

Production of Sustainable Lightweight Sandcrete and Paving Blocks Using Waste Polyethylene Terephthalate and Periwinkle Shells: A Review

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Abstract- *The construction industry increasingly seeks sustainable alternatives to traditional materials due to growing environmental concerns and material shortages. This review evaluates the potential of integrating waste polyethylene terephthalate (PET) and periwinkle shells (PWS) in the production of lightweight sandcrete and paving blocks. Emphasis is placed on mechanical, physical, and durability performance, as well as the environmental and economic implications. Results from existing studies indicate that PET can partially replace fine aggregates up to 5–10 % without significant loss of strength, while PWS can substitute coarse or fine aggregates up to 30 % to achieve lightweight units. However, excessive use of both materials leads to decreased compressive strength and increased water absorption. Combined application of PET and PWS remains underexplored, representing a promising avenue for sustainable construction research.*

Keywords: Sandcrete blocks, Paving blocks, Polyethylene terephthalate, Periwinkle shells, Sustainable construction, Lightweight materials

I. INTRODUCTION

The global construction sector is responsible for a significant proportion of natural resource depletion and environmental pollution (Olofinnade & Davies, 2021). The extraction of river sand and aggregates not only degrades ecosystems but also increases the cost and environmental footprint of building materials. Concurrently, plastic waste—especially polyethylene terephthalate (PET)—has become a global environmental challenge (Ruslan, Muthusamy, Syed Mohsin, & Kirgiz, 2024).

In coastal regions, periwinkle shells (PWS) constitute another abundant waste product generated from seafood consumption, often disposed of indiscriminately, leading to environmental pollution (Ugwu, Egwuagu, & Ubah, 2022). These two waste

materials present viable options for partial replacement of natural aggregates in masonry production, promoting circular economy principles.

Sandcrete and paving blocks are among the most commonly used walling and paving units in Africa, especially Nigeria (Ayensanmi, Aiyewalehinmi, & Oluyemi-Ayibiowu, 2024). However, many locally produced blocks fail to meet the minimum compressive strength requirement of 2.5–3.5 N/mm² as stipulated by the Nigerian Industrial Standard (NIS 87:2004; Standard Organisation of Nigeria [SON], 2004). Integrating waste PET and PWS could help improve sustainability, reduce weight, and lower costs while minimizing environmental impacts.

II. SANDCRETE AND PAVING BLOCKS: COMPOSITION AND CHALLENGES

Sandcrete blocks consist primarily of cement, fine aggregates (sand), and water. Paving blocks often include coarse aggregates to enhance strength. Key properties include compressive strength, density, and water absorption. Common issues with local sandcrete blocks include non-uniform composition, poor curing, and excessive weight (Osamuyi, Nwankwo, & Iyoha, 2021).

Environmental concerns surrounding natural aggregate extraction and cement production have spurred research into using alternative materials, such as recycled plastics and marine shells, to achieve lightweight and eco-friendly blocks.

Table 1 (Suggested):
Summary of properties and standards for
conventional sandcrete and paving blocks

Property	Typical Range	NIS Requirement	Notes
Compressive Strength (N/mm ²)	2.5–3.5	≥ 2.5 (non-load bearing)	Inadequate in many locally produced units
Density (kg/m ³)	2100–2400	-	Reduced by inclusion of lightweight waste materials
Water Absorption (%)	6–12	≤ 12	Increases with porous materials like PET and PWS

III. WASTE POLYETHYLENE TEREPHTHALATE (PET) IN MASONRY MATERIALS

Material Properties and Processing

PET is a thermoplastic polymer derived from beverage containers and packaging. It is lightweight (density $\approx 1.38 \text{ g/cm}^3$), hydrophobic, and chemically inert. Before use in construction, PET waste is typically washed, shredded, and incorporated as partial replacement for sand or coarse aggregates (Olofinnade & Davies, 2021).

Influence on Mechanical and Physical Properties

Studies show that incorporating PET up to 5–10 % by volume of fine aggregate can maintain acceptable compressive strength and reduce density (Olofinnade & Davies, 2021; Olutoge, Oladipupo, & Ajamu, 2020). Beyond 15–20 %, strength declines sharply due to poor bonding and void formation (Davies & Olofinnade, 2021). PET's smooth surface and hydrophobicity reduce cement matrix adhesion, leading to weaker interfacial zones.

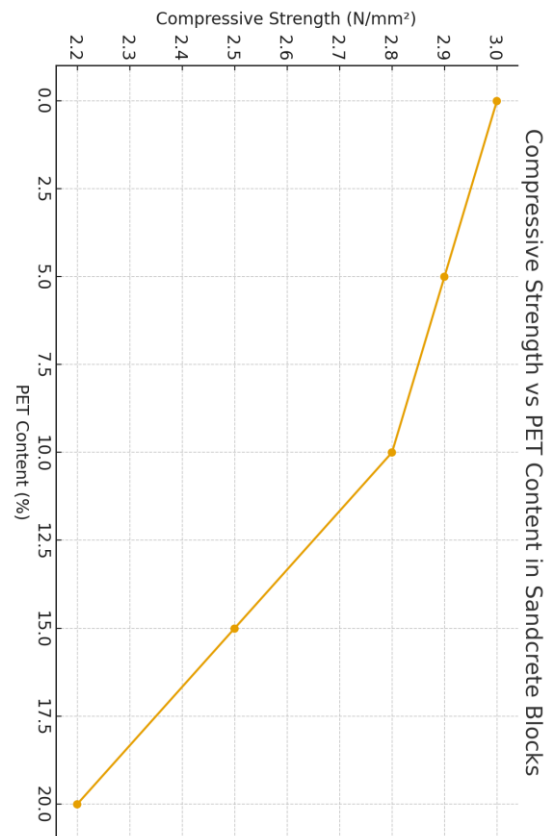


Figure 1. Variation of compressive strength with PET content in sandcrete blocks.

Durability and Limitations

High PET content increases water absorption and reduces durability due to weak interfacial bonding and non-polar chemical structure (Olofinnade, Ede, & Oyeibisi, 2022). Mechanical performance is often improved by adding superplasticizers, surface-treated PET, or blended cements.

IV. PERIWINKLE SHELLS (PWS) AS AGGREGATE REPLACEMENT

Composition and Availability

Periwinkle shells are rich in calcium carbonate (CaCO_3), making them suitable as aggregate substitutes after crushing or grinding (Ruslan et al., 2024). Their density ($\approx 1.6 \text{ g/cm}^3$) and angular texture help reduce block weight and improve bonding compared to PET.

Strength and Workability

Ayensanmi et al. (2024) reported that up to 50 % replacement of sand with crushed PWS achieved compressive strengths of 2.55–2.67 N/mm², sufficient for non-load-bearing applications. Ugwu et al. (2022) found that 20 % replacement using

mashed PWS yielded acceptable compressive strength and lower density. However, higher PWS content (> 40 %) increases porosity and reduces workability (Osamuyi et al., 2021).

Table 2. Summary of mix ratios and performance of PWS-modified sandcrete blocks

PWS Replacement (%)	Compressive Strength (N/mm ²)	Density (kg/m ³)
0	3.0	2300
10	2.9	2100
20	2.8	2000
30	2.6	1900
40	2.4	1850

Durability and Sustainability

PWS improves sustainability by reducing aggregate mining and reusing marine waste. However, blocks with high shell content tend to exhibit higher water absorption and reduced durability unless sealed or coated (Ruslan et al., 2024).

Combined Use of PET and PWS

Limited studies have explored the combined use of PET and PWS in masonry units. Theoretical considerations suggest that PWS could offset PET's bonding weakness, while PET could further reduce density (Ayensanmi et al., 2024). Developing optimal hybrid ratios could result in strong, lightweight, and environmentally sustainable blocks.

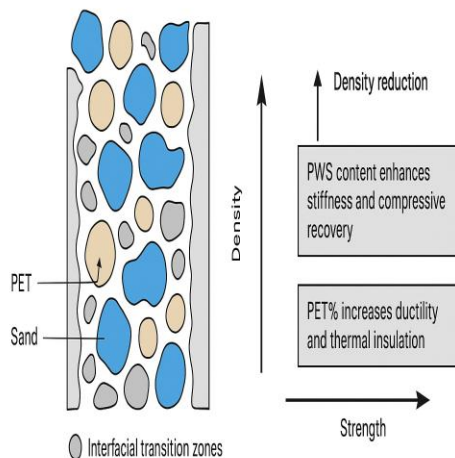


Figure 2. Schematic concept of hybrid PET-PWS sandcrete block micro-structure and expected performance balance

This combination remains an open area for experimental validation, particularly concerning strength, bonding, and durability optimization.

V. ENVIRONMENTAL AND ECONOMIC IMPLICATIONS

Using PET and PWS reduces waste accumulation, environmental pollution, and natural resource consumption. Recycling PET diverts plastics from landfills and oceans, while PWS utilization mitigates coastal waste disposal (Olofinnade & Davies, 2021; Ruslan et al., 2024).

Economically, both materials are locally available and low-cost. However, PET processing (collection, washing, shredding) introduces additional cost and energy demand. Life-cycle assessment (LCA) studies are limited but indicate that PET-PWS blocks can reduce embodied energy and carbon footprint compared to conventional materials.

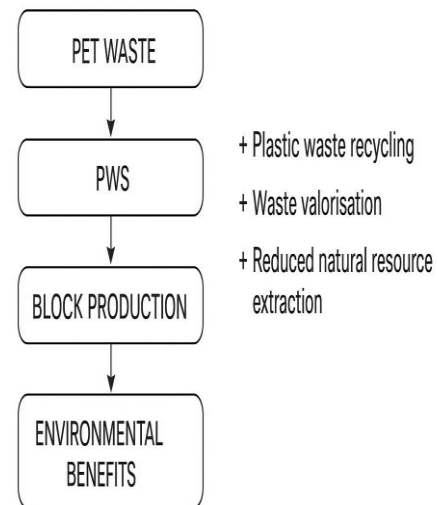


Figure 3. Life-cycle schematic showing environmental benefits of PET and PWS incorporation in block production

VI. RESEARCH GAPS AND FUTURE DIRECTIONS

The following key areas require further study:

1. Combined PET-PWS use and its mechanical/durability performance.
2. Long-term durability testing under environmental exposure (moisture, freeze-thaw, UV).
3. Surface treatment methods to improve PET-cement bonding.
4. Standardized testing and design procedures for recycled aggregate blocks.

5. Life-cycle and techno-economic analyses for practical implementation.

CONCLUSION

This review demonstrates the potential of waste PET and periwinkle shells as sustainable, lightweight materials for sandcrete and paving block production. Optimum PET replacement ($\leq 10\%$) and PWS substitution ($\leq 30\%$) achieve acceptable compressive strength, lower density, and reduced environmental impact. The integration of both materials represents an untapped opportunity for innovation in sustainable construction.

Future work should focus on hybridization strategies, durability enhancement, and developing standard guidelines for recycled-material masonry products.

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