rather than as a direct substitute for structural concrete or high-strength paving units. Its main advantages are waste utilization, reduced density and moderate compressive strength. However, field application should only be considered after durability, dimensional stability, water resistance, abrasion behaviour and product-scale performance are verified.

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Use of AI Declaration

The authors declare that an artificial intelligence (AI)-assisted tool (Chat-GPT) was used solely to support language editing, sentence refinement, and improvement of readability during manuscript preparation. The AI tool did not generate experimental data, results, figures, or scientific conclusions. All technical content, analysis, interpretation, and final revisions were critically evaluated and approved by the authors, who accept full responsibility for the contents of the manuscript

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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