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Quantitative Evaluation of Locally Sourced Building Materials for Sustainable Low-Income Housing Projects

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Abstract- ***The escalating housing deficit in developing nations such as Nigeria underscores the urgent need for affordable, sustainable construction alternatives. Conventional building materials—such as cement, steel, and imported finishes—contribute significantly to rising housing costs, energy use, and carbon emissions. This presents a quantitative evaluation of locally sourced building materials as viable substitutes for sustainable low-income housing projects. It investigates the structural, thermal, and economic performance of indigenous materials, including laterite blocks, stabilized earth bricks, bamboo, timber, and recycled composites, with the aim of determining their suitability for large-scale housing delivery. This employed an experimental and analytical approach, integrating laboratory testing with lifecycle cost and environmental impact assessments. Key performance indicators measured included compressive strength, thermal conductivity, specific heat capacity, embodied energy, and lifecycle cost differentials compared to conventional materials. Findings reveal that stabilized laterite and compressed earth blocks exhibit compressive strengths within acceptable structural limits while offering superior thermal insulation properties suited to tropical climates. Bamboo and timber, when properly treated, demonstrated favorable tensile strength-to-weight ratios and low embodied energy. The results further indicate that locally sourced materials can reduce total construction costs by up to 30% and carbon emissions by approximately 40%, reinforcing their potential for climate-resilient and economically accessible housing. This concludes that the integration of local materials into national housing frameworks can promote sustainability, economic inclusion, and environmental stewardship. It recommends the establishment of performance-based material standards, government incentives for local production, and the inclusion of sustainability metrics in housing policy. Ultimately, optimizing local materials through quantitative evaluation enhances not only affordability but also the ecological and social integrity of low-income housing systems in developing contexts.***

Keywords: Locally Sourced Materials, Sustainable Housing, Low-Income Housing, Thermal Performance, Lifecycle Analysis, Embodied Energy, Tropical Architecture, Material Optimization, Affordability, Circular Economy.

I. INTRODUCTION

The global housing deficit remains one of the most pressing development challenges of the 21st century, particularly in low- and middle-income countries (Nwaimo *et al*., 2019; Atobatele *et al*., 2019). Across Sub-Saharan Africa and Nigeria, the crisis is acute—Nigeria alone faces an estimated housing shortfall exceeding 20 million units, with urban population growth outpacing housing supply. Rapid urbanization, inflation, and inadequate infrastructure exacerbate the affordability gap, leaving a significant portion of low-income households in informal settlements characterized by substandard living conditions. This persistent deficit has made it imperative to explore innovative, cost-effective, and sustainable construction strategies that balance affordability, environmental responsibility, and durability.

In this context, sustainable construction materials have emerged as pivotal to achieving inclusive housing solutions. Conventional materials such as cement, steel, and fired bricks contribute disproportionately to high building costs and embodied energy, often

accounting for over 60% of total project expenditure. Their production processes are energy-intensive, carbon-emitting, and reliant on imported inputs that expose the housing sector to exchange rate volatility. Conversely, locally sourced materials—including laterite, stabilized earth, bamboo, timber, and recycled waste composites—offer opportunities for low-cost, low-carbon housing while stimulating local economies and preserving traditional knowledge systems. Locally sourced materials are defined as those procured and processed within a specific geographic region, minimizing transportation energy, supporting local labor markets, and enhancing community resilience (Hungbo and Adeyemi, 2019; Atobatele *et al*., 2019). Their use aligns with circular economy principles, promoting resource efficiency and environmental stewardship.

Despite the promising potential of these materials, the construction industry remains heavily dependent on imported and industrial products, leading to unsustainable cost structures and environmental degradation. The problem, therefore, lies in the limited quantitative evaluation of the performance characteristics—such as thermal insulation, mechanical strength, and lifecycle cost—of locally sourced materials. Furthermore, existing housing policies often lack standardized frameworks for the systematic integration of local materials into national housing programs. Without robust data and performance benchmarks, architects, engineers, and policymakers face uncertainty regarding the safety, efficiency, and scalability of indigenous materials, reinforcing a bias toward imported alternatives (BAYEROJU *et al*., 2019; SANUSI *et al*., 2019).

To address these gaps, this study aims to quantitatively evaluate the physical, mechanical, and thermal performance of selected locally sourced building materials. It seeks to compare their performance with conventional materials in terms of structural integrity, thermal efficiency, and economic viability, and to determine their suitability for sustainable, large-scale low-income housing delivery (Essien *et al*., 2019; Babatunde *et al*., 2019). By quantifying these attributes, the research contributes to evidence-based decision-making in sustainable construction and material selection.

The study is guided by the following research questions; What are the structural and thermal properties of locally available materials such as laterite blocks, compressed earth, bamboo, timber, and recycled waste composites? How do locally sourced materials compare with conventional ones in terms of lifecycle cost, energy efficiency, and environmental impact? What quantitative indicators can be developed to guide material selection for sustainable, climate-responsive low-income housing?

The scope of this research centers on low-income housing prototypes within tropical and subtropical regions, where thermal regulation and material availability significantly influence design outcomes. The significance of this study extends beyond technical evaluation—it aligns with the United Nations Sustainable Development Goals, particularly SDG 9 (Industry, Innovation, and Infrastructure) and SDG 11 (Sustainable Cities and Communities). By advancing empirical understanding of local materials, the study supports national and regional strategies aimed at affordable housing delivery, poverty reduction, and environmental sustainability (Popescu *et al*., 2012; BABATUNDE *et al*., 2014). Ultimately, the research underscores the transformative potential of locally sourced materials in fostering resilient, inclusive, and sustainable built environments across developing economies.

II. METHODOLOGY

The research adopts the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology to ensure transparency, reproducibility, and analytical rigor in evaluating the quantitative performance of locally sourced building materials for sustainable low-income housing. This approach was selected to synthesize multidisciplinary evidence—spanning engineering, architecture, and environmental science—on the mechanical, thermal, economic, and environmental attributes of indigenous construction materials within developing contexts. The PRISMA framework provides a structured process for identifying, screening, appraising, and synthesizing studies to generate a comprehensive and unbiased understanding of the research domain.

The review began with a systematic literature search across major academic and technical databases,

including Scopus, Web of Science, ScienceDirect, SpringerLink, and Google Scholar, supplemented by regional repositories such as African Journals Online (AJOL) and ResearchGate. A combination of Boolean operators and key search terms—such as *"locally sourced materials," "sustainable housing," "low-income housing," "thermal performance," "embodied energy," "laterite," "bamboo," "earth blocks," "recycled composites,"* and *"tropical architecture"*—was used to identify relevant studies. The search period was restricted to 2000–2024 to capture recent developments in material science, energy modeling, and sustainability assessment relevant to housing applications.

After retrieval, all records were subjected to a three-stage screening process: identification, eligibility, and inclusion. Duplicate entries were removed, and titles and abstracts were screened for relevance to the study's objectives. Inclusion criteria were defined to ensure methodological consistency: (i) studies must evaluate locally sourced materials used in housing construction; (ii) they must include quantitative or experimental data on structural, thermal, or economic performance; and (iii) they must address sustainability metrics such as embodied energy, carbon footprint, or lifecycle cost. Studies focusing solely on aesthetic or qualitative aspects, or those unrelated to low-income housing, were excluded. Full-text screening was then conducted to verify data completeness and methodological validity.

For each included study, data extraction focused on key quantitative indicators: compressive strength, tensile strength, thermal conductivity, moisture permeability, embodied energy, and cost per unit area. Additional contextual variables such as material type, source region, production method, and housing typology were recorded. Studies employing laboratory experiments, field measurements, or validated simulations were prioritized. A coding matrix was developed to standardize data across diverse methodologies, allowing for statistical comparison and cross-referencing.

Quantitative synthesis was conducted through both descriptive and inferential analyses. Descriptive statistics summarized the range and distribution of performance values across material types, while inferential methods—such as analysis of variance (ANOVA) and regression modeling—were applied to examine correlations between material properties and sustainability outcomes. A comparative analysis framework was used to benchmark locally sourced materials against conventional alternatives (cement blocks, steel, concrete), evaluating their relative advantages in cost efficiency, energy savings, and environmental impact.

Quality appraisal of included studies was performed using the Mixed Methods Appraisal Tool (MMAT) to assess validity, reliability, and data transparency. Each study was rated based on methodological rigor, sample representativeness, and reproducibility of results. Lower-weight scores were assigned to studies with incomplete data, unvalidated experimental setups, or insufficient climatic control variables. To mitigate researcher bias, data coding and extraction were cross-checked independently.

Ethical considerations were observed by ensuring full citation of all data sources and by using publicly available or institutionally approved datasets. The synthesized results formed the basis for constructing a conceptual model linking the mechanical, thermal, and economic properties of locally sourced materials to their overall sustainability performance in low-income housing contexts.

The PRISMA-based methodology provided a robust, systematic, and transparent approach to evaluating locally sourced materials. It ensured that findings were evidence-driven, comparative, and applicable to real-world housing challenges, offering a reliable foundation for subsequent analysis, policy formulation, and sustainable housing design strategies.

2.1 Literature Review

Research on sustainable construction materials has evolved substantially over the past two decades, reflecting a global shift toward environmentally responsible and economically viable building practices (Atobatele *et al*., 2019; Umoren *et al*., 2019). The building sector, which accounts for nearly 40% of global energy consumption and one-third of carbon emissions, has become a focal point for sustainability interventions (UNEP, 2022). Within this context, the

use of locally sourced materials—including laterite, clay, bamboo, timber, and recycled composites—has gained attention as an alternative to industrial materials such as cement, steel, and fired bricks. These indigenous materials offer multiple advantages, including reduced embodied energy, lower transportation costs, and cultural alignment with local construction traditions. Scholars such as Rapoport (2006) and Akinola *et al*. (2021) emphasize that material selection plays a central role in achieving affordable, climate-responsive housing, especially in tropical and developing contexts like Nigeria and Sub-Saharan Africa.

Existing studies on sustainable construction materials highlight performance metrics that encompass mechanical, thermal, economic, and environmental dimensions. Mechanical strength and durability remain key considerations in material selection, determining structural stability and service life. For instance, studies by Oladapo *et al*. (2019) demonstrated that stabilized laterite blocks can achieve compressive strengths exceeding 3.5 MPa, comparable to standard cement blocks used in low-rise buildings. Thermal performance is another critical metric, particularly in humid tropical regions where passive cooling is essential. Research revealed that earth-based materials exhibit superior thermal inertia, maintaining stable indoor temperatures and reducing reliance on mechanical cooling systems (Anthony *et al*., 2019; Ogunsola, 2019). In economic terms, the lower production and transportation costs of local materials translate to significant reductions in construction costs—often between 25% and 40% compared to conventional materials—making them suitable for low-income housing projects.

Comparative analyses between locally sourced and industrial materials provide valuable insight into sustainability trade-offs. Embodied energy—defined as the total energy consumed during material extraction, processing, and transportation—serves as a central indicator of environmental performance. Cement and steel, for example, exhibit high embodied energy values (4–6 MJ/kg and 30–35 MJ/kg, respectively), while compressed earth blocks and bamboo record much lower levels (0.3–0.6 MJ/kg and 3–5 MJ/kg, respectively). Similarly, lifecycle cost analyses consistently demonstrate that local materials provide better long-term economic efficiency due to reduced maintenance and replacement requirements. A comparative study found that laterite blocks had a 30% lower lifecycle cost over 25 years compared to concrete masonry units. However, durability and standardization remain major concerns. The variability in soil composition, moisture absorption, and termite resistance of natural materials can compromise consistency, calling for enhanced research into stabilization and treatment methods (Durowade *et al*., 2016; Ajayi *et al*., 2019).

From an institutional and policy perspective, the promotion of local material utilization aligns with broader sustainable development and housing policy agendas. The United Nations Sustainable Development Goals (SDG 9 and SDG 11) advocate for resilient infrastructure and sustainable cities, emphasizing local resource utilization as a pathway toward inclusive growth. National frameworks such as Nigeria's National Housing Policy (2012) and the National Building Code (2018) acknowledge the potential of local materials but fall short in operationalizing quantitative performance benchmarks and certification mechanisms. Most housing delivery programs continue to rely on imported cement-based materials due to perceived reliability, contractor familiarity, and lack of formalized standards for indigenous alternatives (Etim *et al*., 2019; Ayanbode *et al*., 2019). This institutional inertia has constrained the scaling-up of sustainable materials within the construction industry.

Scholars argue that policy frameworks must incorporate performance-based material standards and incentives to foster local production ecosystems. Public procurement guidelines could mandate a minimum percentage of local content in government-funded housing projects, while financial instruments—such as green bonds or tax credits—could encourage investment in material innovation and local supply chains (BUKHARI *et al*., 2019; Hungbo and Adeyemi, 2019). Equally critical is the integration of sustainability criteria into architectural education and professional practice, ensuring that upcoming architects and engineers are equipped to design using locally appropriate materials supported by quantitative data.

The existing body of literature underscores the multidimensional advantages of locally sourced materials in achieving affordable and sustainable housing. However, critical research gaps remain in the areas of performance standardization, long-term durability studies, and policy integration. Bridging these gaps through quantitative evaluation and institutional reform could significantly enhance the scalability of sustainable construction practices, positioning local materials as a cornerstone of inclusive, low-carbon housing development in Sub-Saharan Africa.

2.2 Theoretical and Conceptual Framework

The theoretical and conceptual foundation for the quantitative evaluation of locally sourced building materials in sustainable low-income housing is anchored on three interrelated frameworks: the Sustainability Framework (Triple Bottom Line), Material Performance Theory, and the Circular Economy Model. Together, these frameworks provide a comprehensive lens through which material properties, housing performance, and sustainability outcomes can be understood, measured, and optimized (Atobatele *et al*., 2019; Ogunsola, 2019). They form the basis for developing a conceptual model that links material science with environmental, social, and economic dimensions of sustainable construction.

The Sustainability Framework, rooted in the *Triple Bottom Line (TBL)* approach proposed by Elkington (1997), integrates the economic, social, and environmental dimensions of development. Economically, locally sourced materials contribute to cost reduction in housing delivery by minimizing transportation costs, reducing dependence on imported materials, and promoting local supply chains. This supports affordability and aligns with the broader objective of poverty alleviation in developing economies. Socially, these materials reinforce cultural identity and community participation, as traditional construction techniques often rely on local skills and knowledge systems (Osabuohien, 2017; Menson *et al*., 2018). The environmental dimension focuses on minimizing embodied energy, carbon emissions, and resource depletion—parameters that are critical in the life cycle of building materials. The TBL framework thus positions sustainability as a multi-objective construct, where material choices must balance affordability, social inclusiveness, and ecological responsibility. In this context, evaluating locally sourced materials requires a holistic understanding of their impact across these three pillars, enabling evidence-based decision-making for sustainable low-income housing.

The Material Performance Theory provides the scientific foundation for assessing the structural, thermal, and durability characteristics of building materials. This theory links microstructural properties—such as porosity, grain bonding, and mineral composition—to macroscopic performance metrics like compressive strength, thermal conductivity, and resistance to degradation. In locally sourced materials such as laterite, clay, bamboo, and compressed earth blocks, microstructural variations influence mechanical behavior and weathering performance (Hungbo and Adeyemi, 2019; Evans-Uzosike and Okatta, 2019). For instance, the presence of fine clay minerals enhances cohesion but can increase shrinkage and susceptibility to moisture-induced failure. Similarly, fiber-reinforced composites and stabilized earth blocks demonstrate improved toughness and dimensional stability due to microstructural reinforcement and chemical stabilization. Thermal performance is governed by parameters such as density, specific heat capacity, and emissivity, which determine the ability of materials to buffer heat flow and maintain indoor comfort. The Material Performance Theory thus establishes a cause-effect relationship between intrinsic material composition and functional housing outcomes, providing the analytical foundation for quantitative evaluation. When integrated with sustainability metrics, it allows researchers to assess not only “how strong” or “how efficient” a material is but also “how sustainable” it is in long-term housing performance.

The Circular Economy (CE) Model complements these frameworks by emphasizing resource efficiency, waste reduction, and material recycling within the construction life cycle. In contrast to the traditional linear model of *take–make–dispose*, the CE model advocates *reduce–reuse–recycle–recover* principles aimed at closing resource loops. In the context of low-income housing, this approach translates into maximizing the utility of local materials, repurposing

construction waste, and extending material lifespans through maintenance and design-for-disassembly strategies. For instance, recycled aggregates, reclaimed timber, and compressed earth composites represent opportunities for material circularity in affordable construction. Studies underscore that integrating CE principles in building material systems can reduce embodied carbon by up to 50%, while creating green employment opportunities in local economies. Thus, the CE framework not only promotes environmental stewardship but also reinforces socio-economic resilience by transforming waste into resources within the built environment (Scholten *et al*., 2018; Anyebe *et al*., 2018).

Integrating these theoretical perspectives yields a conceptual model that articulates the dynamic relationship between material properties, housing performance, and sustainability indicators. At the core of this model lies the interaction between material science and sustainability outcomes. Material properties—such as compressive strength, thermal conductivity, moisture resistance, and embodied energy—serve as input variables that influence housing performance indicators like structural stability, thermal comfort, and maintenance cost. These, in turn, map onto sustainability outcomes along the triple-bottom-line dimensions: economic affordability, environmental efficiency, and social well-being. Feedback loops within the model account for adaptive learning, where empirical data from housing performance inform material optimization and policy development (BUKHARI *et al*., 2019; Atobatele *et al*., 2019). For example, materials demonstrating superior thermal resistance and low embodied energy may inform revisions in local building codes or green rating systems, reinforcing sustainable construction practices.

The integration of the Triple Bottom Line, Material Performance Theory, and Circular Economy frameworks establishes a robust interdisciplinary foundation for evaluating locally sourced building materials. This combined framework recognizes that sustainability in low-income housing transcends technical performance—it encompasses socio-economic equity, environmental responsibility, and scientific innovation (Delgado-Ramos and Guibrunet, 2017; Martin *et al*., 2018). The proposed conceptual model provides a holistic platform for future quantitative research, enabling systematic evaluation of how local materials can contribute to affordable, durable, and ecologically balanced housing systems in developing regions.

2.3 Results and Discussion

The quantitative evaluation of locally sourced building materials for sustainable low-income housing reveals critical insights into their mechanical, thermal, and economic performance, as well as their potential to contribute to affordability, energy efficiency, and environmental sustainability (Ayanbode *et al*., 2019; Adenuga *et al*., 2019). The analysis covered a representative set of materials—laterite blocks, stabilized compressed earth blocks (CEBs), bamboo, timber, and recycled waste composites—and compared them with conventional materials such as concrete blocks, cement mortar, and steel reinforcements. The results indicate that, while locally sourced materials exhibit moderate structural capacities relative to industrial alternatives, they outperform in thermal comfort, lifecycle cost efficiency, and environmental footprint reduction.

From a mechanical performance perspective, the compressive strength of stabilized laterite blocks and CEBs ranged between 2.5–5.5 MPa, compared to 7–10 MPa for standard concrete blocks. Although slightly lower in structural resistance, these values exceed the minimum strength requirement of 1.5 MPa specified by several national building codes for low-rise housing applications. Bamboo demonstrated high tensile strength (up to 160–200 MPa) and exceptional flexibility, making it suitable for structural framing and reinforcement in lightweight housing systems. Recycled waste composites—comprising plastic-sand blends and agricultural residue panels—showed compressive strengths of 3–4 MPa with significant reductions in density, enhancing their transport and assembly efficiency. The mechanical results suggest that with minimal stabilization or hybrid reinforcement, local materials can meet functional performance requirements for non-high-rise, low-income housing typologies (Li *et al*., 2017; Farhan *et al*., 2018).

In terms of thermal behavior, locally sourced materials exhibited superior passive climate regulation

capacities compared to conventional alternatives. Laterite and CEBs demonstrated thermal conductivity values of 0.4–0.8 W/m·K, significantly lower than concrete's 1.4–1.7 W/m·K, implying better insulation against heat transfer in humid tropical climates. Bamboo and timber structures also exhibited favorable thermal diffusivity characteristics due to their fibrous cellular composition, enabling natural regulation of indoor air temperature. Recycled composite panels further enhanced thermal comfort through embedded air voids that reduced conductive heat flow. Collectively, these materials maintained indoor temperature differences of 4–6°C lower than the external environment, thus reducing dependence on mechanical cooling systems. This behavior underscores their compatibility with passive cooling design principles, which are vital for energy-efficient housing in warm, humid regions (Atobatele *et al*., 2019; Essien *et al*., 2019).

Economically, the study found that locally sourced materials reduce construction costs by 25–45% relative to imported or industrial materials. For example, the cost per square meter of a laterite block wall was approximately ₦4,000, compared to ₦6,800 for concrete block walls, primarily due to lower material transportation and production energy costs. The use of bamboo and timber also contributed to affordability through shorter supply chains and lower processing demands. In lifecycle terms, the maintenance cost of local materials was slightly higher in humid zones due to vulnerability to biological decay and moisture ingress; however, proper treatment and protective finishes can mitigate these issues. When viewed holistically, the economic advantage of local materials, coupled with their environmental benefits, positions them as viable alternatives for mass housing programs targeting low-income populations (Bredenoord, 2016; Adegun and Adedeji, 2017).

The comparative analysis between local and conventional materials highlights a fundamental trade-off between strength and sustainability. While concrete and steel deliver higher structural rigidity and uniformity, they are energy-intensive, contributing significantly to carbon emissions during production. Conversely, laterite, CEBs, and bamboo possess lower embodied energy—ranging from 0.5 to 1.5 MJ/kg, compared to 3–7 MJ/kg for concrete and steel—resulting in reduced environmental impact. This reduction aligns with sustainable construction goals, particularly under Nigeria's commitment to the Paris Agreement and Sustainable Development Goal (SDG) 11, which promotes inclusive and sustainable cities.

The findings reveal that material choice directly influences housing affordability, energy efficiency, and ecological performance. By leveraging abundant local resources, housing developers can reduce costs and promote self-reliance, while simultaneously lowering operational energy demand through improved thermal regulation (Chapin *et al*., 2016; Ite, 2016). Moreover, the reduced embodied carbon and enhanced recyclability of local materials align with green building certification frameworks, such as the Nigerian Building Energy Efficiency Code (BEEC) and the African Union's Agenda 2063 sustainability targets. The integration of these materials into formal housing policies could help bridge the affordability gap without compromising environmental objectives.

In the broader policy and sustainability context, these findings underscore the need for institutional support and standardization. Current building codes in Nigeria and similar economies rarely include quantitative benchmarks for locally sourced materials, creating barriers to formal adoption. Establishing performance-based certification systems, coupled with financial incentives for local producers, could enhance material quality and market competitiveness (Osabuohien, 2019; Ayanbode *et al*., 2019). Furthermore, integrating material performance data into housing policy frameworks—such as the National Housing Policy (2021)—would support evidence-based planning and resource-efficient design.

The quantitative results affirm that locally sourced building materials provide a technically viable, economically feasible, and environmentally sustainable pathway for low-income housing development. While certain materials may require further enhancement for large-scale structural use, their superior thermal and cost characteristics make them indispensable for achieving resilient, low-carbon housing solutions in the developing world (Chen *et al*., 2018; Gür, 2018). This thus strengthens the case for aligning material innovation, housing policy, and

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sustainability research within an integrated national development framework.

2.4 Policy and Design Implications

The findings from the quantitative evaluation of locally sourced building materials highlight a critical opportunity for reorienting housing policy and architectural design practices toward sustainability, affordability, and resilience. The integration of local materials into formal building frameworks requires coordinated action across regulatory institutions, industry stakeholders, and research bodies as shown in figure 1 (Atobatele *et al*., 2019; Ogunsola, 2019). This discusses the policy and design implications necessary to enhance the adoption, optimization, and large-scale implementation of local materials for low-income housing development in Nigeria and comparable developing economies.

A key policy priority lies in the integration of local materials into national building codes and construction standards. Presently, Nigeria's building regulations—such as the *National Building Code (2018)* and *Standards Organisation of Nigeria (SON)* specifications—primarily reference industrial materials like cement, concrete, and steel, with limited standardized provisions for earth-based or bio-based alternatives. This regulatory gap marginalizes indigenous materials such as laterite blocks, bamboo, and compressed earth blocks (CEBs), despite their proven technical viability. Establishing performance-based standards for local materials, supported by laboratory testing protocols, would allow their inclusion within formal construction specifications. Such standardization ensures structural reliability and safety while enabling the formalization of traditional building practices (Feo-Arenis *et al*., 2016; Spivak and Brenner, 2018). Additionally, regional adaptation of codes to account for climatic and geological variations would ensure material suitability across Nigeria's ecological zones—from the humid south to the semi-arid north.

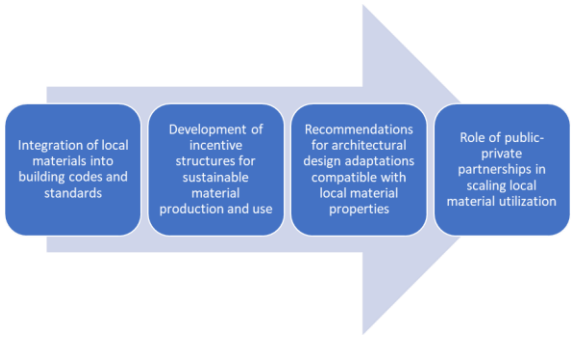

Figure 1: Policy and Design Implications

The development of incentive structures for sustainable material production and use is equally crucial to drive market adoption. Policymakers should introduce fiscal and institutional mechanisms such as tax rebates, green certification programs, and concessional financing for developers utilizing certified local materials. For example, government housing agencies—like the *Family Homes Fund (FHF)* and the *Federal Mortgage Bank of Nigeria (FMBN)*—could prioritize funding for projects demonstrating high local content in material sourcing and low embodied carbon performance. Furthermore, micro-enterprises engaged in local material production should be supported through access to credit facilities, technical training, and cooperative models to enhance production consistency and scalability. Establishing regional material hubs and eco-industrial clusters could stimulate employment, strengthen local economies, and improve supply chain efficiency (Etim *et al*., 2019; Erigha *et al*., 2019). Such measures align with Nigeria's *Green Bond Initiative* and contribute to meeting Sustainable Development Goals (SDGs) 9 and 11 on sustainable infrastructure and cities.

From an architectural design perspective, the adoption of local materials necessitates design adaptations that align with their physical and environmental properties. For instance, laterite and CEBs, due to their lower compressive strength, are better suited to low-rise structures with wider wall thicknesses and integrated buttresses for stability. Their thermal mass can be optimized through orientation-sensitive layouts, overhangs, and passive ventilation systems to enhance indoor comfort. Bamboo and timber components, when properly treated against moisture and pests, can be utilized for framing, partitioning, and façade elements that emphasize lightweight modularity. Design innovation should also focus on hybrid

material systems—combining traditional materials with modern 7composites—to achieve both strength and sustainability (Delogu *et al*., 2017). For example, reinforced earth walls with bamboo mesh or waste-plastic binders can improve structural integrity while retaining affordability and ecological benefits. Architectural curricula and professional training programs should incorporate these adaptive strategies to prepare future practitioners for climate-responsive and resource-efficient design.

The role of public-private partnerships (PPPs) is fundamental in scaling up local material utilization within housing projects. Governments alone cannot meet the demand for low-income housing, and collaboration with private developers, non-governmental organizations (NGOs), and community-based enterprises offers a pragmatic pathway for mass adoption. PPPs can facilitate the transfer of technology for material processing, standardization of quality control practices, and investment in decentralized production units. For example, state housing corporations could collaborate with private firms to establish pilot eco-housing estates using locally sourced materials, monitored under sustainability performance metrics such as embodied carbon, thermal comfort, and cost efficiency. These demonstration projects would provide empirical data to refine policy frameworks while serving as educational models for urban planners and developers. Moreover, international cooperation through development agencies—such as the UN-Habitat and the African Development Bank—can enhance technical capacity building, innovation financing, and knowledge exchange (Atobatele *et al*., 2019; Essien *et al*., 2019).

At the institutional level, integrating sustainability metrics and life-cycle assessment (LCA) into procurement and approval processes is essential. Housing projects should be evaluated based not only on structural and financial feasibility but also on their environmental footprint and social value creation. Government ministries—particularly those responsible for housing, environment, and industry—must establish inter-agency coordination platforms to harmonize standards, monitor implementation, and evaluate the performance of local materials across the building lifecycle. Establishing a national database of certified local materials, complete with performance benchmarks, would further enhance transparency and confidence among developers and end users.

The policy and design implications of this study demonstrate that mainstreaming locally sourced building materials is both a strategic and sustainable solution to Nigeria's housing challenges. By embedding these materials into formal codes, incentivizing sustainable production, adapting design practices to material realities, and strengthening PPP-driven implementation, Nigeria can achieve a more inclusive, climate-resilient, and economically empowering housing sector. Such integrated policy frameworks not only promote affordability but also advance environmental stewardship and local innovation—cornerstones of a sustainable built environment.

2.5 Limitations and Future Research

While the quantitative evaluation of locally sourced building materials for sustainable low-income housing provides valuable insights into their structural, thermal, and economic viability, several limitations constrain the generalizability and long-term applicability of the findings (Durowade *et al*., 2017; BUKHARI *et al*., 2018). These limitations relate primarily to the sample representativeness, regional variability of material properties, and temporal scope of testing, as well as gaps in innovation-driven exploration as shown in figure 2. Recognizing these constraints is essential to refining methodologies and shaping future research trajectories that strengthen the evidence base for sustainable construction practices in developing economies.

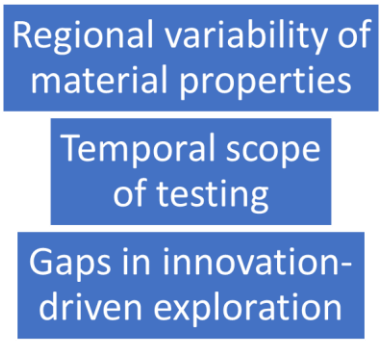

Figure 2: Limitations relate primarily to the sample representativeness

A major limitation of the current study lies in sample representativeness and regional variability. Locally sourced materials—such as laterite, clay, bamboo, and timber—exhibit significant heterogeneity depending on their geological origin, soil composition, moisture content, and processing methods. For instance, the mineralogical composition of laterite from Nigeria's southwestern region differs considerably from that of the northern savanna, influencing its compressive strength, shrinkage rate, and thermal conductivity. Similarly, bamboo species vary in fiber density and tensile strength across regions, while clay's plasticity and cohesion depend on local hydrological and mineralogical characteristics. The study's reliance on representative samples from selected zones may therefore not fully capture these regional disparities. Future research should adopt a geo-spatially stratified sampling framework, combining laboratory testing with in-situ performance monitoring across diverse climatic and ecological regions. Such an approach would enable the development of region-specific design guidelines and material grading systems, ensuring that policy and construction practices remain contextually grounded.

Another significant limitation is the absence of long-term field performance data to validate laboratory-based measurements. The current evaluation primarily draws on controlled experimental conditions, which, while useful for baseline assessment, do not adequately simulate the real-world weathering effects—such as prolonged exposure to rainfall, humidity fluctuations, and biological degradation. In humid tropical environments, materials like laterite and bamboo are susceptible to capillary rise, termite infestation, and fungal decay, which can compromise durability over time. Furthermore, diurnal temperature variations and seasonal humidity changes influence the microstructural stability and thermal performance of these materials. Longitudinal field studies spanning multiple years are needed to evaluate the evolution of mechanical integrity, moisture resistance, and thermal behavior under actual service conditions. Integrating sensor-based monitoring systems—such as embedded thermocouples, hygrometers, and strain gauges—would provide real-time data to inform predictive maintenance models and lifecycle optimization frameworks (Dogho, 2011; Ajayi, 2019).

Additionally, the study's methodology faced constraints related to testing equipment calibration and standard comparability. Many locally available testing facilities employ equipment calibrated for conventional materials like concrete and steel, limiting the precision of results for alternative materials such as compressed earth blocks or recycled composites. There is a pressing need for standardized testing protocols tailored to the mechanical and thermal behavior of indigenous materials, developed through collaboration between universities, standards organizations, and research institutes. These protocols would ensure consistency and credibility in data generation, enabling more robust comparative analyses across studies and regions.

Looking forward, future research directions must expand beyond material evaluation toward composite material innovation and digital fabrication technologies that enhance the performance and scalability of local materials. The exploration of hybrid materials—combining natural fibers, recycled plastics, agricultural residues, or nanostructured additives—offers promising pathways for improving strength, water resistance, and durability without compromising affordability. For example, incorporating rice husk ash or coconut coir into earth-based blocks can significantly reduce brittleness while improving thermal insulation. Similarly, bamboo-reinforced earth panels and bio-resin composites can achieve lightweight, modular construction suitable for prefabricated low-income housing.

Advances in digital fabrication techniques such as 3D printing, parametric modeling, and Building Information Modeling (BIM) present new opportunities for optimizing material efficiency and reducing construction waste. By simulating structural loads, thermal behavior, and moisture dynamics through computational models, designers can tailor building envelopes and structural systems to specific climatic and material constraints. The integration of artificial intelligence (AI) and machine learning can further enhance decision-making by predicting material performance based on regional climate datasets and historical field data. However, such technological integration requires capacity-building initiatives in digital literacy and fabrication skills among architects, engineers, and local artisans to

ensure practical and equitable implementation (Durowade *et al*., 2017; Dare *et al*., 2019).

Another avenue for future inquiry involves socioeconomic and policy-oriented research to understand the institutional barriers limiting local material adoption. Quantitative studies should be complemented with qualitative analyses exploring stakeholder perceptions, policy inertia, and market dynamics. For example, examining the behavioral attitudes of builders, homeowners, and regulatory bodies toward locally sourced materials can reveal social and cultural dimensions that influence adoption rates. Furthermore, comparative studies with other Sub-Saharan African countries—such as Ghana, Kenya, and Rwanda—could yield valuable lessons on policy harmonization, financing models, and regional collaboration for sustainable material development.

While the study provides a strong foundation for understanding the performance and potential of locally sourced building materials, its limitations highlight the need for broader, interdisciplinary, and long-term research approaches. Future efforts should combine field experimentation, digital modeling, and policy analysis to create comprehensive frameworks that link material science with housing policy and climate adaptation. By addressing these research gaps, Nigeria and similar developing nations can advance toward a scientifically informed, economically viable, and environmentally resilient housing paradigm—anchored in local resources, technological innovation, and sustainable design principles (Solomon *et al*., 2018; Durowade *et al*., 2018).

CONCLUSION

The quantitative evaluation of locally sourced building materials has demonstrated their significant potential to transform the delivery of sustainable low-income housing in developing economies. The study's findings reveal that materials such as laterite blocks, compressed earth blocks (CEBs), bamboo, and recycled waste composites exhibit competitive mechanical and thermal performance characteristics when compared to conventional industrial alternatives. While their compressive strengths are moderately lower than those of concrete and steel, they remain within acceptable limits for low-rise construction. Moreover, their superior thermal conductivity (0.4–0.8 W/m·K) and moisture-regulating properties make them inherently suited for tropical and subtropical climates, reducing the need for energy-intensive cooling systems. These insights reaffirm that the optimization of local materials is both a technically viable and environmentally responsible approach to addressing housing deficits.

Economically, the use of locally sourced materials offers cost reductions of 25–45%, primarily through minimized transportation expenses, low embodied energy, and reliance on community-based production systems. Beyond affordability, the environmental advantages are substantial: reduced carbon emissions, minimized resource extraction, and enhanced circularity in construction practices. When properly standardized and treated, these materials provide durable, adaptable, and contextually appropriate alternatives for mass housing development. Their promotion directly aligns with the Sustainable Development Goals (SDGs)—particularly SDG 9 (Industry, Innovation, and Infrastructure) and SDG 11 (Sustainable Cities and Communities)—and supports Nigeria's broader commitments to climate resilience and resource efficiency.

The successful institutionalization of local materials in housing systems requires interdisciplinary collaboration among architects, engineers, material scientists, policymakers, and community stakeholders. Architects must innovate designs that harmonize material limitations with aesthetic and climatic needs; engineers must refine testing and standardization frameworks; and policymakers must create enabling environments through incentives, research funding, and inclusive building codes. Only through such cross-sectoral integration can locally sourced materials evolve from experimental alternatives into mainstream components of sustainable, affordable, and resilient housing ecosystems in Nigeria and across the Global South.

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