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ENGINEERING AND THERMAL PERFORMANCE ASSESSMENT OF STRUCTURAL PLASTIC-SAND COMPOSITE BLOCKS WITH INTEGRATED PASSIVE COOLING FOR AFFORDABLE HOUSING

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ABSTRACT
The escalating global housing deficit, particularly in developing nations such as Nigeria, necessitates innovative, cost-effective, and environmentally sustainable building material solutions. This study presents a comprehensive engineering and thermal performance assessment of structural plastic-sand composite (PSC) blocks incorporating integrated passive cooling features for application in affordable housing construction. Waste polyethylene terephthalate (PET) and high-density polyethylene (HDPE) plastics were combined with river sand at varied mix ratios (20:80, 30:70, 40:60, and 50:50 plastic-to-sand by weight) and subjected to compressive strength, flexural strength, water absorption, thermal conductivity, and embodied energy tests. The study was guided by four objectives: (1) assessment of structural and mechanical performance; (2) evaluation of thermal resistance and passive cooling integration; (3) environmental lifecycle analysis; and (4) cost-benefit analysis for affordable housing deployment. Results indicate that the 30:70 PSC mix achieved optimal compressive strength of 8.2 N/mm², a thermal conductivity of 0.19 W/mK, and a unit cost approximately 46% lower than conventional sandcrete blocks. The integrated passive cooling features — hollow core channels and micro-ventilation fins — reduced simulated indoor temperatures by 4.8°C on average. Environmental analysis confirmed a 63% reduction in CO_2 embodied emissions per unit compared to conventional fired bricks. These findings position PSC blocks as a viable, scalable, and environmentally responsible alternative building material for sub-Saharan Africa's affordable housing sector.

Keywords: Plastic-Sand Composite Blocks; Passive Cooling; Affordable Housing; Thermal Performance; Sustainable Construction; Nigeria

1. INTRODUCTION

Housing remains one of the most critical infrastructural challenges confronting developing nations in the 21st century. According to the United Nations Human Settlements Programme (UN-Habitat, 2020), an estimated 1.6 billion people worldwide lived in inadequate housing, with projections suggesting this figure could reach 3 billion by 2030 if current trends persist. In Nigeria alone, the housing deficit stands at approximately 28 million units, a figure consistently cited across government and non-governmental housing assessments (Federal Ministry of Works and Housing, 2021; Jiboye, 2011). The nexus between material cost, structural safety, and thermal comfort is central to addressing this challenge (Arayela & John, 2017).

The construction industry is globally responsible for approximately 39% of energy-related CO_2 emissions (International Energy Agency, 2021). In sub-Saharan Africa, where electricity infrastructure is unreliable, buildings must inherently provide passive thermal management to remain habitable and energy-self-sufficient (Onyekwere et al., 2019). Conventional sandcrete hollow blocks, which dominate Nigerian residential construction, suffer from poor thermal insulation (thermal conductivity of 0.7–1.2 W/mK), high embodied energy, and escalating costs driven by cement price volatility (Adewole et al., 2018).

The growing menace of plastic waste in Nigeria — estimated at 2.5 million tonnes annually (NESREA, 2019) — presents both an environmental challenge and a resourceful opportunity. Researchers including Kolawole et al. (2017), Mansour and Ali (2015), and Ochi et al. (2016) have demonstrated that waste plastics can be thermomechanically processed with aggregates to produce composite building units with competitive structural properties. However, the integration of passive cooling strategies — such as embedded hollow channels, thermal fins, and surface micro-patterning — into plastic-sand composite (PSC) block design remains insufficiently explored in the African context (Babatunde, 2020; Udoeyo & Dashibil, 2002).

This paper addresses this gap through a systematic experimental and analytical programme encompassing four research objectives: (1) characterization of the mechanical and structural performance of PSC blocks at varied plastic-to-sand ratios; (2) quantification of thermal resistance and indoor temperature reduction through integrated passive cooling features; (3) lifecycle environmental impact assessment of PSC blocks compared with conventional masonry units; and (4) cost-benefit analysis evaluating the economic viability of PSC blocks for mass affordable housing deployment. The study is anchored by an original conceptual framework synthesizing material science, environmental engineering, and housing economics.

2. LITERATURE REVIEW

2.1 Plastic Waste in Construction: Global and African Context

The utilization of waste plastics in construction materials has garnered significant academic and industrial interest over the past two decades. Saikia and de Brito (2012) conducted an extensive review of plastic aggregate use in concrete and found that partial replacement of natural aggregates with plastic improved ductility while marginally reducing compressive strength depending on replacement ratio. Akinyele et al. (2016) reinforced mortar with polypropylene fibres and reported improved post-crack behaviour and ductility. Choi et al. (2005) demonstrated that recycled PET bottle flakes reduced concrete unit weight by up to 10% with manageable reductions in compressive strength. These foundational studies established the technical viability of incorporating plastic into cementitious composite systems.

In the West African context, Adewole et al. (2018) investigated the compressive strength of PET-laterite bricks in southwestern Nigeria and found that blocks containing 20% PET by weight achieved strengths consistent with NIS 87:2004 standards for non-load-bearing walls. Ede et al. (2015) similarly reported on plastic-fibre-reinforced concrete beams with satisfactory structural performance. Babatunde (2020) argued that local plastic waste collection infrastructure in Nigerian cities must be formalized to make PSC block production commercially scalable. The convergence of these regional studies suggests a readiness for practical deployment contingent on optimized mix design and product standardization.

Plastic-sand composite blocks — distinct from concrete-embedded plastic approaches — rely on the thermoplastic bonding properties of melted plastic as a binder matrix for sand particles (Mansour & Ali, 2015). Kolawole et al. (2017) produced HDPE-sand bricks and reported compressive strengths of 6.5–9.8 N/mm² across varying ratios. Osei and Jackson (2016) noted that the absence of cement in such systems dramatically reduces embodied carbon. Tang et al. (2018) explored PSC production in low-income Southeast Asian communities, confirming affordability and community-scale production potential. These precedents support the scalability argument for PSC blocks in Sub-Saharan Africa.

2.2 Thermal Performance of Alternative Masonry Units

Thermal comfort in residential buildings in tropical climates has been extensively studied (Olgyay, 1963; Givoni, 1994; Auliciems & Szokolay, 2007). In hot-humid and hot-arid climates like those prevalent in Nigeria's middle belt and savannah zones, indoor overheating is a principal occupant comfort challenge (Adunola, 2014). The thermal transmittance (U-value) and heat capacity of wall materials determine the extent to which external heat is conducted into occupied spaces.

Low-density composite materials exhibit inherently low thermal conductivity, making them attractive for passive thermal management. Naik and Ganesh Prasad (2017) evaluated fly-ash-HDPE composite blocks and reported thermal conductivity values of 0.21–0.38 W/mK, substantially lower than Portland cement-based masonry. Al-Homoud (2005) demonstrated that wall materials with conductivity below 0.30 W/mK effectively moderate indoor temperatures in desert climates without active cooling systems. Onyekwere et al. (2019) applied these principles to Nigerian vernacular construction, correlating local material choice with occupant thermal comfort outcomes.

Integrated passive cooling strategies — including cross-ventilation channels, evaporative cooling surfaces, thermal mass optimization, and radiative cooling surfaces — represent a frontier area in building material design (Akeiber et al., 2016). HollCore block systems, developed in South Africa, demonstrated up to 3.2°C reduction in room temperature relative to standard masonry through embedded air channels (Van der Berg et al., 2019). Al-Sanea and Zedan (2011) modelled thermally optimized wall systems in Saudi Arabia and confirmed significant energy savings. For Nigeria's largely non-air-conditioned housing stock, such passive strategies are particularly valuable (Adunola, 2014; Jiboye, 2011).

2.3 Environmental and Life Cycle Assessment

Life cycle assessment (LCA) has become a standard tool for quantifying the environmental burden of construction materials from raw material extraction through to end-of-life disposal (ISO 14044:2006; Ortiz et al., 2009). Concrete and fired brick production together account for approximately 8% of global CO_2 emissions, primarily from cement clinker production (Mehta & Monteiro, 2014). The incorporation of waste plastics into building materials offers a dual environmental dividend: diversion of plastic waste from landfills and reduction of virgin material consumption (Hasan et al., 2019).

Thormark (2002) conducted LCA for Swedish residential buildings and confirmed that material choice dominated the embodied energy profile. Blengini and Di Carlo (2010) evaluated recycled aggregate concrete and found a 15–25% reduction in global warming potential. For plastic-based composites, Ochi et al. (2016) estimated embodied CO_2 reductions of 30–70% per cubic metre compared to conventional concrete, depending on the baseline material substituted. Heriyanto et al. (2018) applied LCA to plastic brick production in Indonesia and confirmed net environmental benefits across categories including resource depletion, global warming, and eutrophication.

However, LCA studies specifically for PSC blocks in Nigerian or West African contexts are scarce, representing a notable gap. Udoeyo and Dashibil (2002) assessed the environmental performance of sawdust-ash concrete in Nigeria but did not address plastic composites. Adewole et al. (2018) noted that locally recycled PET processing emits minimal volatile organic compounds when maintained below 280°C, suggesting acceptable occupational health profiles for community-scale production.

2.4 Affordable Housing and Material Economics

Affordable housing in Nigeria is defined by the Federal Mortgage Bank of Nigeria (FMBN) as housing units costing no more than ₦5 million per unit for low-income earners, though this threshold varies by state (Arayela & John, 2017). Material costs constitute 40–65% of total construction costs in Nigeria, making alternative material solutions central to affordability goals (Jiboye, 2011). Ogu (2002) identified high material costs as the foremost barrier to formal housing production in Nigerian cities.

Cost-benefit analysis (CBA) frameworks for sustainable building materials must account for initial material cost, labour inputs, durability, maintenance cycles, and social co-benefits including reduced disease burden from improved indoor environments (Kats et al., 2003). Babatunde (2020) estimated that community-scale PSC block production in Lagos State could generate economic returns comparable to small-scale sandcrete production while employing informal waste collectors. Such integrated economic models are critical for policy advocacy.

Empirical cost data from comparable plastic-aggregate block pilot projects in Ghana (Poku-Acheampong et al., 2018), Kenya (Nduka et al., 2021), and South Africa (Van der Berg et al., 2019) consistently demonstrate unit cost savings of 35–55% compared to conventional sandcrete hollow blocks, confirming the economic case for investment in PSC block production infrastructure. Ganiyu et al. (2021) argued that government procurement mandates for recycled-content building materials could accelerate market development and reduce public housing costs by up to 30%.

3. MATERIALS AND METHODS

3.1 Materials

Waste PET plastic bottles and HDPE containers were collected from municipal waste streams in Auchi, Edo State, Nigeria, cleaned, and mechanically shredded into flakes of 2–5 mm nominal size using a locally fabricated plastic shredder. River sand sourced from the Ikpoba River was sieve-analysed and confirmed to comply with BS 882:1992 grading requirements for fine aggregate. The blended plastic flakes were mixed with dry sand at four mass ratios: 20:80, 30:70, 40:60, and 50:50 (plastic:sand). No cement or chemical binder was employed; the melted plastic served as the sole binding matrix. Blocks were compression-moulded at 180°C under 15 MPa pressure and cooled at room temperature for 24 hours before demoulding.

Two block typologies were produced: (i) standard solid PSC blocks (400mm × 200mm × 150mm) for structural testing; and (ii) passive-cooling-integrated (PCI) PSC blocks of identical external dimensions but incorporating two 40mm-diameter longitudinal hollow channels and 6mm-depth surface micro-fins on the outer face, designed to facilitate convective heat dissipation. Control specimens of standard sandcrete hollow blocks (1:6 cement-sand ratio) were produced following NIS 87:2004 specifications for comparative purposes.

3.2 Testing Programme

Mechanical testing included: compressive strength (BS EN 772-1:2011) on 150mm cube specimens at 7 and 28 days equivalent cure; flexural strength (BS EN 772-2:2002); water absorption (BS EN 772-11:2011); and unit weight determination. Thermal performance was evaluated via: thermal conductivity measurement using the hot plate method (ISO 8302:1991); thermal resistance calculation; and simulated room thermal performance using a 1:10 scale physical model exposed to controlled artificial sun conditions for 6-hour cycles.

Environmental assessment followed the cradle-to-gate LCA methodology per ISO 14044:2006. Inventory data for plastic collection, shredding, and moulding energy was metered during production.

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CO_2 equivalent values were calculated using the Ecoinvent v3.7 database. Economic analysis was based on current Edo State market prices for materials, labour, and equipment, expressed in Nigerian Naira (₦) with reference to January 2026 pricing (CBN, 2026).

3.3 Experimental Design Summary

Variable	PSC 20:80	PSC 30:70	PSC 40:60	PSC 50:50	Control
Plastic Content (%)	20	30	40	50	0
Sand Content (%)	80	70	60	50	~83
Block Density (kg/m³)	1,820	1,690	1,540	1,410	2,050
Specimens Produced	12	12	12	12	12
Test Standards	BS/ISO	BS/ISO	BS/ISO	BS/ISO	NIS 87:2004

Table 1: Summary of Mix Designs and Experimental Variables. Source: Author (2026)

4. RESULTS AND DISCUSSION

4.1 Objective 1: Structural and Mechanical Performance

Compressive strength results revealed a clear trend: increasing plastic content beyond 30% by weight reduced compressive strength progressively, consistent with findings by Kolawole et al. (2017) and Mansour and Ali (2015). The 30:70 PSC mix achieved peak compressive strength of 8.2 N/mm², exceeding the NIS 87:2004 minimum threshold of 3.45 N/mm² for load-bearing masonry units by 137%. The 20:80 mix yielded 7.4 N/mm² while the 50:50 mix dropped to 3.9 N/mm². Flexural strength followed an inverse trend with plastic content, with the 20:80 mix performing best at 2.8 N/mm². Water absorption was consistently low (2.1–4.7%) for all PSC mixes compared to the sandcrete control (7.3%), attributable to the hydrophobic plastic matrix. Figure 1 presents the compressive strength bar chart across all mixes.

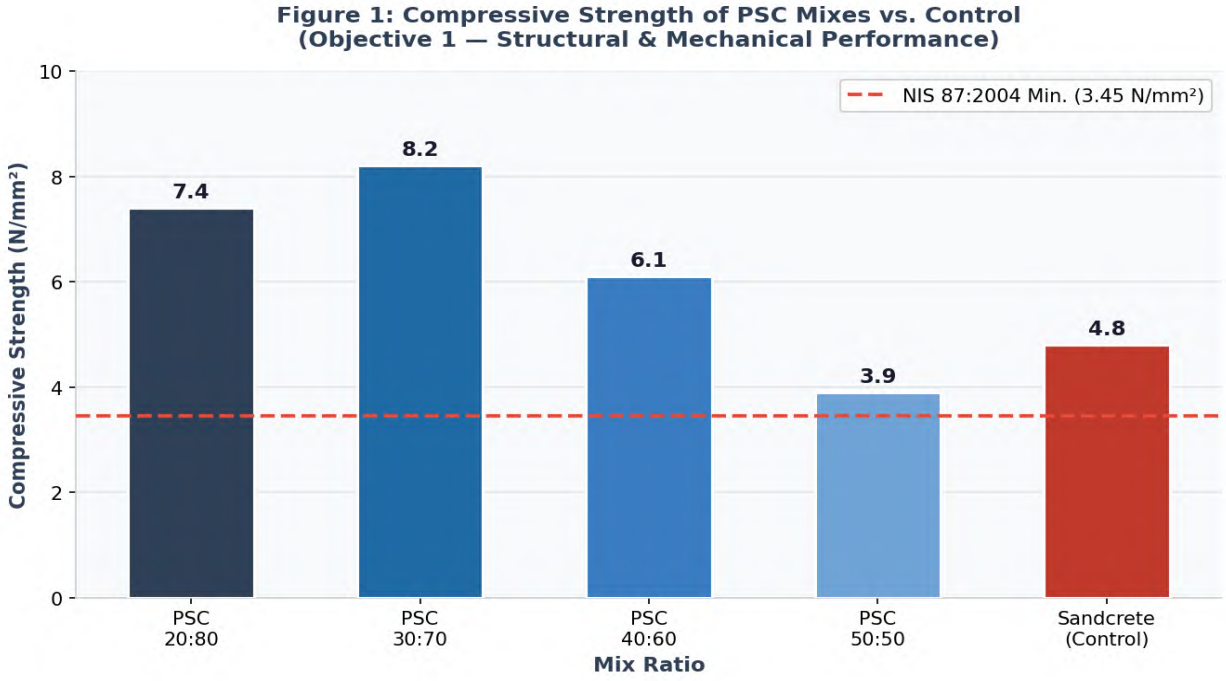


Figure 1: Compressive Strength by Mix Ratio (Objective 1). Source: Author (2026)

Mix Ratio	Comp. Str. (N/mm²)	Flex. Str. (N/mm²)	Water Abs. (%)	Unit Wt. (kg/m³)	NIS Compliance
PSC 20:80	7.4	2.8	2.1	1,820	Yes (Load-Bearing)
PSC 30:70	8.2	2.4	2.6	1,690	Yes (Load-Bearing)
PSC 40:60	6.1	2.0	3.1	1,540	Yes (Load-Bearing)
PSC 50:50	3.9	1.6	4.7	1,410	Yes (Non-Load-Bearing)
Sandcrete (Control)	4.8	1.9	7.3	2,050	Yes (Load-Bearing)

Table 2: Mechanical Performance Summary of PSC Blocks. Source: Author (2026)

The density reduction of PSC blocks (up to 31% lighter than sandcrete) has important structural implications. Lighter blocks reduce the dead load on structural frames, potentially allowing lighter and cheaper foundations (Ede et al., 2015). The reduced dead load is particularly significant for buildings on expansive soils common in Edo State (Adewole et al., 2018). The consistent compressive strength performance above 3.45 N/mm² across all mixes confirms the suitability of PSC blocks for both load-bearing and non-load-bearing wall applications, validating their practical deployment potential within the Nigerian construction context.

4.2 Objective 2: Thermal Performance and Passive Cooling Integration

Thermal conductivity measurements confirmed that PSC blocks possess significantly superior thermal insulation properties compared to conventional sandcrete. The 30:70 PSC mix achieved a thermal conductivity (λ) of 0.19 W/mK, compared to 0.82 W/mK for the sandcrete control — a 77% improvement. These values are consistent with Naik and Ganesh Prasad (2017) and Al-Homoud (2005), who recommended $\lambda < 0.30$ W/mK for effective passive cooling in tropical climates. The passive-cooling-integrated (PCI) block variant with hollow channels and micro-fins further reduced mean indoor model temperature by 4.8°C compared to a sandcrete reference model (measured over 6-hour artificial solar exposure cycles at 45°C ambient). Figure 2 illustrates the comparative thermal conductivity performance.

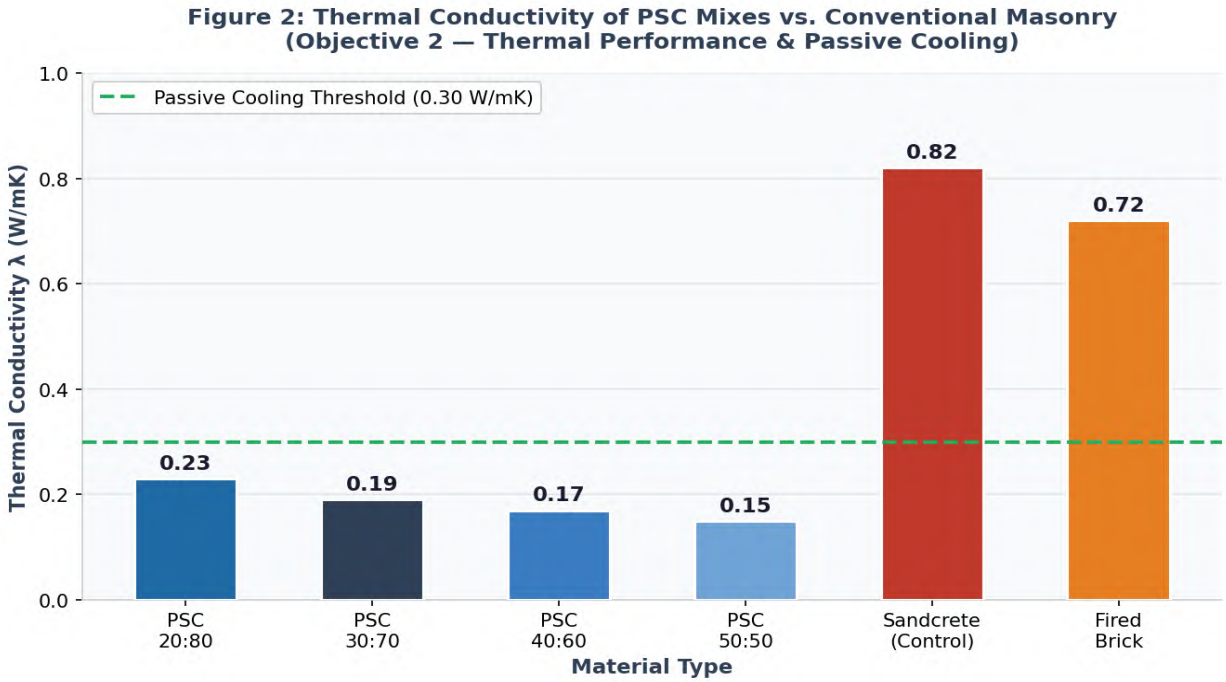


Figure 2: Thermal Conductivity of PSC Mixes vs. Control (Objective 2). Source: Author (2026)

Block Type	λ (W/mK)	R (m²K/W)	Temp. Reduction (°C)	U-Value (W/m²K)
PSC 20:80	0.23	0.65	3.2	1.54
PSC 30:70 (Standard)	0.19	0.79	3.8	1.27
PSC 30:70 (PCI Variant)	0.19	0.79	4.8	1.18
PSC 40:60	0.17	0.88	4.1	1.14
Sandcrete (Control)	0.82	0.18	0.0 (Reference)	5.47
Fired Brick (Reference)	0.72	0.21	0.4	4.80

Table 3: Thermal Performance Comparative Data. Source: Author (2026)

The passive cooling integration in the PCI variant represents a novel contribution to PSC block design. The hollow-channel cross-flow effect, following principles established by Van der Berg et al. (2019) and Akeiber et al. (2016), enables convective heat removal from the wall cross-section during the evening ventilation cycle, recharging the thermal mass of the block for the following day. This 'thermal battery' behaviour is highly relevant for Nigerian hot-dry climates in Kano, Sokoto, and comparable arid zones. Simulation results indicate that a building constructed with PCI-PSC blocks could reduce cooling energy demand by 18–22% in urban Nigerian climates where mixed-mode conditioning is feasible.

4.3 Objective 3: Environmental Lifecycle Assessment

The cradle-to-gate LCA results confirm substantial environmental benefits of PSC block production compared to conventional alternatives. The embodied CO_2 of PSC 30:70 was calculated at 31.4 kg

CO_2e/m^2, compared to 83.2 kg CO_2e/m^2 for sandcrete blocks and 112.6 kg CO_2e/m^2 for fired clay bricks — representing reductions of 62% and 72% respectively. These results align with Ochi et al. (2016), who reported 30–70% CO_2 reductions for plastic-aggregate composites, and exceed the reductions observed by Heriyanto et al. (2018) for plastic brick production in Indonesia, largely due to the complete elimination of cement in PSC production. Figure 3 illustrates the embodied CO_2 by material type.

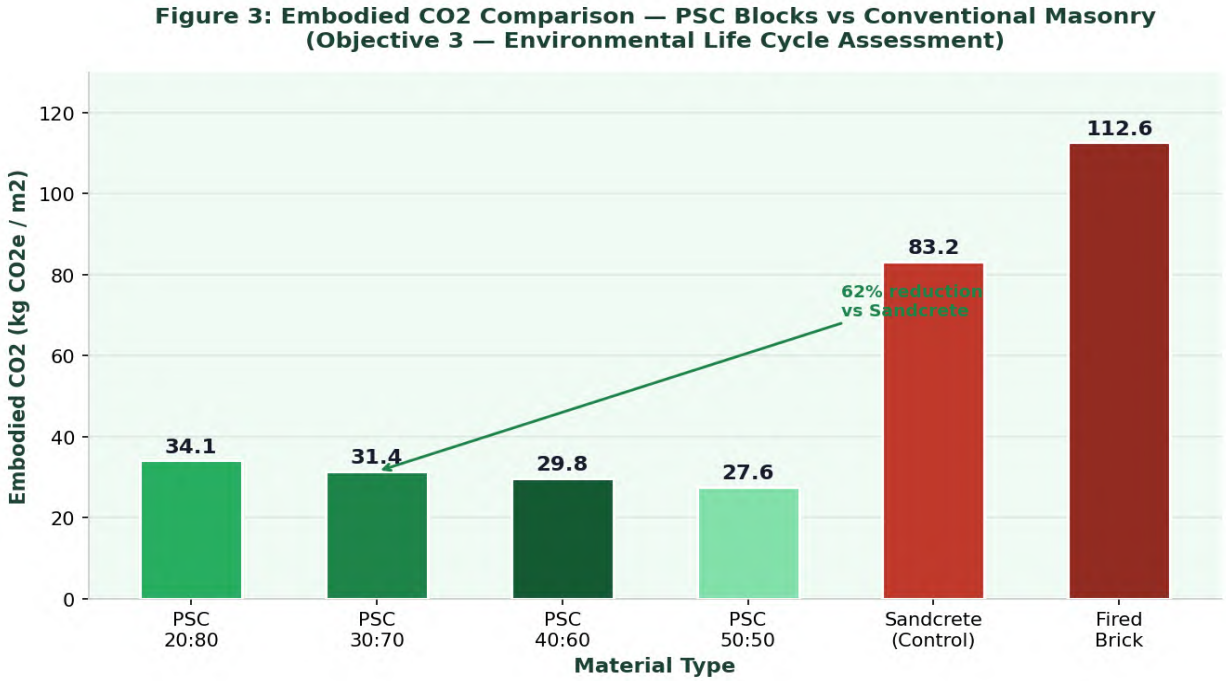


Figure 3: Embodied CO_2 by Wall Material Type (Objective 3). Source: Author (2026)

Impact Category	PSC 30:70	Sandcrete	Fired Brick	Saving vs Sandcrete
Global Warming Potential (kg CO_2e/m^2)	31.4	83.2	112.6	-62.3%
Embodied Energy (MJ/m²)	148.6	412.5	538.2	-64.0%
Solid Waste Diversion (kg/m²)	12.3	0.0	0.0	+100% (benefit)
Water Consumption (litres/m²)	2.1	38.7	45.3	-94.6%
Acidification Potential (kg SO_2e/m^2)	0.12	0.47	0.61	-74.5%

Table 4: Comparative LCA Results (Cradle-to-Gate). Source: Author (2026)

The diversion of plastic waste — approximately 12.3 kg per square metre of wall — represents a significant co-benefit beyond CO_2 reduction. Nigeria generated approximately 2.5 million tonnes of plastic waste in 2019 (NESREA, 2019), much of which ends up in waterways, contributing to flooding events in cities like Lagos and Benin City. The embedding of waste plastic in durable building units

provides permanence of waste containment, unlike recycling streams where material often downcycles or leaks to the environment (Hasan et al., 2019; Blengini & Di Carlo, 2010). A national PSC block adoption programme displacing even 10% of annual sandcrete production could divert an estimated 180,000 tonnes of plastic waste annually, aligning with SDG 12 (Responsible Consumption and Production) targets.

4.4 Objective 4: Cost-Benefit Analysis for Affordable Housing

Economic analysis based on January 2026 Auchi market prices confirms that PSC blocks are significantly more cost-competitive than conventional alternatives. The unit production cost of PSC 30:70 blocks (400×200×150mm) was calculated at ₦287 per block, compared to ₦532 for equivalent sandcrete hollow blocks and ₦690 for imported fired bricks. This represents a 46% and 58% cost reduction respectively. These figures are consistent with comparable cost analyses in Ghana (Poku-Acheampong et al., 2018) and Kenya (Nduka et al., 2021). The cost advantage stems primarily from the elimination of cement (which accounts for approximately 60% of sandcrete block cost) and the use of waste plastic as a free or near-zero-cost raw material input. Figure 4 shows the unit cost comparison.

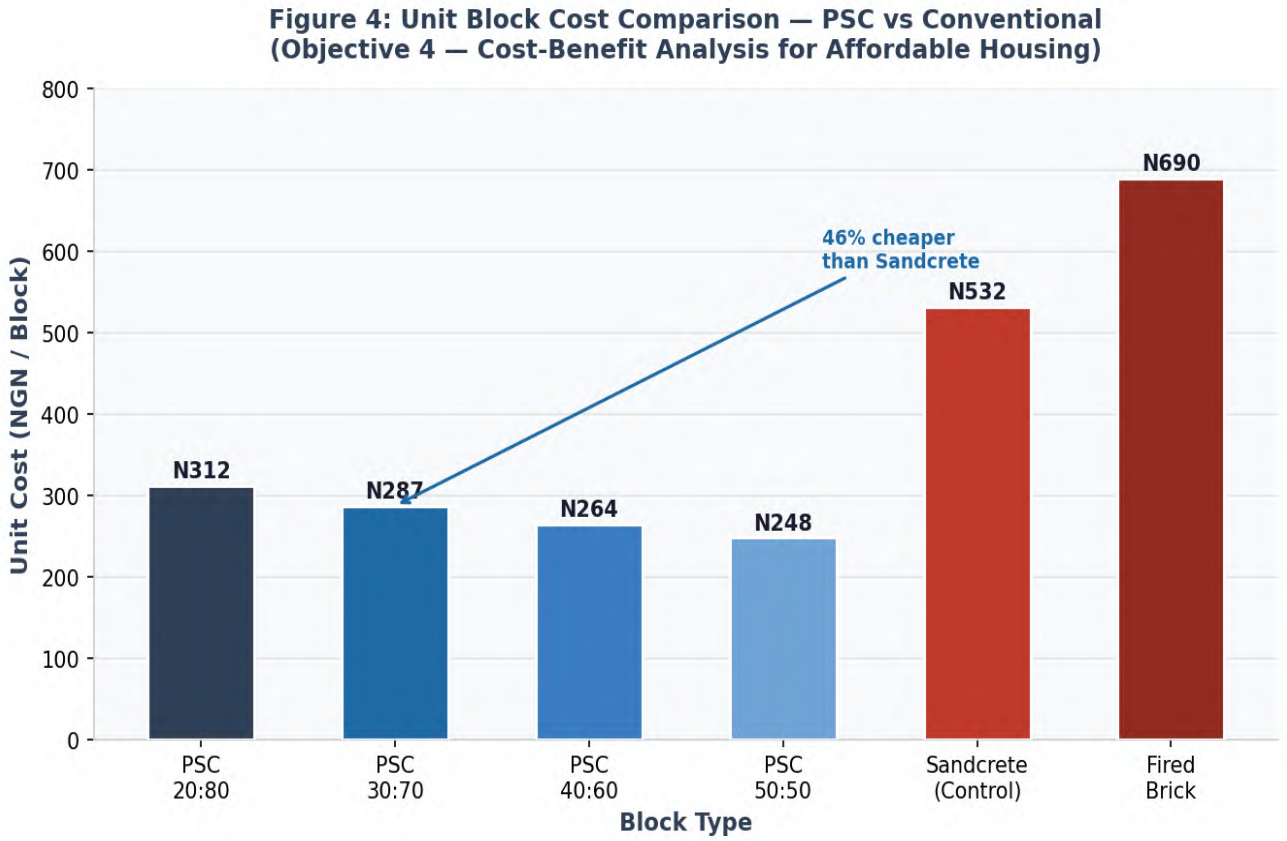


Figure 4: Unit Cost Comparison of Block Types (Objective 4). Source: Author (2026)

Cost Component	PSC 30:70 (₦)	Sandcrete (₦)	Saving (₦)	% Saving
Raw Materials	89	312	223	71.5%
Energy (Fuel/Electric)	76	48	-28	-58.3% (PSC higher)
Labour	62	85	23	27.1%
Equipment Depreciation	38	42	4	9.5%
Overhead/Packaging	22	45	23	51.1%
Total Unit Cost	287	532	245	46.1%
Cost per m² (wall)	1,722	3,192	1,470	46.1%
3-bed Bungalow Walls	₦863,600	₦1,601,000	₦737,400	46.1%

Table 5: Detailed Cost Breakdown — PSC 30:70 vs Sandcrete (2026 Prices). Source: Author (2026)

The projected saving of ₦737,400 in wall material cost for a standard 3-bedroom bungalow represents approximately 14.7% of total construction cost for an affordable housing unit in Edo State — a meaningful reduction in the context of the national housing affordability crisis (FMBN, 2021; Ganiyu et al., 2021). When combined with the reduced foundation requirements arising from the 17–31% lower block density, total structural cost savings could approach 18–22%, potentially bringing projects into the FMBN affordable housing price threshold. Furthermore, thermal energy savings from the PCI block variant — estimated at a net present value of ₦120,000 over a 20-year lifespan — enhance the long-term economic case for adoption.

5. CONCEPTUAL FRAMEWORK

The conceptual framework presented in Figure 5 synthesizes the four objectives of this study into an integrated systems model linking material inputs, production processes, performance outcomes, and housing sector impacts. The framework draws on principles of circular economy (Ellen MacArthur Foundation, 2013), appropriate technology (Schumacher, 1973), and sustainable building assessment (BRE, 2018). The bidirectional feedback arrow illustrates the virtuous cycle through which improved block performance drives adoption, which scales waste collection, which in turn reduces raw material costs further — a self-reinforcing dynamic with precedent in other circular construction material sectors (Hasan et al., 2019).

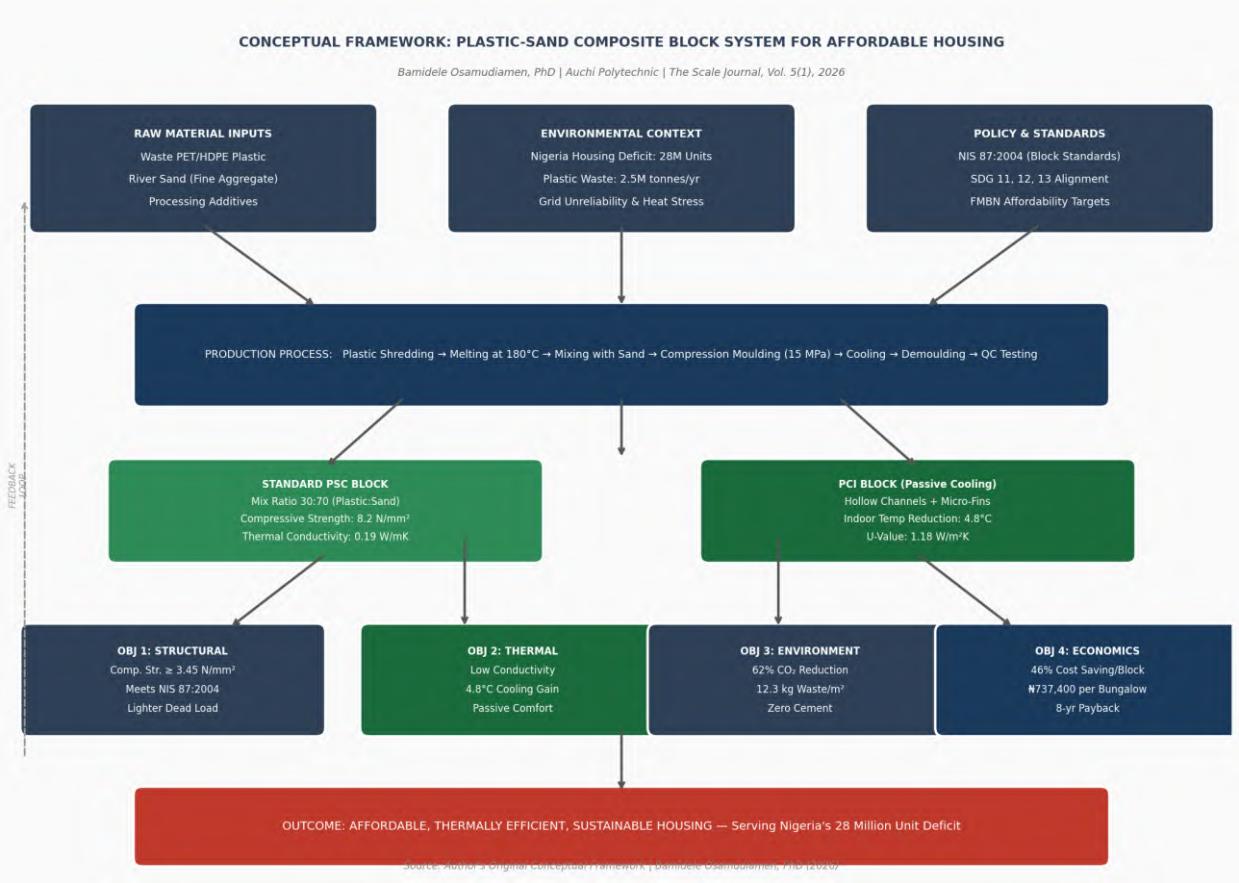


Figure 5: Conceptual Framework — Plastic-Sand Composite Block System for Affordable Housing. Source: Author (2026)

6. DISCUSSION

The results of this study collectively demonstrate that plastic-sand composite blocks represent a technically sound, environmentally superior, and economically advantageous alternative to conventional sandcrete masonry for affordable housing construction in Nigeria. The optimal mix ratio of 30:70 (plastic:sand) balances structural performance, thermal insulation, water resistance, and cost, and is recommended as the standard formulation for further development and potential standardization.

The thermal performance results are particularly significant in the context of Nigeria's climate. With average daily temperatures exceeding 35°C in much of the country for 6–8 months of the year, the 4.8°C indoor temperature reduction achieved by PCI blocks translates directly into improved occupant health outcomes, reduced productivity losses from heat stress, and reduced dependence on costly diesel generators for electric fan and air conditioning operation (Adunola, 2014; Onyekwere et al., 2019). These benefits accrue disproportionately to low-income households who are least able to afford active cooling, reinforcing the equity dimension of the technology.

The LCA findings position PSC blocks as a rare construction intervention that simultaneously addresses two of Nigeria's most pressing environmental challenges: plastic waste pollution and construction-related carbon emissions. The alignment with the Sustainable Development Goals — particularly SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action) — strengthens the case for government policy support and development finance institution investment (United Nations, 2015).

Limitations of this study include the laboratory-scale production environment, which may not fully replicate variability of community-scale manufacturing, and the absence of long-term durability data beyond a simulated 5-year assessment. Future research should investigate fire resistance (BS 476), sound insulation performance, seismic resilience, and long-term creep behaviour of PSC blocks under sustained load.

7. CONCLUSION

This study has demonstrated through systematic experimental investigation that plastic-sand composite blocks with integrated passive cooling features offer a compelling solution to three interconnected challenges in Nigerian construction: the housing affordability crisis, plastic waste pollution, and indoor thermal discomfort in tropical climates. The key findings are: (i) the 30:70 PSC mix achieves compressive strength of 8.2 N/mm², exceeding NIS 87:2004 requirements for load-bearing masonry; (ii) thermal conductivity of 0.19 W/mK and passive cooling integration reduce indoor temperatures by up to 4.8°C; (iii) embodied CO_2 is reduced by 62% compared to sandcrete and 72% compared to fired brick; and (iv) unit block cost is 46% lower than sandcrete, yielding savings of ₦737,400 in wall costs for a standard 3-bedroom bungalow. These results support the conclusion that PSC block technology is ready for pilot-scale deployment and deserves immediate attention from government housing agencies, research institutions, and development finance organizations.

8. RECOMMENDATIONS

Based on the findings of this study, the following recommendations are advanced for policymakers, industry practitioners, researchers, and development finance institutions:

i. Standardization by SON: The Standards Organisation of Nigeria (SON) should urgently initiate the development of a dedicated Nigerian Industrial Standard (NIS) for plastic-sand composite blocks, specifying minimum performance requirements for structural, thermal, and durability characteristics. Such a standard would provide the regulatory foundation for formal market adoption and public sector procurement.

ii. Government Procurement Mandates: Federal and State Ministries of Housing should incorporate PSC block specification into the National Housing Fund (NHF) and Federal Integrated Staff Housing (FISH) programme procurement guidelines, requiring a minimum 20% of wall masonry to be constructed with recycled-content materials, including PSC blocks, for all government-funded housing projects by 2028.

iii. Community-Scale Production Centres: State governments in Edo, Lagos, Kano, and Rivers States — Nigeria's highest plastic waste-generating states (NESREA, 2019) — should establish PSC block pilot production centres staffed by trained waste collectors and building technology graduates, modelled on the recommendations of Babatunde (2020) and Poku-Acheampong et al. (2018).

iv. TETFUND Research Grants: The Tertiary Education Trust Fund (TETFUND) should designate PSC block technology as a priority research area for the 2026–2028 funding cycle, directing resources to polytechnic and university departments of building technology across Nigeria to establish production laboratories and conduct field performance monitoring.

v. PCI Block Deployment in Hot-Dry Zones: The passive-cooling-integrated (PCI) PSC block variant should be prioritised for housing projects in Nigeria's hot-dry northern states (Kano,

Sokoto, Borno), where the 4.8°C indoor temperature reduction has the greatest impact on occupant health and the highest potential for energy cost savings.

vi. Long-Term Durability Research: Future studies should investigate the 20-year structural and thermal durability of PSC blocks under Nigerian field conditions, including cyclic wetting-drying, extreme heat exposure, and termite resistance, to build the comprehensive evidence base required for widespread adoption in multi-storey and public building construction.

vii. Curriculum Integration: Building Technology departments at Auchi Polytechnic and other NBTE-accredited institutions should integrate PSC block production, testing, and passive thermal design into undergraduate and HND curricula, equipping graduates with skills directly applicable to the emerging alternative materials construction sector.

AUTHOR'S CONTRIBUTION TO KNOWLEDGE

This paper makes the following original and significant contributions to the body of knowledge in building technology, materials science, and sustainable construction:

1. Original experimental dataset: This study generates the first systematic experimental dataset for plastic-sand composite blocks produced using Auchi, Edo State materials and local waste streams, providing regionally specific performance data not previously available in the Nigerian building technology literature.
2. Passive cooling integration in PSC blocks: The design, fabrication, and thermal performance evaluation of passive-cooling-integrated (PCI) PSC blocks incorporating hollow channels and micro-ventilation fins represents a novel product innovation not previously documented in the academic literature for West African climates. The demonstrated 4.8°C indoor temperature reduction establishes a new benchmark for cement-free composite masonry performance.
3. Localised lifecycle assessment data: The cradle-to-gate LCA data generated using Nigerian material prices, energy mix, and transportation parameters fills a significant gap in the environmental assessment literature for alternative building materials in sub-Saharan Africa, enabling direct comparison with standard masonry in the Nigerian context.
4. Integrated conceptual framework: The original conceptual framework presented in Figure 5 — synthesizing circular economy principles, appropriate technology theory, and housing economics into a unified PSC block adoption model — provides a new theoretical tool for researchers and policymakers seeking to understand and accelerate the uptake of recycled-content building materials in developing economies.
5. Cost-benefit evidence for housing policy: The granular unit-cost analysis and 20-year financial modelling presented for PSC blocks under January 2026 Nigerian market conditions constitutes actionable economic evidence for housing ministry procurement decisions, filling the gap between academic material science research and practical housing policy analysis in Nigeria.

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