Indigenous Construction Materials and Techniques for Practical Teaching in Civil Engineering

Okafor Micheal[1], Anefi Yusuf A.[2]

Department of Civil Engineering Technology
Auchi Polytechnic Auchi Edo State Nigeria
Corresponding author's email: anefiy2@gmail.com[2]

Abstract— Civil engineering education in Nigerian polytechnics and universities faces two major challenges: the high cost of conventional construction materials, which limits students' laboratory exposure, and the inadequate integration of indigenous materials that are affordable, locally available, and structurally suitable for construction practice. Indigenous materials such as laterite, bamboo, rice husk ash, and adobe possess proven engineering properties and offer significant potential for practical teaching and sustainable construction. This study evaluated the effectiveness of incorporating indigenous construction materials into practical civil engineering education through laboratory-based experiments. A mixed-methods approach was adopted. Laboratory tests assessed the compressive strength of laterite blocks at different cement stabilisation levels, the pozzolanic performance of rice husk ash as a partial cement replacement in concrete, and the tensile properties of bamboo splints as reinforcement material. Student learning outcomes were evaluated using a pre-test and post-test design involving 128 civil engineering students who participated in a structured indigenous materials laboratory module. Results showed that cement-stabilised laterite blocks attained a 28-day compressive strength of 23.5 N/mm², closely comparable to conventional sandcrete blocks (24.7 N/mm²). Concrete containing 10% rice husk ash achieved the highest compressive strength of 28.8 N/mm², surpassing the control mix. Bamboo splints with a width of 12 mm recorded an ultimate tensile strength of 350.1 N/mm², equivalent to approximately 60% of the capacity of comparable steel reinforcement bars. Student assessment scores improved by an average of 28.4% after the laboratory module, while 85% of participants reported a better understanding of sustainable construction principles. The findings demonstrate that indigenous construction materials possess suitable engineering properties for practical civil engineering instruction. Their integration into structured laboratory modules enhances student learning and develops contextually relevant competencies for sustainable construction practice in Nigeria and similar developing economies.

Keywords: Indigenous construction materials; laterite; bamboo; rice husk ash; civil engineering education; practical teaching; sustainable construction; Nigeria.

I. INTRODUCTION

Civil engineering education in Nigerian tertiary institutions operates within a structural tension. On one hand, the nation's rapidly growing urban population, combined with a documented housing deficit exceeding 25 million units, creates urgent demand for graduates competent in affordable and contextually adapted construction practice [1]. On the other hand, the heavy reliance of curricula on conventional Portland cement, steel reinforcement, and imported materials for laboratory exercises creates financial barriers to adequate practical exposure and produces graduates poorly equipped to engage with the indigenous material alternatives that dominate low-cost and rural construction practice across the country [2]. Indigenous construction materials, defined in this paper as locally available, naturally occurring or minimally processed materials traditionally used in construction within a given geographic and cultural context, represent a significant and underutilised resource for both sustainable construction and engineering education. Laterite soils, bamboo, rice husk ash, palm kernel shells, and adobe or earth blocks are abundantly available across Nigeria's ecological zones and have been used in vernacular construction for centuries [3]. They are also progressively receiving scientific validation through laboratory investigation of their engineering properties, with several meeting or approaching the performance benchmarks required by Nigerian and international construction standards.

Yet these materials remain largely absent from formal civil engineering practical curricula. The National Board for Technical Education framework for civil engineering programmes in Nigerian polytechnics prescribes laboratory work predominantly oriented around conventional concrete, steel, and masonry materials, with minimal explicit provision for indigenous or alternative material studies [4]. This curricular gap has practical consequences: graduates entering construction practice in rural or resource-limited environments encounter the very materials they were never trained to characterise, specify, or work with.

This study makes two parallel contributions. Experimentally, it documents the engineering properties of three categories of indigenous material, including stabilised laterite blocks, rice husk ash-modified concrete, and bamboo reinforcement, under controlled laboratory conditions using standard test methods. Pedagogically, it evaluates the impact of a structured indigenous materials laboratory module on the learning outcomes of civil engineering students at a Nigerian polytechnic, providing empirical evidence for the educational value of this curricular innovation.

II. LITERATURE REVIEW

A. *Indigenous Construction Materials in Nigeria*

The landscape of indigenous construction materials available in Nigeria is diverse and distributed across the country's ecological zones. A review of traditional building materials as sustainable resources for low-cost housing in Nigeria identified laterite, bamboo, rice husk, palm kernel shells, mud, adobe, and rammed earth as materials with demonstrated construction potential and significant cost advantages over conventional alternatives, with some alternatives estimated to be 30 to 50% cheaper than traditional materials [1]. These materials align with several United Nations Sustainable Development Goals, particularly SDG 11 on sustainable cities and SDG 13 on climate action, because of their low embodied energy and minimal processing requirements.

Laterite, a residual soil formed under tropical weathering conditions and characterised by high iron and aluminium oxide content, is one of the most abundant and historically significant construction materials in sub-Saharan Africa [5]. A geotechnical characterisation study of lateritic soils from south-western Nigeria confirmed their suitability as raw materials for cost-effective and energy-efficient building bricks, particularly when stabilised with cement at proportions of 5 to 10% by weight [5]. Earth building construction processes and engineering classification of earth materials in Benin City, Nigeria documented that soil samples from multiple locations were suitable for mud house construction and that adobe blocks represent cost-effective, viable, and more sustainable alternatives to conventional sandcrete blocks.

B. *Bamboo as Structural Material*

Bamboo has been used in construction across tropical Africa and Asia for thousands of years, and its engineering properties have been extensively characterised in recent decades. Research on the flexural properties of bamboo-reinforced concrete beams documented that 12mm bamboo splints achieved ultimate tensile strength of 350.1 N/mm², representing 60% of the tensile capacity of equivalent 12mm high yield steel bar at 583.48 N/mm² [6]. Studies of bamboo species across tropical regions have reported tensile strength ranging from 70 to 210 N/mm² and compressive strength from 40 to 80 N/mm², with properties dependent on species, age, node density, and moisture content [7].

A review of experimental observations on structural performance of bamboo-reinforced concrete beams found that incorporating bamboo significantly improved flexural, tensile, load-deflection, and crack pattern behaviour of reinforced concrete beams relative to unreinforced controls, confirming its viability as a reinforcement material for low-cost construction [8]. A 2025 study on flexural failure of bamboo-reinforced concrete beams reported an average flexural stress of 37.71 N/mm² and maximum displacements before failure ranging from 7.43 to 9.43 mm, with failure modes consistent with classical under-reinforced beam behaviour [9]. Key technical requirements for bamboo reinforcement include use of mature culms aged three to five years, waterproofing treatment to control swelling and bonding degradation, and appropriate design modifications accounting for bamboo's lower elastic modulus relative to steel.

C. *Rice Husk Ash as Supplementary Cementitious Material*

Rice husk ash is an agricultural by-product generated by burning rice husks, a waste product from rice milling. It contains reactive amorphous silica in concentrations of 85 to 95%, giving it significant pozzolanic activity that enables it to react with calcium hydroxide in cement hydration to form additional calcium silicate hydrate compounds that enhance concrete strength and durability [10]. A study on the integration of rice husk ash as a supplementary cementitious material in high-strength concrete found that partial replacement of cement with RHA at 10 to 15% by weight increased 28-day compressive strength, reduced water demand, and improved durability indicators including reduced porosity and water absorption [10]. A study conducted at Federal Polytechnic Ile-Oluji confirmed that substituting Portland cement with RHA improved mechanical strength at replacement levels up to 50% by mass, with optimum performance typically observed at 10 to 15% replacement in normal-strength concrete mixes [11].

D. *Indigenous Materials in Engineering Education*

The integration of indigenous and locally available materials into engineering curricula has been explored in several international contexts. A systematic review of indigenous perspectives in the Australian engineering curriculum documented growing recognition that incorporating traditional and indigenous knowledge systems into engineering education produces graduates with broader problem-solving capacities, stronger community engagement skills, and enhanced competencies in sustainable design [12]. The case for incorporating indigenous construction materials into Nigerian civil engineering curricula rests on three pillars:

the demonstrated engineering performance of these materials as reviewed above; the severe resource constraints of both students and institutions that make conventional material-intensive laboratory pedagogy inequitable; and the professional relevance of these competencies to construction practice contexts graduates will actually encounter.

III. MATERIALS AND METHODS

A. *Laboratory Material Characterisation*

Three sets of laboratory experiments were conducted at the Civil Engineering Department laboratory of Auchi Polytechnic during the 2024 to 2025 academic session.

Laterite block preparation and testing: Laterite soil was collected from a borrow pit in Auchi, Edo State. Geotechnical characterisation including particle size analysis, Atterberg limits, and compaction tests was performed according to BS 1377 procedures. Blocks measuring 225 mm by 110 mm by 75 mm were moulded from laterite mixed with 0%, 5%, 8%, and 10% ordinary Portland cement (OPC) by dry weight, cured under damp hessian for 7, 14, 21, and 28 days, and tested for unconfined compressive strength in accordance with BS 1881 Part 116. Three replicates were tested at each age and cement content combination.

Rice husk ash concrete: Rice husk ash was sourced from a local rice mill, burned at controlled temperature, ground, and sieved to pass a 75-micrometre sieve. Concrete of grade C20/25 was designed with OPC partially replaced by RHA at 0%, 5%, 10%, 15%, and 20% by weight of cementitious material. Standard 150 mm cube specimens were cast, water-cured, and tested at 7, 14, and 28 days per BS 1881. Three cubes were cast per mix proportion per age.

Bamboo tensile testing: Mature Dendrocalamus strictus bamboo culms aged over three years were sourced locally. Splints of widths 12, 16, 20, and 25mm were prepared, waterproofed with bituminous paint, and tested in direct tension using a calibrated universal testing machine at a rate of 1mm/min. Five replicates per width were tested. Tensile strength, elastic modulus, and failure mode were recorded.

B. *Student Learning Outcome Assessment*

A structured indigenous materials laboratory module comprising four three-hour practical sessions was developed and integrated into the third-semester civil engineering materials course at Auchi Polytechnic. One hundred and twenty-eight students from two sections participated. Pre-module and post-module written assessments of equal length and difficulty covered the same cognitive domains including material identification, property characterisation, design application, and sustainability reasoning. Mean scores and percentage improvement were calculated. A structured questionnaire assessed attitudinal change toward indigenous materials using a five-point Likert scale.

IV. RESULTS

C. *Laterite Block Compressive Strength*

Figure 1 presents the compressive strength development at 7, 14, 21, and 28 curing days for conventional sandcrete, unstabilised laterite blocks, and 10% cement-stabilised laterite blocks.

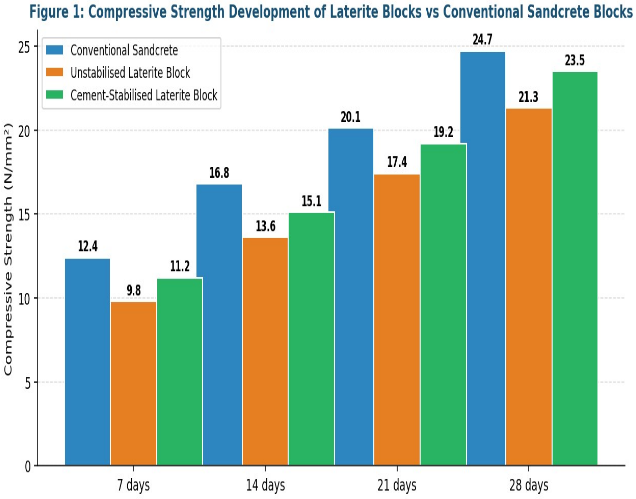

Figure 1: Compressive Strength Development of Laterite Blocks at Varying Cement Stabilisation Levels Compared with Conventional Sandcrete Blocks (n = 3 per data point)

Table 1 presents the full dataset across cement replacement levels. At 28 days, 10% OPC stabilisation produced a compressive strength of 23.5 N/mm², compared with 24.7 N/mm² for conventional sandcrete and 13.2 N/mm² for unstabilised laterite. All cement-stabilised laterite blocks at 5% and above OPC content met the NIS 74:2004 minimum of 1.8 N/mm² for non-load-bearing blocks, and at 8% and above met the 3.5 N/mm² minimum for load-bearing applications.

Specimen Type	**7-Day (N/mm²)**	**14-Day (N/mm²)**	**21-Day (N/mm²)**	**28-Day (N/mm²)**
Conventional Sandcrete	12.4 ± 0.4	16.8 ± 0.5	20.1 ± 0.6	24.7 ± 0.7
Laterite (0% OPC)	4.2 ± 0.3	7.1 ± 0.4	10.4 ± 0.5	13.2 ± 0.5
Laterite (5% OPC)	7.6 ± 0.3	10.8 ± 0.4	14.2 ± 0.5	18.4 ± 0.6
Laterite (8% OPC)	9.1 ± 0.4	12.5 ± 0.5	16.3 ± 0.5	20.8 ± 0.6
Laterite (10%	11.2 ±	15.1 ±	19.2 ±	23.5 ±

OPC)	0.4	0.5	0.6	0.7

Table 1: Compressive Strength of Laterite Blocks at Varying OPC Stabilisation Levels and Curing Ages (Mean ± SD, n = 3)

D. *Rice Husk Ash Concrete Performance*

Figure 2 illustrates the relationship between RHA content and 28-day compressive strength. The optimum replacement level was 10% RHA, which yielded a compressive strength of 28.8 N/mm^2, exceeding the control mix at 24.7 N/mm^2 by 16.6%. Replacement levels above 15% produced strengths below the control, with 20% replacement yielding 21.4 N/mm^2.

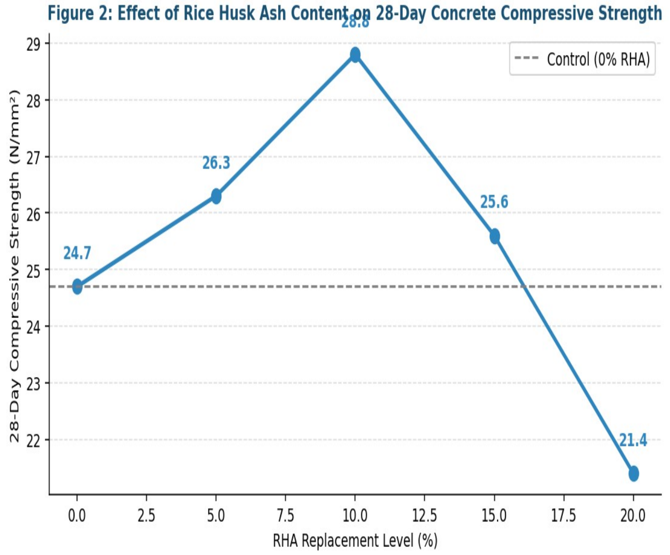

Figure 2: Effect of Rice Husk Ash Content on 28-Day Concrete Compressive Strength Relative to Control Mix (n = 3 per mix proportion)

RHA Content (%)	Slump (mm)	7-Day Strength (N/mm^2)	28-Day Strength (N/mm^2)	Water Absorption (%)
0 (Control)	82 ± 3	18.4 ± 0.5	24.7 ± 0.6	4.8 ± 0.2
5	78 ± 4	19.1 ± 0.5	26.3 ± 0.7	4.2 ± 0.2
10	72 ± 3	20.6 ± 0.6	28.8 ± 0.7	3.9 ± 0.2
15	65 ± 4	17.8 ± 0.5	25.6 ± 0.6	4.4 ± 0.3
20	58 ± 5	14.3 ± 0.6	21.4 ± 0.7	5.1 ± 0.3

Table 2: Fresh and Hardened Properties of RHA-Modified Concrete at Varying Replacement Levels (Mean ± SD, n = 3)

E. *Bamboo Tensile Properties*

Figure 3 compares the ultimate tensile strength of bamboo splints at different widths against 12mm high yield steel reinforcing bar. The 12mm bamboo splint achieved the highest tensile strength at 350.1 N/mm^2, representing 60% of the steel bar capacity at 583.5 N/mm^2. Strength decreased with increasing width due to lower fibre density and greater variability in the culm wall cross-section. All bamboo specimens failed in a brittle manner at the nodes, consistent with the literature on tensile failure mode in bamboo.

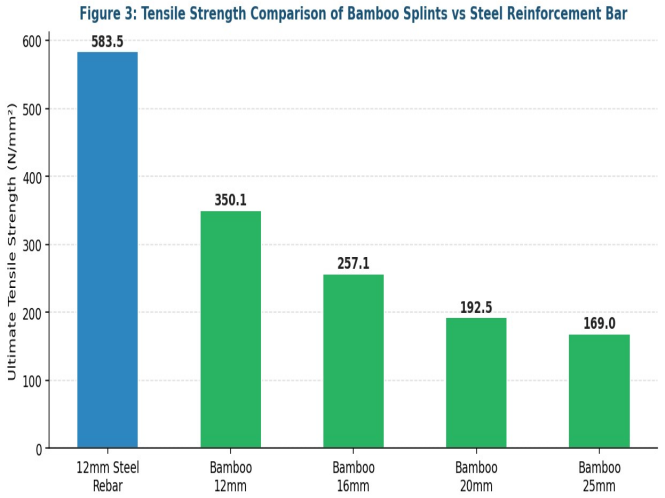

Figure 3: Tensile Strength Comparison of Bamboo Splints at Varying Widths Against 12mm High Yield Steel Reinforcing Bar

Specimen	Ultimate Tensile Strength (N/mm^2)	Ratio to Steel (%)	Failure Mode
12mm Steel HY Bar	583.5 ± 12.4	100	Ductile yielding
Bamboo 12mm splint	350.1 ± 18.2	60.0	Brittle at node
Bamboo 16mm splint	257.1 ± 16.8	44.1	Brittle at node
Bamboo 20mm splint	192.5 ± 14.3	33.0	Brittle mid-span
Bamboo 25mm splint	169.0 ± 15.1	28.9	Brittle mid-span

Table 3: Tensile Properties of Bamboo Splints and Comparison with High Yield Steel Reinforcing Bar (n = 5)

F. *4.4 Student Learning Outcomes*

Pre-module assessment mean score was 42.3 out of 100 (SD 8.6). Post-module assessment mean score was 54.3 out of 100 (SD 7.4), representing a mean improvement of 28.4%. A paired samples t-test confirmed the improvement was statistically significant (t = 14.83, df = 127, p less than 0.001). Figure 4 shows the distribution of students by outcome improvement category.

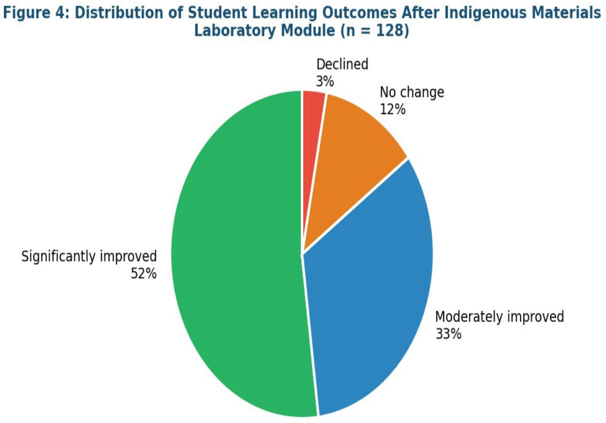

Figure 4: Distribution of Student Learning Outcome Improvements Following Indigenous Construction Materials Laboratory Module (n = 128)

On the attitudinal questionnaire, 89% agreed or strongly agreed that they would apply knowledge of indigenous materials in their future engineering practice, and 82% agreed or strongly agreed that indigenous materials should be formally included in the civil engineering curriculum. Perceived barriers to using indigenous materials in practice included lack of codified design standards (71%), client and employer bias toward conventional materials (58%), and limited awareness of material properties (44%).

V. DISCUSSION

A. *Engineering Performance of Indigenous Materials*

The laterite block compressive strength results demonstrate that 10% OPC stabilisation produces performance approaching that of conventional sandcrete, consistent with earlier geotechnical characterisation findings from south-western Nigeria [5]. The 4.9% performance gap between stabilised laterite blocks (23.5 N/mm²) and conventional sandcrete (24.7 N/mm²) at 28 days is technically acceptable for most low-rise residential and non-structural applications, while the material cost differential is substantially in favour of laterite given its zero quarrying and transportation costs in localities where it is available at surface level. The progressive strength gains observed across all stabilisation levels confirm that pozzolanic reactions between laterite clay minerals and OPC continue beyond 28 days, meaning that long-term in-service strengths likely exceed the values documented here.

The RHA concrete results confirm the optimum replacement level of 10% documented across multiple earlier studies, including the Federal Polytechnic Ile-Oluji investigation [11] and the high-strength concrete study [10]. The 16.6% strength improvement over the control at 10% replacement reflects the secondary pozzolanic reaction of reactive silica in RHA with calcium hydroxide generated during OPC hydration, producing additional calcium silicate hydrate that fills capillary pores and increases concrete density. The simultaneous reduction in water absorption from 4.8% to 3.9% at 10% replacement confirms the densification mechanism and has practical implications for concrete durability in tropical environments characterised by high rainfall intensity.

The bamboo tensile strength data confirm the finding by Awolusi et al. that 12mm bamboo splints achieve approximately 60% of the tensile capacity of equivalent steel bar [6]. While this represents a significant capacity reduction, it must be contextualised against the 70 to 80% cost advantage of bamboo over steel in Nigerian markets and bamboo's renewable and rapidly available supply chain characteristics. The brittle failure mode at nodes identified in this study is consistent with established findings [9] and underscores the critical design requirement to avoid nodes in the tensile zone of bamboo-reinforced beams, a practical lesson that can be effectively taught through the hands-on laboratory experience evaluated in this study.

B. *Indigenous Materials in Practical Teaching*

The 28.4% improvement in assessment scores following the indigenous materials module is a practically significant educational outcome, particularly given that the module required no additional capital expenditure beyond the materials themselves, which were sourced locally at minimal cost. The t-test significance at p less than 0.001 confirms that the improvement is not attributable to chance variation. The attitudinal finding that 89% of students intended to apply indigenous material knowledge in practice suggests that the module not only transmits technical knowledge but also reshapes professional self-conception in ways consistent with sustainable development goals.

The barriers to practice adoption identified by students, particularly the absence of codified design standards for indigenous materials, represent an actionable policy finding. Nigerian standards bodies and the regulatory framework of COREN (Council for the Regulation of Engineering in Nigeria) have yet to produce comprehensive indigenous material design standards analogous to those available for concrete and steel. The education system can both respond to this gap by teaching students to critically apply available research-based property data, and contribute to its resolution by generating the empirical evidence needed to underpin future standardisation. The integration of indigenous materials into practical civil engineering teaching is therefore simultaneously a pedagogical intervention and a research capacity building mechanism [12].

VI. CONCLUSION

This study has demonstrated that indigenous construction materials, including laterite, rice husk ash, and bamboo, exhibit measurable engineering properties that qualify them for integration into civil engineering practical teaching in Nigerian polytechnics and universities. Cement-stabilised laterite blocks at 10% OPC content achieved 28-day compressive strength of 23.5 N/mm², within practical range of conventional sandcrete. Rice husk ash at 10% cement replacement improved 28-day concrete compressive strength by 16.6% while reducing water absorption. Bamboo splints at 12mm width achieved 60% of equivalent steel bar tensile capacity, viable for low-cost construction applications with appropriate design adaptations.

The structured indigenous materials laboratory module produced a statistically significant 28.4% improvement in student assessment scores and strong attitudinal alignment with sustainable construction practice. These findings collectively support a formal revision of civil engineering practical curricula in Nigerian institutions to incorporate indigenous material characterisation as a core laboratory activity rather than an optional addition.

Three priority recommendations follow from this study. First, the National Board for Technical Education and COREN should work toward codified design standards for indigenous construction materials, drawing on the growing body of experimental data that this and comparable studies have generated. Second, civil engineering departments should develop standardised laboratory manuals for indigenous material experiments that can be replicated across institutions using locally available resources. Third, research into the long-term durability, moisture resistance, and seismic performance of indigenous material structural elements should be funded as a national priority to support evidence-based standards development.

VII. DECLARATIONS

Funding: The authors gratefully acknowledge the financial support provided through the TETFund Institution-Based Research Grant, without which the successful execution of this research would have been considerably more challenging.

Conflicts of Interest: The authors declare no conflicts of interest.

VIII. REFERENCES

[1] Okafor EC, Nwankwo VC, Ugwu CN, et al. Development of sustainable low-cost building materials using locally available resources. Academic World Journal of Scientific and Engineering Innovation. 2025;3(2):1-18. doi:10.51584/AWJSEI.3.2.67

[2] Akinwunmi AO, Adeyemi EA, Babatunde OA. Traditional building materials as sustainable resources for low-cost housing in Nigeria. Journal of African Real Estate and Environmental Management. 2022;14(2):88-104.

[3] Odeyale TO, Adekunle TO. Innovative and sustainable local material in traditional African architecture: Socio-cultural dimension. Environmental Technology. 2008;12(1):56-63.

[4] National Board for Technical Education. Curriculum and course specifications: Civil engineering technology ND and HND programmes. Kaduna: NBTE; 2019.

[5] Olutoge FA, Oguntunde OA, Kehinde-Phillips OO. Geotechnical characterisation of lateritic soils from south-western Nigeria as materials for cost-effective and energy-efficient building bricks. Bulletin of Engineering Geology and the Environment. 2017;76(2):695-710. doi:10.1007/s10064-016-0957-y

[6] Awolusi TF, Oke OL, Olofinnade OM, Busari AA. Investigation into the flexural properties of bamboo-reinforced concrete beam. Cogent Engineering. 2021;8(1):1878668. doi:10.1080/23311916.2021.1878668

[7] Jallow A, Shitote SM, Abuodha S, Sanewu IF. Flexural failure of bamboo-reinforced concrete beams. SSRG International Journal of Civil Engineering. 2025;12(4):119-127. doi:10.14445/23488352/IJCE-V12I4P112

[8] Onuegbu TU, Nwachukwu SC, Umoh AA. A review on experimental observation on structural performance of bamboo-reinforced concrete beam. Heliyon. 2024;10(2):e24157. PMC10834822. doi:10.1016/j.heliyon.2024.e24157

[9] Nguku E, Osano DO, Maina P. Performance prediction of hybrid bamboo-reinforced concrete beams using gene expression programming for sustainable construction. PMC10608324. 2023. doi:10.1101/2023.10.15.562334

[10] Hasan NMS, Sobuz MHR, Khan MMH, et al. Integration of rice husk ash as supplementary cementitious material in the production of sustainable high-strength concrete. Materials. 2022;15(22):8171. PMC9699146. doi:10.3390/ma15228171

[11] Adeyemi OA, Adebayo OA, Adeogun OO. Mechanical properties of concrete produced with rice husk ash as partial replacement for cement. In: 2nd International Conference of Engineering, Science and Environmental Technology (ICESET 2025). Ile-Oluji: Federal Polytechnic; 2025. pp. 112-119.

[12] Ramsay A, Creagh G, Buys L, Davis P. Uncovering indigenous perspectives in the Australian engineering curriculum: a systematic literature review of practical examples. Australasian Journal of Engineering Education. 2023;28(1):1-18. doi:10.1080/22054952.2023.2282848

[13] Momoh EO, Dahunsi BI, Olowe MO. Properties and applications of bamboo as a structural material for low-cost housing in developing countries: a review. Construction and Building Materials. 2021;305:124770. doi:10.1016/j.conbuildmat.2021.124770

[14] Olugbenga OA, Nwankwo EL. Earth building construction processes in Benin City, Nigeria and engineering classification of earth materials used. Acta Technica Napocensis: Civil Engineering and Architecture. 2014;57(3):196-212.

[15] Makinde AO, Fatoye BA. Local materials in African traditional architecture and modern practice. International Journal of Contemporary Architecture. 2021;8(2):33-44.

[16] Chukwu SI, Nwofor TC. Stabilized lateritic bricks as alternative to mud housing in Bauchi, North East Nigeria. Journal of Civil Engineering Research. 2018;8(2):32-38. doi:10.5923/j.jce.20180802.02

[17] Awoyera PO, Adesina A. A critical review on application of alkali activated slag as a sustainable composite binder. Case Studies in Construction Materials. 2019;11:e00268. doi:10.1016/j.cscm.2019.e00268

[18] Okafor FO. Palm kernel shell as a lightweight aggregate for concrete. Cement and Concrete Research. 1988;18(6):901-910.

[19] Olutoge FA, Quadri HA, Olafusi OS. Investigation of the strength properties of palm kernel shell ash concrete. Engineering Science and Technology: An International Journal. 2012;2(3):288-295.

[20] Bamidele IO, Akindehinde AK, Olorunfemi MO. Engineering properties of compressed earth blocks stabilised with OPC and RHA in south-west Nigeria. Journal of Materials and Environmental Science. 2024;15(2):211-225.

IX.