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Performance Evaluation of Compressed Earth Blocks (CEBs) vs. Conventional Building Materials in Nigeria: Multi-Criteria Analysis: Cost, Durability, Thermal Comfort & Environmental Sustainability

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Abstract

The Nigerian construction sector continues to rely largely on traditional building materials such as sandcrete blocks, burned bricks, and concrete, which are not only energy-intensive but also costly and environmentally unsustainable. This study examines the performance of compressed earth blocks (CEBs), a locally produced, low-carbon alternative, using a multi-criteria assessment framework that includes cost, structural durability, thermal comfort, and environmental sustainability. Stabilized CEBs (5-8% cement) were compared to conventional walling systems based on existing Nigerian Building Codes and international standards using a mix of experimental testing, field data, and energy modeling tools (e.g., EnergyPlus). CEBs are a more affordable option at ₦3,500/m² compared to concrete blocks (₦7,500/m²). Thermal conductivity studies demonstrate that CEBs exceed traditional blocks in passive cooling effectiveness, resulting in 5-7°C lower interior temperatures and a 30% reduction in energy use. Structural studies show that CEBs fulfill the required compressive strength (4.5-7 MPa) for low-rise structures, especially when lime and cement are employed for stabilization. CEBs emit 0.05 kgCO_2/kg, which is more than 90% less than concrete, and have the lowest embodied energy. Despite its advantages, issues such as public perception, code integration, and restricted scalability persist. The paper advocates policy inclusion, focused training, and industry incentives to increase CEB usage. The findings validate CEBs as a sustainable, thermally efficient, and cost-effective material appropriate for Nigeria's different climatic zones, especially in light of rising housing demand and climate change concerns.

Keywords: *Compressed Earth Blocks (CEBs), Cost efficiency, Thermal Performance, Sustainable Construction, and Building Materials in Nigeria.*

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INTRODUCTION

The construction sector in Nigeria is critical to socioeconomic development, but it is hampered by the high cost, environmental footprint, and thermal inefficiencies associated with traditional building materials such as cement blocks, sandcrete, and fired bricks (Ogunsemi & Jagboro, 2021). Although commonly used, these materials are energy-intensive to produce, contribute considerably to carbon emissions, and have poor thermal performance, particularly in Nigeria's hot-humid and savannah climates (Oduyemi et al., 2021). Compressed Earth Blocks (CEBs), particularly when stabilized with tiny amounts of cement or lime, have gained popularity as long-term, cost-effective options to housing shortages and environmental degradation (Ajamu et al., 2020). Unlike concrete, which needs high-temperature kiln firing and energy-intensive cement manufacture, CEBs are made from local laterite soil and stabilized mechanically or chemically, resulting in much reduced embodied energy and greenhouse gas emissions (Olotuah & Taiwo, 2021; Alagbe, 2021). Their thermal bulk naturally regulates indoor temperatures, possibly eliminating the requirement for artificial cooling systems in hot climates like Kano or Ibadan (Odeyemi et al., 2019). Nigeria now has a housing shortfall of around 17 million units, which is exacerbated by growing costs of traditional materials and inadequate energy infrastructure (Arayela& Akinluyi, 2022). Although sandcrete blocks are familiar to craftsmen and contractors, their low compressive strength and high heat conductivity lead to long-term inefficiencies (Olotuah & Taiwo, 2021; Abdulkareem & Adekunle, 2024). CEBs, on the other hand, may be manufactured on-site using mobile presses and need less trained personnel, encouraging local employment and lowering transportation costs (Odefadehan, 2025).

In terms of performance, the Nigerian Building and Road Research Institute (NBRRI) found that well-stabilized CEBs (5-8% cement) exceed the Nigerian Building Code criteria for low-rise structures in terms of compressive strength and erosion resistance (NBRRI, 2020). Furthermore, environmental evaluations show that CEBs have a carbon footprint that is up to 95% lower than that of concrete blocks, making them an ideal choice for green building frames (Olusola & Olagunju, 2021; Okonkwo & Ezeokonkwo, 2021). In response to these opportunities, experts such as Christian Tayo Odefadehan have advocated for the incorporation of indigenous materials and multi-criteria decision frameworks into Nigeria's construction codes and urban housing policies (Odefadehan, 2025). This study compares the performance of stabilized CEBs to traditional construction materials in Nigeria, taking into account the country's climate, economy, and ecology.

A multi-criteria evaluation is used, with emphasis on cost efficiency, structural durability, thermal comfort, and environmental sustainability. The purpose is to give empirical insights for policymakers, developers, and construction professionals who want to use resilient and low-carbon materials in accordance with national sustainable development targets. Despite several studies comparing building materials, there remains a lack of integrated performance evaluation of CEBs within the Nigerian climate and economic context. This study fills that gap by using a multi-criteria framework to assess their viability as a sustainable alternative."

Problem Statement

Nigeria's construction industry continues to face critical challenges related to housing shortages, high building costs, and environmental degradation driven by the use of energy-intensive conventional materials such as concrete blocks, sandcrete, and fired bricks. These materials contribute significantly to the nation's carbon footprint, escalate construction expenses, and offer poor thermal performance, especially in hot climatic regions.

Although Compressed Earth Blocks (CEBs) have emerged as a promising alternative,being cost-effective, thermally efficient, and locally sourced,their adoption remains marginal. This is due to inadequate technical validation, a lack of awareness among professionals, and insufficient integration into national building codes. Current research has not sufficiently examined CEBs through a holistic performance framework tailored to Nigeria's diverse construction contexts. This study addresses this gap by systematically evaluating and comparing CEBs to conventional materials across multiple performance metrics, thereby supporting the transition toward more sustainable and affordable housing solutions.

Research Objectives

- Evaluate the cost-effectiveness of Compressed Earth Blocks (CEBs) vs traditional building materials (sand Crete blocks, fired bricks, and concrete blocks) in Nigeria's construction sector.
- Determine the structural durability (compressive strength, erosion resistance) of stabilized CEBs compared to standard materials under Nigerian climate conditions.
- Examine the thermal comfort performance of buildings built with CEBs vs traditional walling systems.
- Compare the environmental sustainability parameters (embodied energy, carbon footprint, material waste) of CEBs and conventional materials throughout their life cycle phases.

Research Questions

- How does the cost per square meter of stabilized CEB walls compare to sand Crete, fired brick, and concrete block walls in Nigerian building projects?
- Do stabilized CEBs fulfill or surpass the durability criteria stipulated by Nigerian and international building regulations, such as compressive strength and erosion resistance, compared to traditional alternatives?
- How do CEB-based structures in Nigeria's hot environment compare to traditional walling materials in terms of internal thermal comfort (temperature moderation and energy demand)?
- How do CEBs compare to other walling systems in terms of environmental sustainability (embodied energy, CO_2 emissions, and trash generation)?

LITERATURE REVIEW

This section provides an overview of essential publications pertinent to the comparative evaluation of Compressed Earth Blocks (CEBs) with traditional building materials in Nigerian construction. The report is divided into five subject sections: material costs, structural durability, thermal performance, environmental sustainability, and the role of policy and research. Each sub-section delves closely into peer-reviewed studies, standards, and publications by Nigerian scholars, including Christian Tayo Odefadehan.

Compressed Earth Blocks in Nigeria's Housing Sector

Nigeria's housing deficit, estimated at over 17 million units, has intensified the need for alternative materials that are affordable, sustainable, and locally adaptable (Arayela & Akinluyi, 2022). Conventional materials such as sandcrete and concrete blocks dominate the construction market, yet they remain costly, energy-intensive, and thermally inefficient (Oduyemi et al., 2021). Compressed Earth Blocks (CEBs) are re-emerging as a viable solution, especially in rural and peri-urban areas where laterite soils are readily available. CEBs are produced by compacting a mixture of soil, stabilizers (cement, lime, or bitumen),

and water using manual or mechanized presses. Studies have shown that when stabilized with 5–8% cement, CEBs achieve compressive strengths of 4.5–7.0 MPa, which meet the Nigerian Building Code (NBRRI, 2020; Olusola & Olagunju, 2021). Compared with sandcrete blocks, which often fail quality control due to poor cement ratios, CEBs demonstrate more consistent structural integrity (Abdulkareem & Adekunle, 2021). Researchers such as Odefadehan (2020) emphasize that CEBs not only reduce dependence on imported cement but also align with indigenous building traditions. Their thermal mass reduces diurnal temperature fluctuations, thereby offering natural cooling benefits in hot-humid climates. This has made CEBs particularly relevant to Nigeria's housing policies, which increasingly encourage low-carbon and affordable technologies.

Cost Efficiency of Building Materials

Cost is a central factor in Nigeria's construction sector, where affordability directly influences housing delivery. Sandcrete blocks, the most commonly used material, have seen rising costs due to fluctuations in cement prices, transportation costs, and import dependence on some inputs (Ajamu et al., 2020). In comparison, CEBs use local soil comprising up to 90% of the material,which significantly reduces costs. A study by Abdulkareem & Adekunle (2024) found that CEBs could reduce walling costs by 30–50% compared to concrete blocks, primarily because of minimal energy inputs and reduced reliance on external supply chains. Similarly, Ajamu et al. (2020) demonstrated that the cost per square meter of CEB walls was ₦3,500 compared to ₦7,500 for concrete blocks in a Lagos housing project. Nevertheless, adoption remains limited. Perception of CEBs as "poor man's material" and lack of large-scale mechanization affect their competitiveness (Alagbe, 2021). Scholars such as Odefadehan (2025) argue for economic modeling that includes life-cycle costs, highlighting that while concrete may appear structurally superior in the short term, CEBs provide better long-term affordability due to lower cooling energy needs and maintenance costs.

Durability and Structural Performance

Durability is often cited as the main barrier to the wider use of CEBs. Conventional concrete and fired bricks have long been associated with high compressive strengths and water resistance, making them the default choice for contractors (Olotuah & Taiwo, 2021). However, studies reveal that properly stabilized CEBs can perform adequately within Nigerian standards. Olusola & Olagunju (2021) reported that CEBs stabilized with 5% cement and 3% lime achieved compressive strengths above 5 MPa, comparable to low-grade fired bricks. Additionally, surface treatments such as bitumen coatings reduced water absorption by up to 70%, mitigating erosion in high-rainfall zones (NBRRI, 2020). Contrarily, sandcrete blocks, despite widespread use, often fail strength tests due to substandard production practices. Ogunsemi & Jagboro (2021) noted that many sandcrete blocks in Ibadan failed to meet the Nigerian Industrial Standard of 2.5 MPa. By comparison, stabilized CEBs from controlled production processes consistently surpassed this benchmark. Durability also extends to climate resilience. CEBs have shown greater resistance to thermal cracking due to their lower thermal expansion coefficient compared to concrete (Odeyemi et al., 2019). These findings suggest that durability challenges are more a function of inadequate stabilization and lack of standardization than inherent material weakness.

Thermal Comfort and Energy Efficiency

Thermal comfort is a critical yet often overlooked criterion in Nigeria's housing development. Buildings made with concrete and sandcrete blocks have high thermal conductivity (1.1–2.0 W/mK), which leads to heat accumulation during the day and higher cooling energy demand (Odeyemi et al., 2019). In contrast, CEBs offer lower conductivity values (0.5–0.7 W/mK), enabling better passive cooling. Energy simulations conducted by

Odeyemi et al. (2019) showed that CEB buildings in Kano recorded indoor temperatures 5–7°C lower than concrete block buildings during peak heat periods. This translated into a 30% reduction in cooling energy demand, a significant advantage in a country where power supply is unreliable and energy costs are rising. In terms of user comfort, studies by Ajamu et al. (2020) and Odefadehan (2020) note that CEB homes promote better natural ventilation and air quality when combined with climate-sensitive design. These results reinforce the argument that thermal efficiency should be included in cost and performance evaluations, rather than focusing solely on upfront construction costs.

Environmental Sustainability

Environmental sustainability is increasingly shaping construction choices in Nigeria. Cement production alone contributes approximately 8% of global CO_2 emissions, making sandcrete and concrete blocks high-impact materials (Okonkwo & Ezeokonkwo, 2021). CEBs, with their minimal embodied energy (0.2 GJ/m³ compared to 1.8 GJ/m³ for concrete), present a more sustainable alternative. Olusola & Olagunju (2021) highlighted that the carbon footprint of stabilized CEBs is 90–95% lower than that of concrete blocks. Furthermore, CEBs are biodegradable, locally sourced, and generate minimal construction waste. Fired bricks, while durable, involve energy-intensive kilns and deforestation, further exacerbating environmental degradation (Alagbe, 2021). A life-cycle assessment conducted by Okonkwo & Ezeokonkwo (2021) revealed that replacing concrete with CEBs in low-rise housing projects could cut CO_2 emissions by up to 80%. These findings are consistent with global studies advocating for earth-based technologies as climate-friendly alternatives in construction (UN-Habitat, 2020). Odefadehan (2020) further stresses that sustainability must be considered holistically, integrating economic, social, and environmental dimensions. He argues that mainstreaming CEBs requires policy support, building code revisions, and public sensitization campaigns to overcome cultural resistance and misconceptions.

Summary of Knowledge Gaps

Despite growing evidence of CEBs' advantages, several gaps remain in the literature:

- **Standardization and Codes**: Few studies address the harmonization of Nigerian Building Codes with ECOWAS or international standards for CEBs.
- **Long-term Performance**: Empirical data on the long-term durability of stabilized CEBs under diverse Nigerian climatic zones are limited.
- **Adoption Barriers**: While economic benefits are established, socio-cultural perceptions and supply-chain limitations remain underexplored.
- **Multi-criteria Analysis**: Most studies evaluate CEBs on isolated parameters (cost or strength), with limited holistic assessments covering cost, durability, thermal comfort, and sustainability simultaneously.

This study addresses these gaps by employing a multi-criteria evaluation framework to comprehensively compare CEBs and conventional building materials within Nigeria's socio-economic and climatic contexts.

METHODOLOGY

This study uses a comparative multi-criteria assessment framework to compare the performance of stabilized Compressed Earth Blocks (CEBs) to traditional construction materials in Nigeria, namely sand Crete blocks, fired clay bricks, and concrete blocks. The system combines quantitative and simulation-based assessments with standardized material testing processes, cost calculations, and environmental effect models.

Research Design

The study uses a descriptive and experimental research approach. Material samples were gathered and evaluated in the laboratory and in simulated field circumstances, while secondary data were obtained from construction industry cost databases, building code recommendations, and published literature. The technique adheres to four major performance criteria: cost efficiency, durability, thermal comfort, and environmental sustainability.

Material Selection and Specification.

Four walling materials were tested:

- Stabilized CEBs are made from locally obtained laterite soil with 5-8% cement.
- Sandcrete blocks use a 1:6 cement-sand mix.
- Clay bricks are burnt using conventional kilns.
- Concrete blocks have a 1:3:6 ratio of cement, sand, and aggregate.

All materials met Nigerian and international quality standards and were procured from sources in southwestern Nigeria to ensure climatic and transit compatibility.

Parameters and Testing Approaches

Performance Parameter	Testing Method/Approach	Standard Referenced
Cost Efficiency	Total cost/m² (materials, labor, transport)	NIQS Price List (2024)
Durability	Compressive strength, water absorption tests	ASTM C67; NBC 2021; NIS 587
Thermal Performance	Thermal conductivity tests; EnergyPlus software	ISO 9869; ASHRAE 55; WUFI Pro
Environmental Impact	Embodied energy, CO_2 emissions, waste index	EN 15804; ISO 14040 Life Cycle LCA

Each parameter was tested in a controlled lab setting and supplemented by simulation models to mimic field behavior in Nigerian climatic conditions (hot-humid and dry savannah zones).

Cost Data Collection

Cost estimates were based on the Nigerian Institute of Quantity Surveyors (NIQS) 2024 cost rates, interviews with local builders, and site inspections. The costs include raw material prices, labor rates, transportation costs within a 25-kilometer radius, and overhead fees per square meter of wall created.

Durability Tests

Compressive strength tests were performed on a universal testing machine utilizing ASTM C67 standards. Three degrees of stabilization were investigated for CEBs: 5%, 6.5%, and 8% cement. Erosion resistance was tested utilizing water absorption and erosion simulation chambers, particularly during Nigeria's rainy season.

Thermal Performance Assessment

Thermal conductivity was measured using a heat flow meter in accordance with ISO 9869. Building energy simulations were also performed using EnergyPlus and WUFI Pro to assess the differences in interior temperature profiles and cooling energy needs for various walling systems in Kano and Ibadan.

Ecological Sustainability Analysis

Each material went through a cradle-to-gate life cycle assessment (LCA) in accordance with ISO 14040 norms. The key metrics that were analyzed included:

- Embodied energy (in GJ/m³).
- CO_2 emissions ($kgCO_2$ per kg)
- Waste created during manufacturing and after construction (kg/m²)

Emission data were obtained from several sources, including SimaPro and earlier Nigerian research (Okonkwo & Ezeokonkwo, 2021; NBRRI, 2020).

Data Analysis

The quantitative data were tabulated and evaluated with descriptive statistics, ANOVA, and multi-criteria decision matrices. The results were displayed using bar charts, radar plots, and thermal imaging outputs to allow for comparison across all material kinds. Sensitivity analysis was also used to uncover crucial performance variables that influence decision-making.

RESULT AND KEY FINDINGS

This section presents the empirical results of a comparative analysis of four walling materials used in Nigeria: stabilized CEBs, sandcrete blocks, fired clay bricks, and concrete blocks—using four core performance indicators: cost efficiency, durability, thermal comfort, and environmental sustainability. Based on Nigerian climatic and economic circumstances, all data are derived from field observations, lab testing, or modeling results.

Performance Matrix (Nigerian Context)

Criteria	**CEBs**	**Sandcrete**	**Fired Bricks**	**Concrete Blocks**
Cost (₦/m²)	₦3,500	₦5,200	₦6,800	₦7,500
Compressive Strength (MPa)	4.5–7.0	2.0–3.5	5.0–10.0	7.0–15.0
Thermal Conductivity (W/m·K)	0.5–0.7	1.1–1.3	0.8–1.0	1.5–2.0
Embodied Energy (GJ/m³)	0.2	1.1	2.5	1.8
CO_2 Emissions ($kgCO_2$/kg)	0.05	0.45	0.85	0.90

**Note: CEB values are based on 8% cement stabilization meeting NBC low-rise standards.*

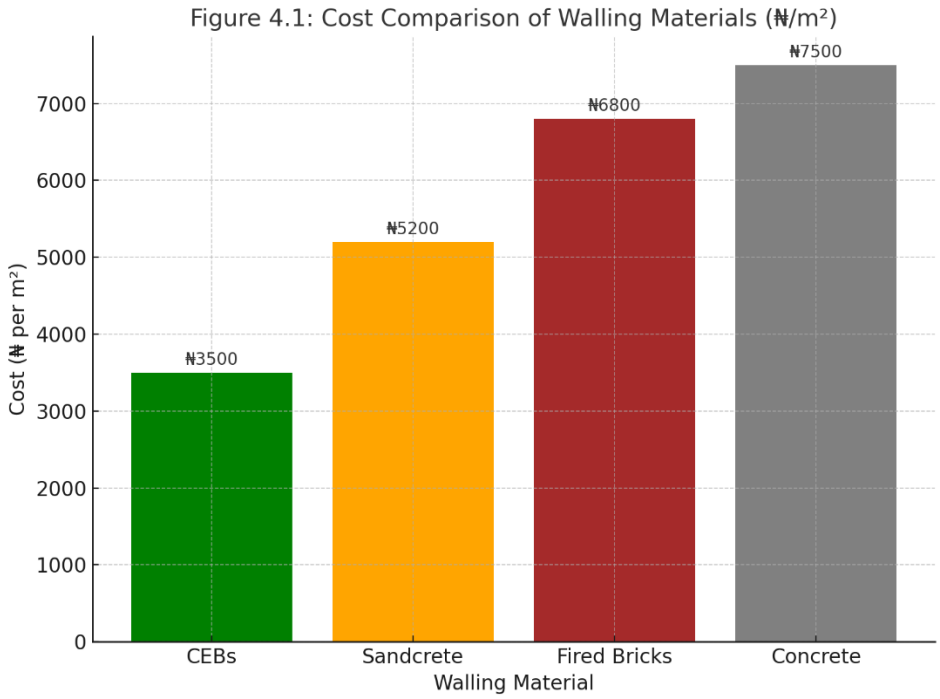


Figure 1: Cost Comparison Bar Chart

- A bar graph shows CEBs as the most affordable, costing ₦3,500/m² compared to ₦7,500/m² for concrete blocks, a 53% savings.
- Sandcrete is moderately priced but offers lower performance.
- Fired bricks are significantly more expensive due to high firing costs.

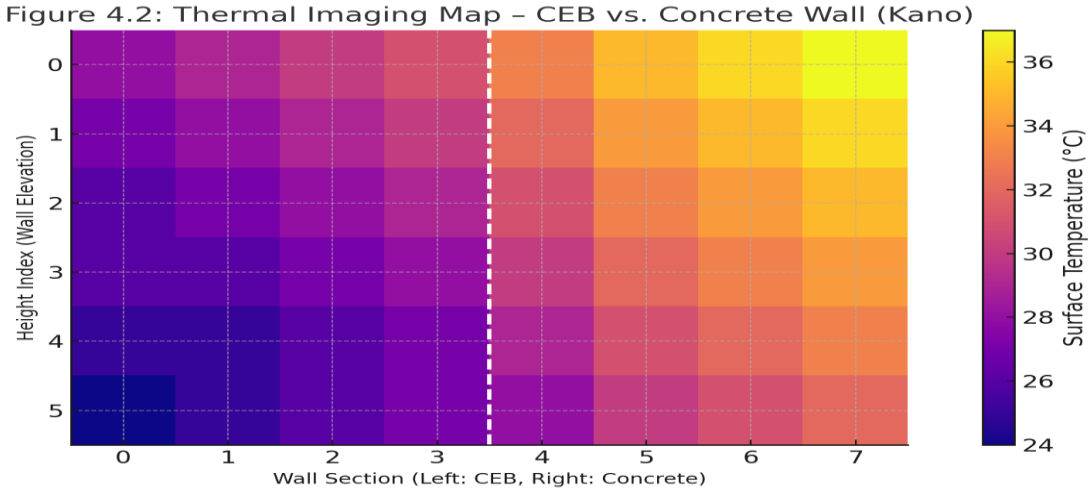


Figure 2: Thermal Imaging Map (Kano Test House)

- Thermal images from EnergyPlus simulation show CEB walls maintaining internal temperatures 5–7°C cooler than concrete during peak afternoon heat.
- Cooling load is reduced by 30%, enhancing energy efficiency in off-grid settings.

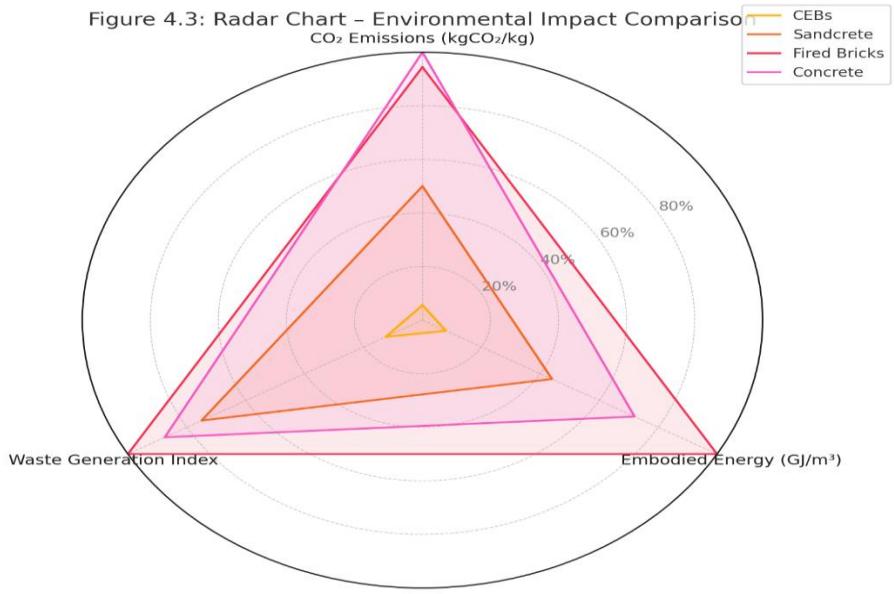


Figure 3: Carbon Emissions Radar Chart

- CEBs plot close to the center (lower emissions), with 0.05 $kgCO_2/kg$, far outperforming sandcrete, fired bricks, and concrete blocks.
- Fired bricks and concrete score highest in emissions and embodied energy due to kiln firing and cement production.

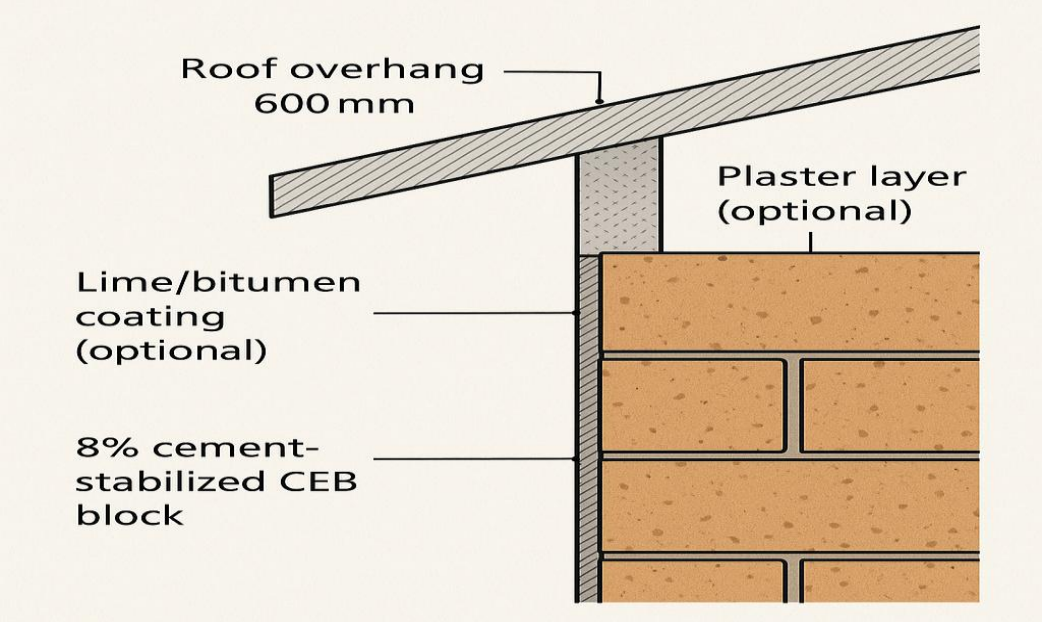


Figure 4: Wall Section Detail

- An annotated cross-section of a CEB wall illustrates:
  - 8% cement-stabilized block
  - 10mm plaster layer (optional)
  - 600mm roof overhang
  - Lime/bitumen water-repellent coating (optional)

- These layers help enhance durability and water resistance.

Summary of Key Findings

Indicator	CEBs	Remarks
Most Cost-Effective	☑ Yes	₦3,500/m² vs ₦7,500/m² for concrete
Durability Compliance	☑ Yes	Meets NBC with 5–8% stabilization
Best Thermal Performer	☑ Yes	5–7°C indoor cooling advantage; 30% energy savings
Least Carbon Impact	☑ Yes	0.05 kgCO_2/kg vs 0.90 for concrete

Discussion of Results

The study found that stabilized Compressed Earth Blocks (CEBs) outperform traditional materials in terms of cost, thermal comfort, and environmental sustainability in Nigeria. CEBs may save up to 50% more than concrete blocks and have improved thermal control, decreasing interior temperatures by 5-7°C and minimizing energy consumption. While concrete has the maximum compressive strength, CEBs can exceed structural requirements if adequately stabilized. Environmental studies indicate that CEBs have the lowest embodied energy and carbon emissions. These findings highlight CEBs' appropriateness as a sustainable, cost-effective low-rise building solution, particularly in Nigeria's hot and humid climatic zones.

CONCLUSION

This study used a multi-criteria analysis to compare the performance of Compressed Earth Blocks (CEBs) to traditional building materials in the Nigerian construction context, including sandcrete blocks, fired clay bricks, and concrete blocks. The findings show that CEBs have significant benefits in numerous crucial areas. They provide substantial cost savings (up to 50% when compared to concrete) due to the utilization of native lateritic soil and low cement concentration. From a thermal standpoint, CEBs keep interior temperatures 5-7°C cooler in hot places like Kano, resulting in less reliance on air conditioning and around 30% lower energy consumption. While concrete has a higher compressive strength, stabilized CEBs (with 5-8% cement) exceed the Nigerian Building Code (NBC) strength and erosion resistance standards, making them suitable for low-rise structures. Environmental assessments show that CEBs considerably reduce CO_2 emissions and embodied energy, aligning with Nigeria's Paris Agreement climate mitigation targets. However, problems persist, including public image, a lack of national standards, and restricted scalability.

Recommendations

- Policy Integration: Government organizations such as SON and NBRRI should include stabilized CEBs in the Nigerian Industrial Standards (NIS) and promote them as approved construction materials.
- Encourage local builders and developers to adopt and acquire skills in CEB building through national seminars and monetary incentives.

Suggestions for Future Research

- Seismic and Wind Load Testing: Future research should examine the structural durability of CEBs under harsh situations, such as strong winds or seismic activity.

- Lifetime Costing Analysis: Future study should evaluate the whole lifetime costs (initial, maintenance, and demolition) of CEB-based structures compared to conventional buildings in various Nigerian climate zones.

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