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**COMPRESSED STABILIZED LATERITE BRICKS
(CSLBs) AS A SUSTAINABLE MEANS OF
AFFORDABLE HOUSING IN NIGERIA**

Adamu Isyaku MUSA

Master's Thesis

Supervisor

Asst. Prof. Dr. Deniz ÇETİN

İstanbul, 2024

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The thesis titled COMPRESSED STABILIZED LATERITE BRICKS (CSLBs) AS A SUSTAINABLE MEANS OF AFFORDABLE HOUSING IN NIGERIA prepared by ADAMU ISYAKU MUSA and submitted on 03/06/2024 has been **accepted unanimously** for the degree of Master of Science in Architecture.

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I hereby declare that all information data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

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XXXXXXXXXX

DEDICATION

In the name of Allah, the Almighty, the source of all strength and wisdom, I humbly dedicate this thesis.

To my beloved parents, Engr. Musa Isyaku (MNSE) and Haj. Maryam Shuaibu, your unconditional love, encouragement, and sacrifices have been my guiding light throughout this journey and beyond. Your faith in me has been my greatest motivation, and I am forever grateful for your endless support.

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ABSTRACT

COMPRESSED STABILIZED LATERITE BRICKS (CSLBs) AS A SUSTAINABLE MEANS OF AFFORDABLE HOUSING IN NIGERIA

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This thesis examines the potential of compressed stabilized laterite bricks towards developing a sustainable means of delivering affordable housing in Nigeria. The study provides input into this discourse for solving the vexing challenges of housing in the country through an analysis of CSLB properties, availability, and environmental benefits, in comparison with conventional building materials like sandcrete hollow blocks. This will be added to the literature review, case studies, and occupancy comfort simulations that all prove the CSLB process is economically viable, environmentally sustainable, and has occupant comfort advantages. The results show a price difference of about 15% that goes to the side of CSLB compared to SHB outlining its potential to provide quality but low-cost housing. This study is focused on key comfort parameters based on occupancy comfort examinations, specifically relative humidity, air temperature, radiant temperature, operative temperature, discomfort hours, and outside dry-bulb temperature, with a series of simulations and data analyses. Generally, SHB showed higher temperatures of the air, radiant, and operative in comparison to CSLB, whose temperature ranges were 36.44°C-45.80°C for SHB and 31.83°C-39.72°C for CSLB. However, CSLB demonstrates lower relative humidity levels ranging from 22.15% to 65.62% compared to SHB, which range from 15.54% to 53.47%. The study in general concludes that CSLB represents a transformative solution to address housing challenges, offering a pathway to inclusive and robust communities in Nigeria.

Keywords: Affordable Housing, Sustainable Housing, Compressed Stabilized Laterite Bricks (CSLB), Sandcrete Hollow Block (SHB), Occupancy Comfort.

ÖZET

NİJERYA'DA SÜRDÜRÜLEBİLİR UCUZ KONUT ARACI OLARAK SIKIŞTIRILMIŞ STABİLİZE LATETERİT TUĞLALAR (CSLB)

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Bu tez, Nijerya'da uygun fiyatlı konut için sürdürülebilir bir araç olarak sıkıştırılmış stabilize laterit tuğlaların (CSLB) potansiyelini araştırıyor. Çalışma, CSLB'nin özelliklerini, bulunabilirliğini ve çevresel faydalarını kumbeton boşluklu bloklar (SHB) gibi geleneksel yapı malzemeleriyle karşılaştırarak inceleyerek ülkedeki acil konut sorunlarını ele alıyor. Literatür taraması, vaka çalışmaları ve kullanım konforu simülasyonlarının bir kombinasyonu yoluyla araştırma, CSLB'nin ekonomik uygulanabilirliğini, çevresel sürdürülebilirliğini ve bina sakinlerinin konfor avantajlarını ortaya koyuyor. Bulgular, SHB ile karşılaştırıldığında CSLB lehine %15'e varan bir maliyet farkını ortaya koyuyor ve kaliteden ödün vermeden uygun fiyatlı konut çözümleri sunma potansiyelini vurguluyor. Bir dizi simülasyon ve veri analizi yoluyla yapılan doluluk konfor incelemelerine dayanan bu çalışma, bağıl nem, hava sıcaklığı, radyant sıcaklık, çalışma sıcaklığı, rahatsızlık saatleri ve dış kuru termometre sıcaklığı dahil olmak üzere temel konfor parametrelerini inceliyor. Bulgular, SHB'nin genellikle CSLB'ye kıyasla daha yüksek hava, ısıtım ve çalışma sıcaklıkları sergilediğini, sıcaklıkların SHB için 36,44°C ila 45,80°C ve CSLB için 31,83°C ila 39,72°C arasında değiştiğini ortaya koyuyor. Ancak CSLB, %15,54 ila %53,47 arasında değişen SHB'ye kıyasla %22,15 ila %65,62 arasında değişen daha düşük bağıl nem seviyeleri sergiliyor. Çalışma genel olarak CSLB'nin konut sorunlarına yönelik dönüştürücü bir çözüm sunduğu ve Nijerya'da kapsayıcı ve güçlü topluluklara giden bir yol sunduğu sonucuna varıyor.

Anahtar Kelimeler: Uygun Fiyatlı Konut, Sürdürülebilir Konut, Sıkıştırılmış Stabilize Laterit Tuğlalar (CSLB), Sandcrete Asmolen Blok (SHB), Kullanım Konforu.



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ABBREVIATIONS

CSLB : Compressed Stabilized Laterite Bricks

SHB : Sandcrete Hollow Block

CSLB : Compressed Earth Bricks

sqm : Square Metre

NGN : Nigerian Naira (Currency)

NE : North East



1. INTRODUCTION

These are expected to be in conjugation with high socio-economic and historical difficulties that North-East Nigeria is faced with, which interprets into major concerns about affordable and sustainable housing (Olayiwola et al., 2005). The history of insurgency rummaging the region, coupled with massive unemployment, has spawned a legacy of inadequate housing and severe crisis. More than ever, the world needs safe, resilient, and sustainable housing; continuous displacements of people and their communities as a result of socioeconomic challenges are only making this worse (Idris, 2024: 2).

Out of this realization, there is growing appreciation and acceptance of the need to seek alternative building materials and methods. Of these alternatives, Laterite Compressed Earth Bricks have been found to be very promising. These bricks are made by compressing locally available laterite soil into solid blocks; hence, they present a more sustainable and environmentally responsible way to meet the housing needs in the region. Importantly, earth material, if well managed, can reduce the resources depletion, pollution, waste generation, and Ecological disturbances that come as an effect of using conventional building materials (Abhilash, 2021).

A study by Abhilash (2021) shows Laterite CSLBs' potential for reducing the housing problem in Northeastern Nigeria. The research provides information about the low environmental impact of earth-based materials and their compatibility with sustainable building practices, thus underlining their environment-friendly benefits. Using locally available materials and innovative construction techniques, Laterite CSLBs offer a practical pathway to deliver low-cost and sustainable housing solutions to the community.

The adoption of Laterite CSLBs also dovetails with wider programs aimed at promoting environmental stewardship and resilience in view of the constraints of resources and changing climate. Currently, this need for sustainable shelter options moves to the front line as communities grapple with the results of rapid urbanization and environment degradation. Further, stakeholders could make the North-East region of Nigeria more resilient and sustainable for the future by using laterite CSLB as an alternate building material in order to meet short-term shelter needs within that region.

1.1 BACKGROUND OF THE STUDY

The North-eastern region of Nigeria is embroiled in a wide array of complex issues whose roots go deep into history, politics, and economy. Political unrest, economic inequality, and historical legacies are at the forefront of making an important mark on the social fabric of the zone, a region known for its rich cultural legacy (Olayiwola et al., 2005:2). Economically, compared to other regions of Nigeria, the North-East has always been backward in terms of development and infrastructure. This is because access to basic services such as healthcare, education, and transport has influenced slow socio-economic progress in the areas, which in turn fuels poverty and inequality. With agrarian economies dominating and little varied economic opportunity existing, livelihood opportunities are therefore limited, and cycles of poverty and vulnerability are perpetuated (Olayiwola et al., 2005:2).

Politically, it was the Boko Haram Insurgency that started early in the 2000s, which spelled insecurity and turmoil in the North-East. The duration of this conflict bequeathed serious consequences, massive displacement of people, and infrastructural destruction, accompanied by loss of lives. Other than affecting social cohesion within communities, the insurgency has brought down societal structures while further marginalizing weaker sections—exacerbating entrenched disparities and grievous interests (Oluwasanmi, 2022: 95).

The North-East is rich in cultural heritage and traditional building practices. Indigenous architectural styles that are historically defining of the region's architectural expression are those of structures built using local materials and vernacular construction methods. However, often, colonial legacies or modernism efforts have marginalized these traditional practices in favor of Westernized construction materials and designs. This has created a gap between local wisdom and contemporary norms of practice in construction (Idris, 2024:1). At the junction of political instability, historical complexity, and economic challenges lies the severe housing crisis in the Northeast. In particular, the Boko Haram insurgency worsened the rather very acute shortage in housing that was hitherto prevailing in the region through massive displacement and destroying housing infrastructure (Oluwasanmi, 2022).

In that regard, what human beings need are affordable, resilient, and sustainable housing solutions; therefore, first priority must be accorded to them by the communities, practitioners, and legislators alike.

Because of the likelihood of their potential to alleviate the housing problem with affordability and sustainability, innovative building materials like Laterite Compressed Earth Bricks have caught attention. In the Northeast of Nigeria, CSLBs will provide a promising route for community reconstruction, economic development, and environmental sustainability, because they are rooted in local resources and vernacular construction traditions. The figure below Figure 1.1 shows the different geo-political zones and locations in Nigeria.

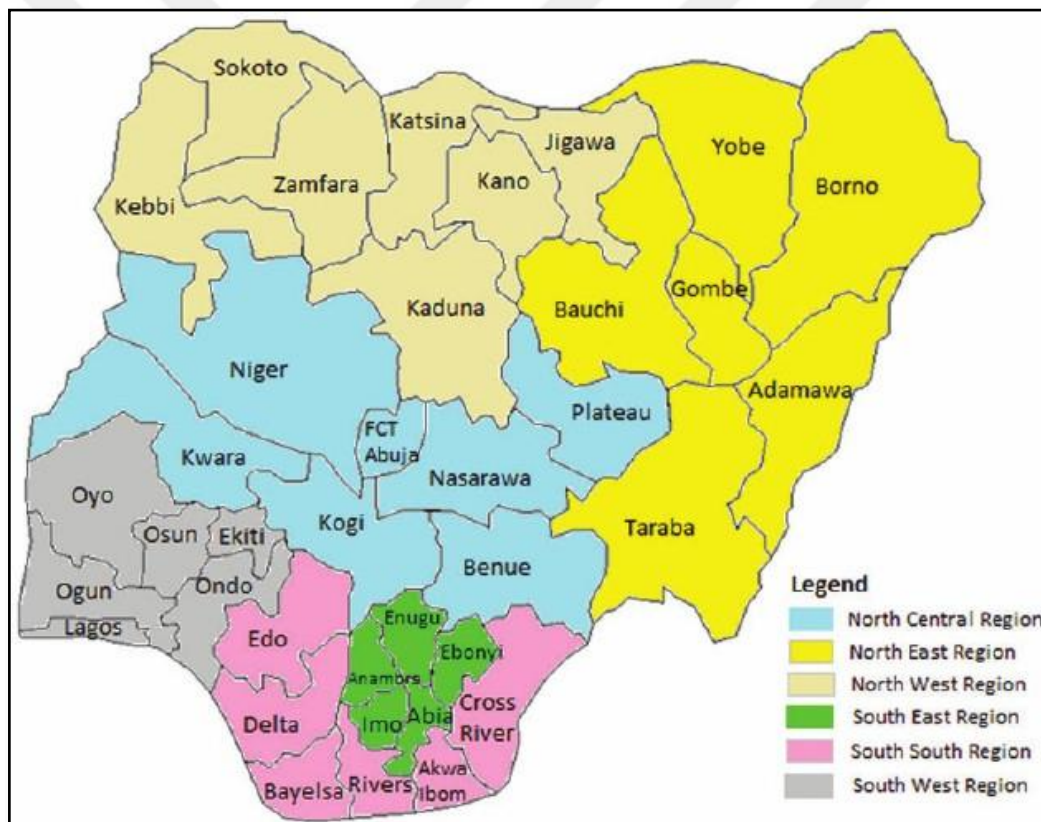


Figure 1.1: Map of Nigeria Showing Geo-Political Zones (Wikipedia, 2020).

1.1.1 Housing Challenges in Nigeria

Nigeria, Africa's most populous nation, deals with a multitude of housing challenges that disproportionately affect its low-income urban residents. These challenges are deeply rooted and complicated, encompassing issues related to affordability, accessibility, and

sustainability (Idris, 2024: 1). In northern Nigeria specifically, poor property development and management worsen the housing crisis, compounding the difficulties faced by residents.

The use of private methods for home supply is one of the main problems fuelling Nigeria's housing crisis. Numerous issues have resulted from this strategy, such as the hiring of untrained laborers, the incapacity to follow building codes, and difficulties obtaining financing for houses. As a result, a lot of housing developments don't live up to fundamental standards, which exposes occupants to poor living circumstances.

Because of Abuja's Federal Capital Territory's rapid urbanization and population increase, the housing crisis is especially severe there. The gap between housing needs and supply is growing as a result of the demand for sustainable housing delivery significantly exceeding the supply (Muhammad, 2015: 27). Comprehensive policies that consider the social, economic, and environmental aspects of housing construction are needed to address these issues.

The housing situation in Nigeria is further complicated by insufficient infrastructure, especially sanitation facilities and water. Such facilities are lacking in most of the cities, making them uncondusive for living. Slums and informal settlement currently increases, thereby giving rise to social inequalities and health risks among residents (UN-Habitat, 2016).

Contending with these challenges, approaching the problem of housing in Nigeria demands a holistic approach that integrates elements of community, policy, and sustainable development practices. In other words, adequate and affordable housing for all Nigerians will have to involve increasing affordability, building financing alternatives, and regulatory framework strengthening.

1.1.2 Importance of Sustainable Building Materials

Sustainable construction materials drive most of the environmental, cost, and long-term viability features of building and construction projects. Their importance is realized in connection with their potential to reduce natural environment degradation by improving resource efficiency and fostering general sustainability of built environments (Gharehbaghi et al., 2022: 741).

Development of green buildings calls for the adoption of sustainable building techniques through the use of environmentally friendly materials and new construction practices. Examples of such materials include bricks, which is long-lasting and can be rolled over and over again, therefore reducing wastage and impacting the environment less (Rehman, 2014: 279).

Besides, one of the strategic measures toward advancing sustainability in the building sector is to incorporate bio-building materials and other environmental amenities. These are low-carbon and renewable materials that provide viable means of reducing environmental impacts associated with the building's construction and operations (De Luca et al., 2017: 141). Although attention is gradually being given to the issue of sustainable construction materials, their most visible problem is the lack of a standard framework of assessment and selection. Universal acceptability is barred by a lack of universally agreed-upon standards that will enable the incorporation of issues of sustainability in a coherent way into material procurement and building methods (Baharetha et al., 2013).

In view of the current state of modern construction, it cannot be overemphasized how sustainable building materials make a difference in expected outcomes. These can enhance the ecological accountability of sustainable development objectives and promote a more sustainable constructed environment by focusing on economical use of resources and enduring robustness.

1.2 PROBLEM STATEMENT AND RESEARCH QUESTIONS

The North-East region of Nigeria faces serious issues of housing shortages, worsened by economic inequality, political instability, and inheritance of insurgency. The displacement of communities in a bid to handle insurgency has heightened demands for sustainable and affordable housing within that part of the country. The prevailing housing types are usually expensive, unsustainable, and relatively scarce to afford adequate shelter to most residents and protect them from displacements. It will take innovative solutions that address affordability, sustainability, and community resilience to overcome this housing crisis.

This research tries to establish whether Laterite Compressed Earth Bricks might offer viable possibilities for tackling the acute shortage in housing accommodation in North-Eastern

Nigeria. The paper dwells on three basic parameters—affordability, sustainability, and accessibility—to answer the questions of whether CSLBs are greatly contributive to a solution for this problem.

This study, therefore, is expected to help in deepening such understanding regarding the contribution CSLBs can make to reducing the housing crisis and laterite for its sustainability as a building material. The progression toward facilitating practical, affordable, sustainable, and accessible housing solutions that respond to the North-East region's housing challenges is envisioned through supportive policy and practice in the area, backed by further research. The research will look to address certain problems and seek to provide answers to pertinent questions that make a difference in this domain.

- a. To what extent will the use of Laterite Compressed Stabilized Earth Bricks (CSLBs) improve the affordability and accessibility of housing in North-East Nigeria?
- b. What are the environmental advantages of using Laterite CSLBs in low-cost housing when compared with other conventional building materials?
- c. How do the thermal properties of Laterite CSLBs contribute to energy efficiency and occupant comfort in housing structures?
- d. What are the initial construction costs of building CSLBs compared to SHBs?

1.3 OBJECTIVES AND SIGNIFICANCE OF THE THESIS

The research objectives are formulated to cover all the dimensions related to taking Laterite Compressed Earth Bricks as a means toward a sustainable solution to the housing crisis in North-East Nigeria. This multi-faceted study places itself at the very frontline of providing insightful input into technical, economic, social, and environmental features of CSLB-based housing within the region for policy, practice, and community engagement efforts.

The Objectives of the Research are as follows:

- a. To establish whether Laterite Compressed Stabilized Earth Bricks can suitably be used for Affordable Housing in North-East Nigeria.
- b. Towards assessing the economic viability of CSLBs as a housing solution in North-East Nigeria:
- c. To evaluate the environmental impact of CSLB-based housing on sustainability in North-East Nigeria.

- d. The energy efficiency and thermal performance in buildings constructed with CSLBs and SHBs needs to be evaluated.
- e. Determine initial construction cost for the CSLBs and SHBs.

This becomes important in the context of North-East Nigeria, where CSLBs not only have the potential to deliver low-cost housing but are also in line with other developmental agendas. In using rapidly available resources of laterite soil, CSLBs can drive local economic development and community empowerment with this sustainable approach to construction.

This showdown shall seek to delve into intricate dimensions of Laterite CSLBs as a sustainable means of low-cost housing in North-East Nigeria. It looks at the political situation, economic conditions, and historical perspective on housing, also giving an account of specific challenges posed by the situations in the region.

Drawing on existing research, practical data, and case studies, this thesis intends to look into the suitability, benefits, and challenges in the use of CSLBs within the North-East Nigerian context. The present study has critically analyzed experiences by researchers, practitioners, and communities to identify opportunities for innovation, policy intervention, and community engagement in the development process toward sustainable housing solutions in the region.

1.4 SCOPE AND LIMITATIONS

Scope:

It focuses on Laterite Compressed Earth Bricks as a sustainable means of solving the housing crisis, particularly in the North-East region of Nigeria.

It also extends to scrutiny related to CSLB-based housing based on technical, economic, social, and environmental dimensions.

It will further ascertain the engineering suitability of laterite as a construction material for the CSLB production process and its bearing on sustainability.

It involves the study of thermal properties of Laterite CSLBs resulting in efficient energy and comfortable housing structures.

It would also be focused on the construction cost of building, using CSLBs compared to other conventional building materials.

Limitations:

Thus, the research will be limited geographically to only the North-East of Nigeria and cannot be translated directly to other geographical areas that differ in socio-economic and environmental contexts. Time and resource constraints may further delimit the depth and breadth for which data can be collected and analyzed; this, again affecting the comprehensiveness of findings.

Literature reviews, as well as empirical data and stakeholder interviews, will form the base of the research; these sources themselves are thus subject to bias, inaccuracy, or limitation of the applied research methodologies.

This might miss out on the scope of research to include all factors that could have an influence on the adoption and implementation of CSLB-based housing solutions in a region, therefore missing out on those nuances or complexities.

1.5 METHODOLOGY

Specifically, the methodology adopted for this research is mixed-method in nature, with quantitative cost assessments complemented by qualitative insights from stakeholders and simulation techniques to completely address the hypotheses on the cost-effectiveness and sustainability of Laterite Compressed Stabilized Earth Bricks as compared to Sandcrete Hollow Blocks in housing construction within a North East Nigerian context.

Quantitative Analysis:

The quantitative aspect of the study involves Semi detailed cost assessments, examining initial construction expenses, associated with CSLB and SHB-based housing. These analyses draw upon economic theories and managerial economics principles discussed in the literature review, providing a framework for understanding cost dynamics in housing construction.

Qualitative Data Collection:

In parallel, Data was collected from local suppliers and construction experts in Nigeria. The evaluation criteria included material properties, initial cost, labour cost, and sustainability factors. A typical three-bedroom house construction project served as the basis for comparison.

Simulation Techniques:

Further, simulation techniques are used to analyze the level of thermal comfort and lifecycle performance of buildings constructed with CSLBs and SHBs. Building performance simulation software Design Builder shall be used to model various scenarios and simulate them considering several factors, including thermal comfort, among others.

Thesis Framework:

The methodology is put within a structured framework to ensure it be inclusive and coherent in the research processes. Starting with an introduction, background, and context, literature review, research design are followed by a comparative case study approach with simulation-based methodology to enable intricate and complex analyses of CSLB and SHB-based housing. Data collection strategies will hence range from a set of quantitative to qualitative methods, thereby extending from cost analysis to sustainability assessments and occupant comfort.

2. SUSTAINABLE AND AFFORDABLE HOUSING

2.1 SUSTAINABLE HOUSING

Sustainable housing encompasses a holistic approach to the design, construction, operation, and maintenance of residential buildings, aiming to minimize environmental impact, conserve resources, promote social equity, and enhance occupants' quality of life (Muhammad, 2015: 24). Sustainable housing practices tackle various environmental, economic, and social challenges associated with conventional housing in order to toilet the issues influencing high energy use, large amounts of wastes, habitat destruction, and social exclusion (Sangster & jones, 2018).

The use of renewable resources, Energy efficiency, water conservation, indoor air quality maintenance, climate change resistance, accessibility, and affordability are all essential components of sustainable housing. On top of the sustainable housing initiatives are the priority lists that include integrated green building practices, passive design strategies, renewable energy systems, and leading-edge technologies that help create an economically and socially viable home in the long term as well as ecologically sound (Raven et al., 2021).

2.1.1 Principles and Concepts

Sustainable housing is a multifaceted conception, embracing a holistic approach by embedding dimensions wider than just the environment. Environmental impact, air and water quality, biodiversity, and finality are some of the core dimensions of sustainable housing (Priemus, 2005: 5). Its scope also covers broader social and economic imperatives. For example, while pursuing the rhetoric of sustainability, housing initiatives often have poverty reduction and slum eradication as their objectives, but with an added emphasis on the need for feasible financing mechanisms.

Some of the key pillars of sustainable housing include resilience, social justice, economic feasibility, and environmental duty. It takes an integrated process in designing, constructing, operating, and maintaining residential buildings for their ecological footprint to be reduced while improving quality of life and forging communities that are inclusive. The framework draws on ideas and principles such as:

Energy Efficiency: The theme of sustainable housing is for efficient design and technologies in order to reduce energy use and associated emissions.

Resource Conservation: Reduction of wastes by using eco-friendly materials in housing promotes sustainability.

Social Equity and Inclusion: It provides for affordable and appropriate housing for diverse populations.

Resilience and Adaptability: Long-term sustainability of the designs of housing are taken into consideration in view of climate change and disaster resilience.

Healthy Indoor Environments: Good ventilation, natural illumination, and non-toxic materials enhance occupant health.

Long-Term Affordability: Benign operational costs and innovative financing models improve the affordability of sustainable housing.

Community and Place-making: An important component of sustainable housing is access to vibrant, walkable communities that include appropriately sited amenities and public spaces.

Taking these ideals of sustainable housing into practice involves a great variety of issues linked to architecture, social dynamics, professional-success/ achievement, and how best to renew the stock of existing homes. According to, reducing environmental impact by using available resources efficiently, minimizing generation of wastes, and incorporating renewable energy sources are common basics of sustainable architecture and design. One of the architectural perspectives for sustainable design is modifying architectural layouts considering the particulars of any site and climatic situations. In the final analysis, this principle turns more attention toward attaining improved energy efficiency and comfort for the residents.

2.1.2 Global Trends in Sustainable Housing

A range of global trends in sustainable housing have been identified and highlighted, reflecting a multidimensional approach to addressing environmental, social, and economic challenges in the built environment Rapone et al., (2024: 1). with emphasis on the need for low-cost, energy-efficient, and safe temporary housing, particularly in the face of natural disasters and climate change. Rapone again highlights the potential of smart technologies in

affordable housing to improve sustainability and connectedness, offering insights into how advancements in technology can enhance the liveability and efficiency of housing developments.

Cousins & Hill in their 2021 work, discusses the use of local materials and steps taken to reduce building costs and energy use amid a growing global population. It therefore underlines the importance of resource efficiency and cost-effectiveness in sustainable housing options. According to Tibaijuka (2013), social and economic justice is an important issue in designing sustainable housing in the context of global restructuring and immigrant housing. This has pointed out that inclusive and fair policies and programs pertaining to housing are very essential. All these developments make it clear that subsidized, efficient in energy use, and socially just housing solutions are now needed more than ever before in order to handle the complicated set of problems communities around the world are facing.

For the past two years, there has been a marked increase in the uptake of sustainable housing practices worldwide. These vary from commitments to care for the most fundamental environmental challenges and social injustice, to enhance quality of life for all. According to these trends, as driven by a mix of technological, policy, market, and societal shifts, underlines a sea change in how we imagine, design, and inhabit our built environment.

One major development driving the field of sustainable housing forward is increasing energy efficiency. Buildings account for a huge share of greenhouse gases and energy consumption across the world; accordingly, designing and installing efficient energy use has been at the frontline in mitigating climate change. There is a growing emphasis on high-performance insulation, passive solar design, and integrating renewable energy systems—like solar panels and geothermal heating—to try to lower energy demand and promote creation of renewable energy.

2.1.3 Sustainability of Housing in Nigeria

The concept of sustainable housing grows daily in Nigeria, as the country wrestles with rapid urbanization, environmental degradation, and other socio-economic disparities. These challenges are opportunities that can be fended off by sustainable housing practices through energy efficiency, reduction of carbon emissions, conservation of natural resources, and

enhancement of the resilience of the communities to climate change impacts (Ogunbayo et al., 2022).

The challenges to the adoption of sustainable housing with limited awareness and capacity of reducing waste, a high initial cost of green technologies, poor regulatory frameworks, and development priorities competing for attention, are many (Anaç et al., 2024). Notwithstanding all these challenges, the need for sustainable housing is fast being recognized by Nigeria on account of its concerns regarding energy instability, environmental deterioration, and needs for inclusive growth.

This section cannot be closed without an assessment of the sustainability of housing in the North-East region. Distinctive opportunities and challenges are found in the North-East part of Nigeria for the development of sustainable housing, as part of post-conflict reconstruction and recovery efforts. The region has been under attack due to insurgency by Boko Haram; with devastating destruction of housing infrastructures, displacement of populations, and loss of livelihoods.

The communities need to be rebuilt and reconstructed in a sustainable and resilient way with consideration of future shocks and stresses in the aftermath of the conflict (Rimdans, 2019:85). Such unique demands and objectives for the affected populations of access to safe, secure housing, and access to basic services and chances at economic livelihoods through employment opportunities are scenarios that sustainable housing projects in the Northeast have to take into account. These projects will also need to factor in the socio-cultural setting of the area. Sustainable housing requires that the local communities be involved in the planning, design, and construction of housing projects.

2.2 AFFORDABLE HOUSING

Housing affordability, which is the ability of people or families to acquire affordable housing without much load on their budget, is one of the prime factors that determine the wellbeing of a society (Hulse & Burke, 2016). It is a composite factor that mainly includes issues such as housing prices and costs, income levels, the availability of adequate financing sources for housing, and finally, the cost of living. Affordable housing is paramount in promoting social

equity, economic stability, and quality of life in general, both for individuals and entire communities.

In a larger perspective, the dynamics of supply and demand, government activities, patterns of urbanization, and socioeconomic factors all interact in complicated ways to influence housing affordability underscores (Hulse & Burke, 2016). With the rapid urbanization, population growth common in most parts of the world, and Nigeria in particular, property values and rental rates have increased. Low- and moderate-income households may find it increasingly difficult to access affordable housing as this phenomenon worsens.

2.2.1 Definitions and Criteria for Affordable Housing

Among others, some of the very important and worth considering criteria of affordability include:

Affordability criteria: Affordable housing is usually defined in terms of the percentage of household income that goes toward housing costs. The most commonly mentioned criterion is probably the "30% rule," which states that for housing to be considered affordable, it should not exceed 30 percent of household income (O'Sullivan, 2004). However, the affordability thresholds may differ from one area to another, which is dependent on the thriving local markets, housing policies, and income levels.

Income Levels: Most often, affordable housing is meant for low- and moderate-income families who are unable to afford market-rate housing. The basis of qualification or eligibility for subsidized affordable housing schemes is income eligibility criteria. These limits are generally relative to area median income or poverty guidelines.

Housing Cost Components: An integral factor in affordable housing will be its various housing cost components. This covers rent or mortgage, utilities, property tax, insurance, and maintenance costs. In the process, all such components are expected to be made affordable so that no cost burden falls on residents, making them financially unstable (Hulse & Burke, 2016).

Accessibility and Location: An affordable, decent house should be located in a setting which allows easy access to key amenities, public transport, employment opportunities, and

community services. Accessible housing makes it easy for residents to engage in all activities of daily life and participate fully into the community.

Housing Quality and Adequacy: The minimum standards of affordable housing quality, safety, and habitability are an overview of the residents' well-being and health. Among other adequate housing features described include sufficient space, ventilation, sanitation facilities, and structural integrity (Ibem, 2015).

Long-term affordability: It is where the sustainable affordability aspect ensures that housing shall remain affordable way into the long term where the conditions of the economy or other dynamics of the housing market change. This can be achieved through mechanisms that adjust rent based on income, deed restrictions, or community land trusts to lock in affordability for future generations as written by (Christensen, 2000: 37).

Social Inclusion and Equity: Affordable housing policies should work to advance social inclusion, diversity, and equity of access to decent housing opportunities among underserved groups of the population, such as minorities, elderly citizens, disabled people, and homeless individuals (Palm & Niemeier, 2018: 182).

In summary, affordable housing is that which is, in cost, accessible, sufficiently long term sustainable, and adequate in relation to household income. All these requirements call for a holistic approach to meeting all the criteria while ensuring that safe, decent, and affordable housing is available to everybody.

2.2.2 Housing Affordability in Nigeria

The affordability of housing has become a critical issue in Nigeria, especially within urban areas where rapid population growth and urbanization have put pressure on supplies and raised prices (Olayiwola et al., 2005). The nation faces serious shortages in housing, coupled with other challenges brought about by socio-economic imbalances, expensive construction costs, and a lack of infrastructure. As many have pointed out, Idris, (2024), it was estimated that millions of housing units were short throughout the country (Oluwasanmi, 2022: 96).

Affordability is a very major obstacle standing in the way of housing availability to low- and middle-income earners, among many other Nigerians. Many families and individuals are forced to live in substandard, overcrowded, or informal dwellings—sometimes referred to

as ghetto housing—as a result of this gap between housing expenditures and household incomes, fuelling through the cycle of poverty and inequality (Olayiwola et al., 2005). Moreover, the unaffordability of houses has contributed to many aspects of housing problems in most Nigerian cities with respect to urban sprawl, informal settlements, and housing informality.

The minimum wage is one of the most important standards which, in principle, guarantees equal pay and working conditions for all workers in different sectors in the Nigerian economy. However, over time, this policy on minimum wage has been reviewed several times and changed to suit growing social and economic demands.

This subheading shall be concluded by looking at the Affordability of Housing in the North-East Region of Nigeria. The North-East region of Nigeria has unique affordability challenges with respect to post-Boko Haram insurgency that has displaced millions, with communities in ruins (Oluwasanmi, 2022: 96). The conflict has caused far-reaching destruction of housing infrastructure, loss of livelihoods, and population displacement, thereby worsening the already-acute pressures on housing shortages and affordability for the area as a whole (Anifowose & Raymond, 2022).

The housing problem in the Northeast deteriorated owing to socioeconomic vulnerabilities, restricted access to important services, and disruption of conventional livelihoods Ekoh et al., (2023). A large number of IDPs and returnees face difficulty in gaining affordable housing due to a variety of barriers, including unstable land ownership, problems related to the availability of credit, discrimination on the part of housing markets, among others, upon return (Ekoh et al., 2023). A multimodal approach to northeast which lags behind in housing affordability considers both long-term, sustainable development goals and more immediate humanitarian concerns of the contemporary context (Mojirayo et al., 2021:1155). As communities are rebuilt and economic development is pursued in a manner focused on continuing to advance affordable housing opportunities, such efforts must be adapted to local conditions based on socioeconomic, cultural, and environmental factors that frame the availability and affordability of housing.

2.2.3 Challenges in Achieving Affordable Housing

The quest for affordable housing is an initiative that opens up a whole world of challenges across the economic, social, and policy domains. In this thesis, we have explored a number of challenges that pose a barrier in bringing about accessible and sustainable housing solutions to accommodate diverse populations.

The housing affordability crisis in the US has only deepened, with possible solutions in the areas of supply, stability, and subsidy (Anacker, 2023).

First of all, expensive and unavailable land acts as an obstacle to low-cost housing. Where else, the shortage of land in urban areas raises its prices and is confronted with low development viability as compared to housing projects. This kind of behaviour worsens the affordability crisis in the most heavily populated places (Adabre et al., 2019). Increased development and construction costs attributed to the land cost are formidable difficult hurdles to affordability. With increasing labor, material, and regulatory costs, overall housing project costs escalate, driving affordability further out of reach. Such cost increases have the effect of widening the affordability gap for low- and moderate-income households and thus affect not just affordable but also market-rate projects (Akinwande & Hui, 2024).

Regulatory barriers and zoning restrictions are only part of the challenges in developing affordable housing. Difficult regulation, besides strict building codes and long permitting processes, extends the time a project takes to completion and raises development costs. These regulatory barriers have frustrated innovation and much-needed investment in affordable housing projects, ultimately slowing solutions to address housing affordability (Liang et al., 2020).

Another minimum wage with the national minimum salary act enforced in 2019 effective monthly minimum wage at ₦30,000 for both public and private sectors in Nigeria regarding a minimum wage review (BBC News, 2019). This will be equal to about \$35 at the current rate of inflation and depreciated Naira. This makes owning a home nearly impossible.

More so, the shortage of money is one of the biggest impediments to affordable housing achievement efforts. The current meager tax incentives, state finances and private investments reduce the share of funds that may be channeled into affordable housing

investments. The low-income populations are thus largely affected and have little choice in respect to quality and stable housing (Adabre & Chan, 2019). Incomes disparities and an affordability gap in climbing proportions affect underprivileged groups to get adequate housing. With a surging house price and flat wage growth, it is arduous most households to afford decent shelter. These discrepancies weigh much on the vulnerable populations at risk, from minorities to low-wage workers, bearing the burden of housing insecurity (Smith 2022:172).

Community opposition and the not-in-my-backyard phenomenon greatly hinder the development of affordable housing. Resident opposition from the host area, as a result of concerns about property value and perceived social risks, can retard the approval and implementation process for projects for affordable housing. This perpetuates exclusionary housing practices and undermines efforts to foster diverse and inclusive communities.

Finally, it is political will and policy priorities that represent the last of those missing elements, all attempting to effectively handle housing affordability concerns. Many reforms in policies and investments in the sphere of affordable housing are inhibited by the lack of necessary political capital, interfering interests, and ideological differences. In the absence of powerful political will, founded on policy interventions, sustainable solution to housing affordability remains an eluded objective (Pendall, 1999).

3. LATERITE OVERVIEW

3.1 COMPRESSED STABILIZED LATERITE BRICKS

Compressed Stabilized Laterite Bricks (CSLBs) represent a time-honoured building technique that has been embraced by civilizations throughout history for its simplicity, affordability, and sustainability (Oyelami, 2016). CSLBs, more commonly known as compressed earth blocks (CEB) or mud bricks, are a mixture of soil, water, and sometimes stabilizers compressed into solid blocks under mechanical or manual presses as shown below in Figure 3.1 Once dried, CSLBs possess remarkable strength and durability that renders them very feasible for any construction application.

There is evidence of the use of CSLBs dating back thousands of years across numerous cultures worldwide. According to Gole & Barnes, 2020, examples of earthen construction date back thousands of years. Starting from the ancient civilizations of the Egyptians and the Mesopotamians to the indigenous people in Africa, Asia, and the Americas, CSLBs serve not only as part of the built environment but also as shelter for generations.

3.1.1 Properties and Composition of Laterite

Laterite is a soil or rock type exceptionally rich both in iron and aluminum oxides. The name is derived from the Latin "later," meaning brick. It is well distributed in countries within the tropics and subtropics of the world. Such laterite soils normally form in areas with high rainfalls and warm temperatures, where chemical weathering processes leach away soluble minerals and leave the iron and aluminum compounds behind (Elitok & Tavlan, 2019).

Perhaps the major characteristic of laterite, better still, one of the unusual and easily identified characteristics is the reddish-brown coloring, as shown below in Figure 3.1, that results from the oxidation of iron minerals in the soil (Singh et al., 2023). That coloration gives laterite good looks and makes it different from other structures comprising soils and rocks. Other than its color, laterite is also characterized by being hard and durable, and resistant to erosion; therefore, a potential resource for various construction and engineering applications.

Historically, laterite has been used as a building material in many regions where it is abundant due to its inherent properties and availability (Singh et al., 2023). It has also been

used in several countries in the tropics for the construction of traditional buildings, roads, bridges, and monuments, thereby proving it versatile and strong as construction material (Elitok & Tavlan, 2019).

Interest in laterite as a sustainable and affordable alternative to conventional building materials has recently been renewed, particularly in relation to low-cost housing and sustainable development programs. The advantages of using laterite in construction are that it is abundant, inexpensive, environment-friendly, and thermally stable; therefore, its potential as a resource to alleviate housing shortages adds great promise for making positive contributions to sustainable construction practices worldwide (Singh et al., 2023).



Figure 3.1: Typical Laterite Sample (Oke, 2021).

In the past few years, there has been a re-established interest in CSLB as a sustainable and cost-effective substitute for traditional building materials (López-Rebollo et al., 2024:1). Growing concerns about environmental sustainability, resource scarcity, and needs for affordable housing in the context of rapid urbanization have fuelled renewed interest in CSLBs. It is the CSLB that best uses locally available soil resources and simple, low-tech construction techniques to provide practical means of addressing housing shortages by reducing construction costs and minimizing environmental impact.

This versatility of CSLBs makes it applicable to every Architectural style and Building design, ranging from the simplest rural type to the more complex urban building forms. In this respect, using CSLBs in a variety of building elements—like walls, floors, and even

roofs—does really offer flexibility and adaptability within different climatic conditions and geographical settings.

Moreover, CSLB construction involves the local people as the main actors in practice in the building process and creation of communities that are resilient and sustainable; hence, it fosters skill development and empowerment via community participation. The concepts of independence, ingenuity, and resourcefulness find befitting expression in CSLBs and offer a way toward sustainable development that generally is firmly entrenched in history but still retains enough resilience to respond to today's contemporary problems.

This introduction, emphasizing the historical importance, technical characteristics, and current uses of CSLBs, serves as background information for examining possibilities for CSLBs as a sustainable construction material (Nairaland, 2024).

This study will consider the benefits and drawbacks of, and new developments in, CSLB building to further discourse on sustainable housing and community development into the twenty-first century.



Figure 3.2: Compressed Stabilized Laterite Brick Sample (Arad Branding 2024).

Laterite is a widely distributed formation in the tropics, whose composition is rather complex if one takes into account that the combined action of such different factors as climate, parent rock material, and weathering processes intervenes in its origin (Ghosh et al., 2020). Several

principal constituents combine, as Ghosh et al., 2020 showed, to give laterite its characteristic features and properties.

Iron oxides, primarily hematite (Fe_2O_3) and goethite ($\text{FeO}(\text{OH})$), are essential constituents of laterite and cause its characteristic reddish-brown colour. Inherited from the weathering of iron-rich parent rocks over a long period, as shown below in Table 3.1.

Apart from iron oxides, laterite frequently contains a good amount of aluminium oxides, resulting from the weathering of aluminium-rich parent rocks; this then includes gibbsite, $\text{Al}(\text{OH})_3$, and boehmite, $\text{AlO}(\text{OH})$, according to (Ghosh et al., 2020). Aluminium thus contributes to the general mineralogical composition and eventually controls the mechanical properties of laterite.

Another major constituent of laterite is silica (SiO_2), which comes from weathering silicate minerals in the parent rocks. Silica plays a great role in the mineralogical structure of laterite and consequently in the makeup as a whole.

Laterite contains hydrated iron and aluminium hydroxides, which form as a result of chemical weathering processes involving the oxidation and hydration of certain minerals, such as iron and aluminium (Ghosh et al., 2020). Therefore, these hydrated hydroxides contribute greatly to plasticity and binding properties in laterite, which influence its construction suitability.

Most of the laterites do contain clay minerals, such as kaolinite, montmorillonite, and illite, responsible for their plasticity and binding properties. Clay minerals largely determine the geotechnical properties of the laterite and influence its behaviors in construction applications.

Trace elements such as manganese, nickel, chromium, and titanium may also be found in laterite, derived from the parent rock material and weathering processes (Ghosh et al., 2020). Thus, these trace elements may affect the chemical composition and properties of laterite to a lesser degree than the principal constituents.

Some of the analytical techniques used in determining the mineralogical and elemental composition of laterite samples are XRD, SEM, and EDS.

Table 3.1: Showing the Chemical Composition of Laterite (Smith 2019).

Chemical composition (oxides)	Values (%)
SiO ₂	25.46
Al ₂ O ₃	31.10
Fe ₂ O ₃	35.53
CO ₂	7.91

The identification of rock types and continuism of their nature is done by the physical properties of rocks. The process through which laterite is formed dictates its texture and possible applications, hence its physical properties, according to Jones, 2018. Laterite's among others include hardness, streak, lustre, fracture, porosity, colour, cleavage and strength as its physical properties.

Hardness is a measure of a mineral's resistance to scratching or abrasion and is registered on the Mohs scale. The hardness of laterite is usually 2 according to the Mohs scale, which is described as a soft rock. However, information regarding its compressive strength is not readily available.

Streak refers to the colour of a rock when powdered or crushed and can be determined by scratching the mineral against a streak plate. Laterite exhibits a white streak (The streak of a mineral is the colour of its powder when it is dragged across an unglazed porcelain plate, known as a streak plate) when tested in this manner (Jones, 2020).

Lustre describes the way light interacts with a mineral's surface, with high lustre indicating a brilliant reflection. Laterite is characterized by a dull lustre, suggesting a feeble reflection of light (Jones, 2020).

Fracture refers to the manner in which a mineral break along irregular surfaces, and conchoidal fracture is common in minerals with uniform strength. Laterite typically displays a conchoidal fracture pattern (Jones, 2020).

Porosity, the ratio of pore volume to total volume, is another important property of laterite, with high porosity being characteristic.

Colour, influenced by a mineral's composition, reflects its ability to absorb and reflect light. Laterite's rusty-red colour is attributed to its high iron oxide content.

Cleavage, the tendency to break along specific planes, is not applicable to laterite due to its opaque nature.

3.1.2 Laterite as A Building Material

Laterite, a building material that can be turned into bricks and the walls as seen in Figure 3.3 which is abundant in tropical regions, has gathered significant attention in the construction industries for its potential as a sustainable and cost-effective building material. Indeed, laterite has been tackled by many researchers, including Omolola 2014 who indicated that it is quite suitable for various construction works, particularly in load-carrying structures. Its peculiar characteristics with regard to usage in any form of construction work should be known.

This, however, creates a warning to be more careful when dealing with laterite in construction and particularly road construction. There is a need to take extra care in the question of consideration and specific testing procedures for the incorporation of laterite into road construction, considering its unique properties. Care must be exercised to assure proper testing and quality control by all means to avoid potential problems and ensure that infrastructure projects related to laterite are long-lasting.

Even though laterite has been established as one of the sustainable building materials, Omolola, (2014: 40) maintain that it has been considered one of its advantages. Since it is an abundant material in nature, laterite can be found naturally without a substantial transport and energy

extraction processes. Besides, CSLBs from laterites need no further processing at source, hence exhibiting low energy use and reduced environmental degradation when compared with conventional building blocks of fired bricks or concrete.

Besides, laterite has a good thermal characteristic with a nature of insulation against heat and cold. With all these good properties towards thermal insulation, it will mean enhanced

energy efficiency within buildings, especially in locations with extreme climates. Furthermore, the results showed that those structures built of laterite were resistant to weathering and long-lasting and, therefore, could be applied long termally in divergent environmental conditions.

While these provide for the advantages of laterite-based construction, on the other hand, issues are related to careful siting and testing for structural safety and stability due to variations in laterite composition and properties in different regions. In addition, careful construction and proper practices of maintenance and repair are advocated for the prevention of some problems like cracking due to lack of moisture control or moisture infiltration, and erosion (Omolola, 2014).

Conclusion Laterite has promising potential toward sustainable and low-cost building material, particularly for regions rich in it.



Figure 3.3: A Typical Laterite Wall Malaysia 2018 (Ismail, 2022).

3.1.3 Laterite Availability in Nigeria

Laterite is mostly found in tropical African countries like Nigeria. It is mostly found in clay minerals and has in abundance aluminium and iron. Characterization of laterite is a reddish clay-like material that is strong or stony when parched and forms the uppermost soil in a few tropical or subtropical regions where it is sometimes used for construction. It is found in vast quantities in Abia and Oyo states. Laterite deposits are also found in other states, which include Adamawa, Cross River, Kano, Gombe, Delta, Bayelsa, and Lagos.

Recent geological surveys show that these deposits are predominantly found in the north-eastern states of Nigeria, including Gombe, Adamawa, and Yobe. These are excellent deposits for laterite soil development as they are often located where there are tropical climates and high weathering processes.

There is a potential of the laterite supply in Nigeria for local production of sustainable building materials, especially at times when other material resources are either expensive or inaccessible. Abundant resources that could be derived from laterite would contribute to solving housing problems and complement economic development in the northeastern part of the country, which has been suffering due to a lack of homes.

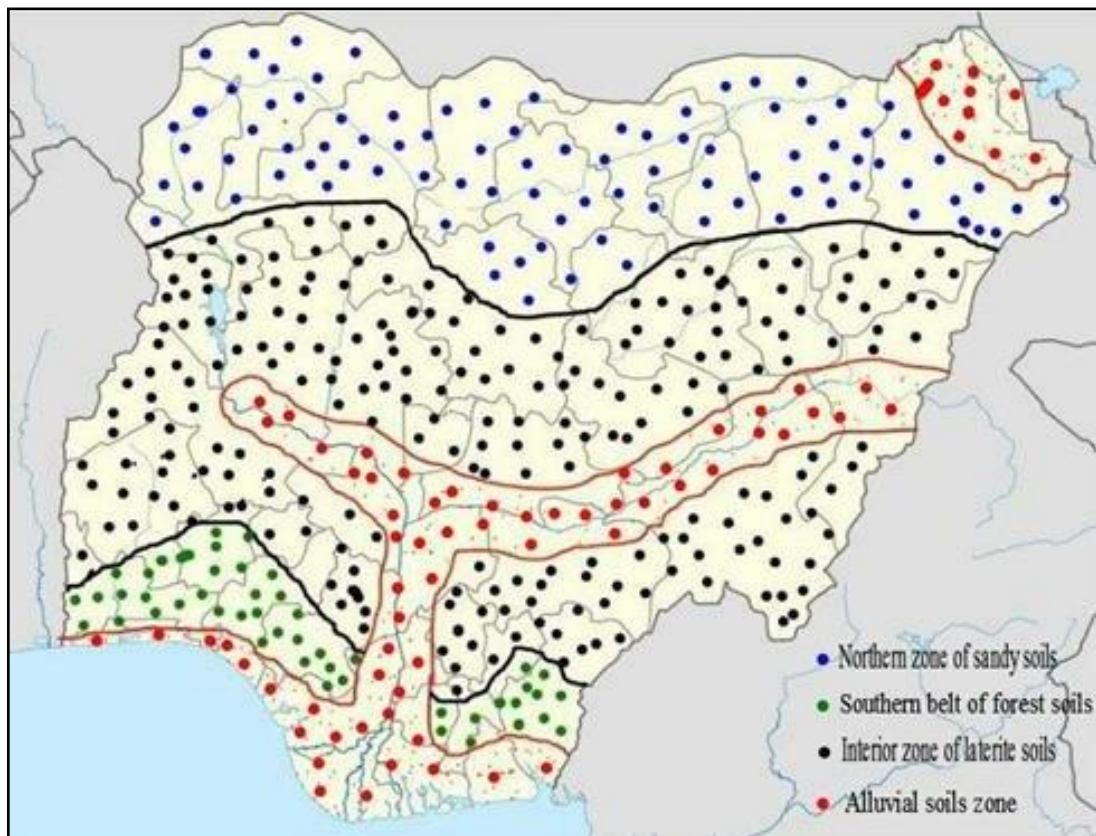


Figure 3.4: Map Showing Abundant Laterite Zone in Nigeria (J. Oke, 2021).

3.2 THERMAL STABILITY AND DURABILITY OF LATERITE CSLBS

Interest in the application of Laterite Compressed Stabilized Earth Bricks (CSLBs) for buildings has been sharp because they exhibit very good durability, thermal stability, and

other positive properties. Therefore, a good number of studies have yet proved them suitable for various building applications, especially producing low-cost housing.

De Castro & de Carvalho (2016:125) examined the mechanical and hydrothermal properties of Laterite CSLBs and presented them as suitable for building construction applications. His work showed not only good mechanical performance in these bricks but also that they are capable of withstanding various loads and environmental conditions. Results of the hydrothermal analysis gave an insight into how good bricks were at regulating the amount of moisture in the interior part to ensure that once one got into their house, they would be met with a cosier and more healthful living space.

Testing in 2016 by Agbede et al., evaluated Laterite CSLBs for durability and their fire resistance, adding greatly to their already considerable credibility. The results verified that the bricks do meet the required safety criteria and the applicable construction codes as regards fire resistance. It was proved that Laterite CSLBs are highly resilient to fire. The durability tests proved that Laterite CSLBs are long-lasting, entailing their structural integrity over a very long time to structures. These make them quite a choice for places where there may be a risk of wildfires or unfavorable weather; in this case, northern Nigeria has hot weather that sometimes rises up to 50 degrees Celsius.

Oyelami (2016) gave more information on the class and compressive strength of laterite CSLBs, thus affirming their suitability for use in low-cost housing. He also brought out the features on sustainability by underlining how inexpensive yet very helpful these bricks are in meeting the needs of low-income communities in regard to housing. Laterite CSLBs, particularly in conditions of limited resources, could very well provide low-cost housing through the use of local materials and eco-friendly construction techniques.

Moreover, in her creative research, Mimboe (2020) developed a new intervention using an advanced stabilizing binder, phosphate-based binder, to improve the Laterite performance of CSLBs. The study results proved that addition of this binder dramatically improved the bricks' resistance to environmental degradation and water penetration. Further, enhanced CSLBs are sure to seal its position as a sustainable building material by adding additional lifetime as well as reliability in construction works through its developed weather resistance and durability.

Due to potential properties described herein for Laterite CSLBs, and being prospective about conceptualising affordable housing construction into reality, the ability of these bricks presents an attractive answer because of their existing excellence in thermal stability, durability, and resistance against external forces to the problems of estate accommodation for the general masses of North-East Nigeria and beyond.

3.2.1 Thermal Performance of Laterite

Laterite has taken center stage in terms of thermal performance due to its wide usage in construction and other engineering-related operations. Research findings have shown that laterite has low thermal conductivity alongside high resistivity, hence making it more resistant to high temperatures and electrical currents as opposed to the conventional materials like clay and sand Bauer. For instance, the studies of laterite, clay, and sand samples for electrical and thermal properties discovered that laterite generally has minimal temperature fluctuation in absorbing heat, and therefore it can bear currents that are high and temperatures that are extreme (De Castro & de Carvalho, 2016).

Some of the factors that affect thermal performance in laterite include ambient air relative humidity, temperature, and electrical and thermal conductivities, aggregate size, curing temperature, and water-cement ratio. End. These studies on thermal conductivity, impedance, and diffusivity were found considerably variable for laterite-mud and concrete-block samples; the latter was 0.435 W/m·K. (Ngezahayo et al., 2019) Furthermore, it has been observed that thermal conductivity of laterite—usually fluctuating in the range of 0.3 to 2.0 W/m·K—is decreased by increasing the aggregate size and water-cement ratio in the mixture; hence, potentially exhibiting better thermal insulation performance when used in construction.

The most commonly used formula to realize the thermal performance, k , is:

$$k = \frac{Q \cdot L}{A \cdot \Delta T} \quad (3.1)$$

Where:

Q : is the rate of heat transfer through the material (in watts, W)

L : is the thickness of the material (in meters, m)

A : is the cross-sectional area of the material through which heat is transferred (in square meters, m²),

ΔT: is the temperature difference across the material (in Kelvin, K).

The experimental results basically established that laterite is associated with excellent thermal characteristics for building and other engineering uses. Therefore, it has a great potential as a sustainable and resilient construction material (Lemougna et al., 2011).

3.2.2 Durability of Laterite

Durability is an aspect of the ability to withstand pressure or damage in construction materials; laterite, a kind of soil usually applied to building, varies because of several factors that influence its durability (Singh et al., 2023). These factors include the number of wetting–drying cycles, curing age time, iron oxide content, porosity and pore-size distribution, aggregate percentage, cement type, and heat resistance (Ngezahayo & Ghataora, 2019). Some studies show that concrete with up to 20% laterite aggregate exhibited durability properties similar to that of plain concrete (Nguyen et al., 2021).

As per the Standards Organization of Nigeria or the Nigerian Building Code, laterite bricks used in building construction should possess enough compressive strength to take the loads and stresses arising first during construction and then withstanding throughout the course of the structure's lifetime. The minimum values for these standards of strength are most often quoted in newtons per square millimetre, N/mm².

By the Nigerian Building Code, for example, laterite bricks are recommended to possess a minimum compressive strength of between 1.5 to 3.5 N/mm²/2-5MPa, according to the structural use and type of mortar for construction. These provide the assurance that the laterite bricks, at that instance, will possess the specified strength to confine post-norms for the guarantee of stability and durability in constructed buildings.

The formula for the calculation of the compressive strength, f_c , is:

$$f_c = \frac{P}{A} \quad (3.2)$$

Where:

f_c : is the compressive strength,

P : is the maximum load applied during the test.

A is the cross-sectional area of the specimen Notwithstanding its advantages, laterite concrete should not be recommended for high-rise buildings or rainfall intensive areas because of its tendency to absorb moisture and vulnerability to acidic leaching as opined (Ngezahayo et al., 2019).

3.2.3 Water Absorption

Laterite is basically a variety of soil that is extensively used in construction works and has varying degrees of water absorption. Water absorption refers to the process by which a material is capable of absorbing water if such contact occurs. This property, owing to any material used for construction purposes, becomes very imperative because too much water absorption may lead to weakness or other forms of deterioration.

Studies establish the water absorption characteristics of laterite and its implications on construction. According to Ngezahayo et al., 2019, laterite has a relatively high-water absorption capacity, typically ranging from 15% to 25%, since it is highly porous with significant composition; the pore spaces in lateritic soils offer pathways for penetration and allow water to be retained therein, which modifies the overall performance of such soil in construction applications.

The calculation of water absorption in laterite can be determined using the following formula (WA) is:

$$WA = \frac{(W_g - W_d)}{W_d} \times 100 \quad (3.3)$$

Where:

WA : is the water absorption percentage.

W_g : is the saturated weight of the specimen after immersion in water.

W_d : is the dry weight of the specimen before immersion.

3.3 HISTORICAL AND CONTEMPORARY USE OF LATERITE

3.3.1 Historical Uses

Monumental architecture is also rich in history, and laterite is at the forefront, as indicated by widespread use in former civilization across the continents. Uchida, E., Maeda, N., & Nakagawa, (1999) even argue that the temple complex in Angkor Wat, Cambodia, is the evidence of architectural ingenuity of laterite Figure 3.5 while using the abundant material in creating the intricate structures. Similarly, the Konark Sun Temple in India has been the perfect example reiterated by Lemougna et al., (2018) for portraying the durability and aesthetic charisma of laterite in monumental construction.



Figure 3.5: Wat Temple Complex, Cambodia (Wikipedia, 2021).

Further, laterite became a material of choice in making infrastructures, including roads and water tanks, due to its resiliency and availability in the tropical region. According to historical evidence, there were quite a lot of laterite roads during ancient times in India and in Southeast Asia that provide strong highways for travel. Added to this asset, communities also harnessed the ability of laterite in constructing water tanks and artificial reservoirs to help them effectively store scarce water in arid climates (Nguyen et al., 2021).

3.3.2 Contemporary Uses

Laterite remains one of the most extensively used materials in modern construction, mainly in the form of Compressed Earth Bricks. According to, these materials for sustainable

building offer the world a friendly environmental substitute for the common brick and cement. CSLBs find increasing application in low-cost housing; particularly in nations like Nigeria, where there is a growing demand for green building materials (Omolola, 2014). However, the versatility of laterite does not stop here in its applications to soil-stabilization techniques in geotechnical engineering. In this regard, researchers like Kumar et al. used laterite in soil stabilization projects by mixing it with additives like cement or lime to enhance the properties of soil having a purpose of construction. This palpably proves the use of laterite in modern infrastructural development and soil engineering practices.

Laterite's historic and modern uses underline continuous significance as a versatile building material with its main applications reaching from monumental architecture and infrastructure projects of ancient civilizations to sustainable construction methods and techniques of soil stabilization today. From some of the scholarly research, it is noted that laterite's sustainable and cost-effective properties make this material very resourceful in addressing contemporary challenges of construction and engineering.

3.4 SUSTAINABLE BUILDING PRACTICES WITH LATERITE

Housing affordability is an important aspect of the search for sustainable development in that it will fulfill the urgent need for shelter and support broader objectives of equity, economic development, and environmental conservation. However, balancing affordability with sustainability in housing is always a delicate matter, considering factors such as location and value for money.

Sustainable building methods can help secure long-term environmental sustainability and provide a vehicle for reducing the housing shortage. According to Nathaniel & Khan, (2020) with the help of sustainable construction techniques such as resource efficiency, renewable sources of energy, and passive design strategies, a considerable reduction in ecological footprint associated with residential projects can be achieved. Sustainable housing continues this greater goal by tending to decrease energy consumption, generation of wastes, and conserving ecosystems.

There are, however, occasions when the demands of both affordability and sustainability clash within considerations, notably location and economic evaluations. illustrates this

tension by finding that greener building materials and technology tend to have higher up-front costs, which could pulverize developers trying to make room for some types of housing with meager funds. The next challenge to affordability is the access to sufficient land for sustainable housing projects, especially in urban centers where land is very expensive.

Even with these challenges, incorporating elements of sustainable design into affordable housing developments can enhance the quality of life for people in general. According to Yau, among these features are energy-efficient equipment, sufficient insulation, green space, and those providing health and well-being benefits to occupants by reducing utility expenses. This would increase accessibility to ensure that the needs of the different age and ability groups of residents are met by adopting universal design principles.

The same case applies to the use of locally available and environmentally-friendly material like laterite. Materials such as bamboo, straw bales, and recycled materials are low-impact, renewable solutions for each more conventional ones like steel and concrete, writes Bredenoord & Kulshreshtha, (2023:2) Besides their environmental advantage, these materials are often more economical and thus provide better support to small-scale businesspeople and craftspeople related to building activities, contributing to diverting money spent on materials within local economic circuits.

3.4.1 Environmental Benefits of Using Laterite

A good number of research projects have been successfully carried out and documented on the benefits of using Compressed Stabilized Laterite Bricks for sustainable development, including reduced carbon footprint and reliance on locally available materials. Many studies have pointed to some key factors that confirm Laterite CSLBs are sustainable in terms of carbon emissions reduction and the use of readily available materials locally.

According to Bishweka et al., 2021 the earth materials used in Laterite CSLBs demonstrated low energy needs and aesthetic appeal. Laterite CSLBs thus present a long-term prospective alternative to conventional construction material since they avoid most of the energy-intensive manufacturing procedures for their production and utilize locally available earth resources. The aesthetic properties of the earth materials were also conducive to visual harmony in architectural projects, thereby improving their environmental appeal.

According to Bishweka et al., 2021, earth materials have low energy requirements and are largely aesthetically pleasing, which are integral components of laterite CSLBs. These CSLBs offer a sustainable alternative to traditional construction material since they cut down on dependence on energy-intensive manufacturing processes and utilize the earth resources available locally. Besides, the atonin coherence of architectural projects is heightened by the aesthetic allure of earth materials.

A 2019 study by Ben-Alon et al., added more evidence to the environmental benefits of earth-based construction through findings that showed cob production required significantly less energy use compared to conventional materials and had less climate change impact globally. As indicated, this describes how the low-energy laterite CSLB production, with the ability to capture carbon, might contribute to lesser environmental degradation and help in the fight against climate change.

Among the benefits mentioned by Riza in 2011 with respect to lime as a stabilization agent in CSLBs are its excellent property in improving the structure of soil and the ability for carbon dioxide absorption in the carbonation process. In this regard, Laterite CSLBs are highly absorptive of carbon through the addition of lime as a stabilizer, which improves structural integrity with reduced greenhouse gases and promotes environmental sustainability. On consideration of the abovementioned studies, they have elaborated how Laterite CSLBs' usage reduces carbon emission and relies highly on locally available resources. This is, with respect to that, Laterite CSLBs offer a very good option toward affordable housing, reduced environmental impact, and increased resilience in the case of climate change within North-East Nigeria—or, indeed, any other region—by using alternative materials, advanced manufacturing processes, and new stabilization techniques to ensure better structural performance.

3.4.2 Environmental Impact

Laterite quarrying has been associated with a number of environmental problems, such as degraded land, destroyed habitats, and even health hazards from the exposure to radioactive materials like uranium and thorium. Quite often, these mining processes involve the use of certain chemicals like ammonia and sulfuric acid, thus causing disturbance in hydrology and finally affecting the local ecosystem. Besides, gaseous emission from mining activity adds

to air pollution and causes respiratory problems like asthma; the noise pollution arising from explosion and transportation disturbs the whole atmosphere. Soil destabilization, loss of biodiversity, and vegetation destruction further add to the environmental disturbances caused by laterite mining.

Despite these drawbacks, laterite mining can serve as a source of employment and income for local communities. To mitigate the environmental consequences of mining, it is imperative to strengthen policy frameworks and regulations governing mining practices. Environmental education and awareness programs should be implemented to foster a greater understanding of the importance of conservation efforts. Additionally, initiatives to replant trees and restore lost plant species can help rehabilitate degraded areas. Governments play a crucial role in this endeavour by issuing guidelines and enacting legislation aimed at minimizing environmental harm from mining activities (Smith, 2019).

3.5 OTHER MATERIALS SIMILAR TO LATERITE

There are so many materials, locally available that are laterite like in terms of properties and can also be used for sustainable construction practices and in this chapter Adobe , kerpic, and cob were picked as can be seen in Figure 3.6, Figure 3.7 and Figure 3.8, they all have similar properties to laterite base on perspectives looked at, and a comparative analysis was done and concluded with laterite superiority in the thesis perspective which is NE Nigeria.

Table 3.2 Showing the Properties of Material Similar to Laterite.

Property	Adobe	Kerpic	Rammed Earth	Cob
Primary Components	Silica (SiO ₂), Alumina (Al ₂ O ₃), Iron Oxides (Fe ₂ O ₃), Organic Materials	Silica (SiO ₂), Alumina (Al ₂ O ₃), Iron Oxides (Fe ₂ O ₃), Organic Materials	Silica (SiO ₂), Alumina (Al ₂ O ₃), Iron Oxides (Fe ₂ O ₃), Stabilizers (e.g., Cement)	Silica (SiO ₂), Alumina (Al ₂ O ₃), Iron Oxides (Fe ₂ O ₃), Organic Materials
pH Level	Slightly acidic to neutral (5.5 - 7)	Slightly acidic to neutral (5.5 - 7)	Neutral to slightly alkaline (7 - 8.5, can be higher with stabilizers)	Slightly acidic to neutral (5.5 - 7)
Cation Exchange Capacity	Moderate	Moderate	Low to moderate (higher when stabilized with additives)	Moderate
Organic Content	Presence of organic binders like straw or grass	Presence of organic binders like straw	Low organic content (depends on soil and additives)	Presence of organic binders like straw
Stabilizers/Additives	Often none, but sometimes lime or cement	Rarely used, traditionally pure materials	Commonly cement, lime, or bitumen to enhance properties	Often none, but sometimes lime or cement
salinity	Low to moderate	Low to moderate	Low to moderate (can vary with soil source)	Low to moderate
Carbonation	Occurs over time, improving strength	Occurs over time, improving strength	Accelerated when lime or cement is used	Occurs over time, improving strength
Water Absorption	High due to porous structure	High due to porous structure	Moderate to low when stabilized	High due to porous structure
Oxidation Resistance	Resistant due to presence of iron oxides	Resistant due to presence of iron oxides	Highly resistant especially with cement stabilization	Resistant due to presence of iron oxides
Hydration	High (clay minerals can absorb and retain water)	High (clay minerals can absorb and retain water)	Moderate (lower when stabilized with cement)	High (clay minerals can absorb and retain water)

Adobe, comprised of earth, clay, sand, and straw, is formed into bricks and dried in the sun, offering excellent thermal insulation and durability. In regions where laterite is scarce, Adobe serves as a viable alternative, utilizing locally available resources and traditional building techniques.

Kerpic, prevalent in Central Asia and Eastern Europe, shares similarities with Adobe and CSLBs, consisting of clay, sand, straw, and water. It has efficient thermal qualities, which

makes it suitable for hot, arid climates, while using sustainable materials and construction practices.

Rammed Earth construction is the compaction of soil, clay, sand, and gravel between formwork in such a way that a lot of toughness is systematically imparted into the creation of buildings with very good thermal mass properties. This will inculcate natural insulation and durability, hence a good option for sustainability in areas rich in earth resources.

Cob - applying walls by hand, thick in section using a mixture of clay, sand, straw, and water, creates strange and peculiar, organic shapes. It provides excellent indoor comfort temperature all through the year and requires less energy for its construction; hence, it works well in temperate climates.

These alternative building materials can supplement Laterite CSLBs in terms of their natural resources utilization, sustainability, and cost-effective construction solutions. This search for alternatives shall increase the resilience toward environmental challenges that face communities and promote sustainable development in the built environment.

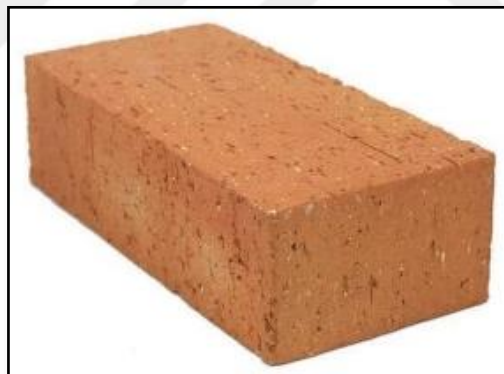


Figure 3.6: Laterite Brick (Arad Branding 2022).

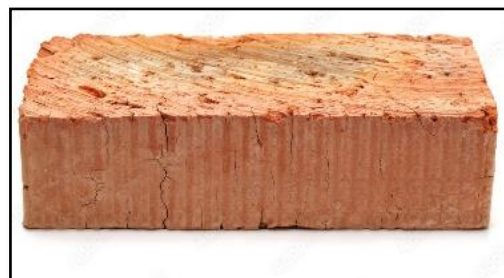


Figure 3.7: Adobe Brick (A.Y Homes 2020).



Figure 3.8: Kerpiç Brick (Arad Branding 2022).

3.6 ECONOMIC VIABILITY AND AFFORDABILITY

Attention is also put into the economic viability and affordability of laterite Compressed Stabilised Earth Block housing due to the bright prospects it holds for solving housing in different regions. The laterite CSLBs hence become very promising alternatives to the other conventional building materials in places where the soil is laterite-rich and other materials, such as cement, are either at high costs or unavailable.

These studies indicate a significant value of laterite CSLBs in reducing construction costs drastically compared to the conventional method of building using either brick or concrete block (Nairaland, 2024). This is accounted for by abundance and low cost of laterite soil, which is used as the primary raw material in the manufacture of CSLBs. Soil also has to be compressed into blocks by manual or mechanical presses during the production of CSLBs, which in itself is simple enough to add to the low cost (López-Rebollo et al., 2024).

Moreover, laterite CSLBs can improve the economic prospects of local communities through the potential employment opportunities that will be created in block production and construction activities. This can stimulate an economy of the region, through local sourcing of materials and labour, and foster community development.

However, the economic feasibility of laterite CSLB housing is also open to various factors, largely associated with the availability of skilled labor, easy access to appropriate levels of technology for block production, and good transportation infrastructure that allows easy distribution of the materials. Quality control-related challenges, building code compliance, and market acceptance could further affect the affordability and viability of laterite CSLB housing projects.

Under all circumstances, even though laterite CSLB housing makes much economic sense in terms of cost-effectiveness and local economic growth, tackling technical, regulatory, and

market challenges remains an attendant condition to see its full potential play out as an affordable housing solution.



4. CASE STUDY AND SIMULATION

4.1 SUSTAINABLE BUILDING PRACTICE WITH LATERITE

To this end, CSLBs have received broad media publicity as an environmental-friendly and inexpensive building material, particularly amongst developing countries that have ample soil resources. The benefits of CSLB are not limited to Nigeria but extend to the global stage.

4.1.1 CSLBS from an International Perspective

The global view of CSLBs puts the potentials of CSLBs in place for answering questions related to disaster resilience, affordable housing, and climate change. Their exploitation can be useful in making progress toward the UN Sustainable Development Goals, especially Goals 11—Sustainable Cities and Communities—and 13—Climate Action. Testing in a number of countries worldwide with success has been done on CSLBs:

India: CSLBs have been significantly deployed in India for low-cost housing and disaster-resilient construction.

Peru: Here, CSLBs have been utilised for earthquake-resistant housing and community centres.

Haiti: CSLBs have been used in Haiti for disaster-resilient housing and community centers after the 2010 earthquake.

Nepal: CSLBs have been used in Nepal for earthquake-resistant housing and community centers in the aftermath of the 2015 earthquake.

Compressed Earth Blocks have become the latest answer to low-cost housing, especially in the developing world's low-income settlement and rural areas. Several studies have been published that have illustrated their own feasibility from the perspectives of cost, environment, and even construction flexibility—all highlighting the potential for CSLBs. While Bredenoord & Kulshreshtha, (2023) argues on the grounds of low diffusion, defends high diffusion of CSLBs as a solution to housing affordability and environmental sustainability. For the case of CSLBs for sustainable housing projects, Bredenoord & Kulshreshtha, 2023 indicates that high-quality pilot projects are very necessary to show

feasibility and benefits. Those projects would increase confidence among stakeholders and enable stronger and wider adoption through successful case studies. In support of this view, Saad 2020 illustrates the feasibility of CSLB from locally available soils, reducing the dependency on imported components to bring down their cost of production. This form of local sourcing aligns fully towards the ideals of sustainable development by promoting self-sufficiency and limiting pressure on the environment. Pointing out the inherent advantages and properties in CSLBs further strengthens the case for the same, through works such as Hoff et al., 2023 depicts the utilization of natural fibres like jute in reinforcing CSLBs to enhance endurance and the structural integrity of these blocks. The invention thus offers a wide range of new opportunities for building in earthquake-prone areas where earthquake resistance comes as a prime consideration. Hoff, in 2023, further explains environmental benefits of CSLBs by mentioning that they have superior thermal resistance with reduced environmental impact compared to more traditional materials like burnt bricks or concrete.

These studies demonstrate the many advantages CSLBs offer in the domain of green housing. They are perfect for low-cost housing projects in low-income groups and rural areas because of their affordability, green features, and flexibility. CSLBs provide one pathway to more resilient, inclusive, and ecologically sustainable solutions to housing through their use of regional resources and their employment of cutting-edge building practices.

4.1.2 International Examples of CSLBs

Bredenoord & Kulshreshtha, (2023:4) stresses the need to take note of the CSLB-related successful initiatives around the globe, notably in Latin America, Africa, and Asia. The author calls for an extended international database that would include such projects. For the second time, Bredenoord & Kulshreshtha (2023:13) demonstrates the flexibility and applicability of CSLBs to a whole range of geographical and socio-economic contexts by bringing forth case studies. This provides the global view that explains how interregional cooperation and knowledge exchange can make great strides to improve and promote sustainable housing solutions.

Varady, (2017) discusses the role that community entrepreneurship might play in neighbourhood regeneration initiatives both in the US and the UK. He provides value to bottom-up strategies for solving housing problems by underlining the role that community-

led development and grassroots activities play. This could mean greater opportunities for cooperative and participative models that mobilize local knowledge and resources for the redevelopment of communities, with an assurance of reducing housing costs. More successful examples are:

Nubian Vault Technique, West Africa:

AVN, a nongovernmental organization, introduced the Nubian Vault technique to propagate the use of CSLBs in Western Africa for affordable housing sensitive to the environment. The CSLBs are heaped in a vaulted roof structure; no wood or steel reinforcement is required in this method—inspired by traditional Nubian Architecture. Working in countries such as Burkina Faso, Mali, and Senegal, the Nubian Vault technique is working to provide durable, energy-efficient housing in rural communities.



Figure 4.1 Nubia Vault Technique (Wikipedia 2020).

Compressed Earth Block Village Mexico:

The Compressed Earth Block Village project in Mexico proves that CSLBs are feasible in making sustainable housing real. This project, being undertaken by the non-profit association Earthship Biotecture, has the intention of constructing off-grid and self-sufficient communities using CSLB and other natural building materials. The village designs involve an extended concept of thermal mass that optimizes passive heating through solar radiation, thus minimizing mechanical heating and cooling systems. It is this kind of demonstration that makes CSLBs smoothly fit into resilient and eco-friendly housing development.

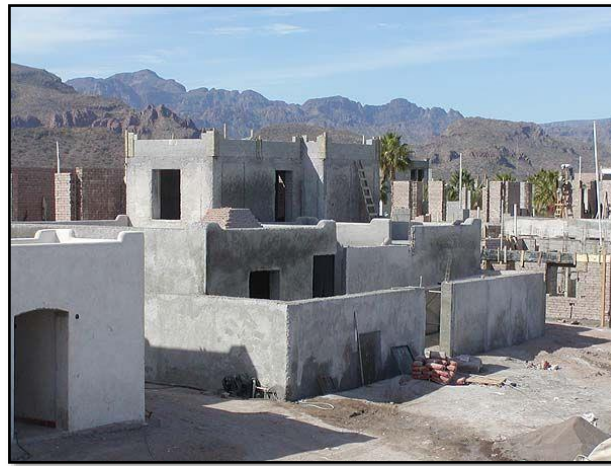


Figure 4.2 Compressed Earth Block Village, Mexico (Wikipedia 2008).

CSEB Technology in India:

CSEBs have gained much attention for use in low-cost housing projects in India. Development Alternatives Group has been at the forefront in promoting CSEB as a more environmentally-friendly alternative to traditional brick construction. The blocks are made from locally available soils mixed with stabilizers like cement or lime, hence reducing the environmental effect from construction. They have been used in various housing projects across India, thus offering the low-income community with affordable housing solutions that are environmentally friendly.

Auroville Earth Institute, India:

Located in Tamil Nadu, India, the Auroville Earth Institute has specialized in earth-based construction techniques, one of which is CSLBs. The institute carries out research, training, and diffusion of knowledge on sustainable building practices using earth-based materials. It has been disseminating CSLBs largely in India and elsewhere through its education and outreach programs, thus promoting an environmentally sensitive and culturally awareness-based architecture.

These examples show both the versatility and strength of compressed earth bricks in different contexts, potentially helping to solve housing challenges in a way that is both sustainable and resilient.

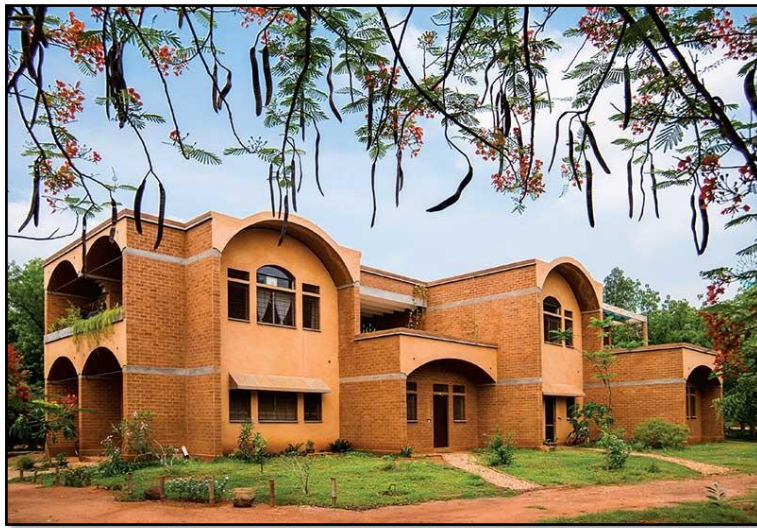


Figure 4.3 Auroville Earth Institute, India (ArchDaily2019).

4.1.3 Example of Laterite CSLB Project in Nigeria (NBRI)

Some researchers, like Bredenoord & Kulshreshtha, (2023) postulate that laterite use stands as a very viable option for sustainable housing and infrastructure construction in Africa. They have further located intrinsic attributes that make laterite a favorable material in environmentally sensitive building methods, particularly within Plateau State in central and northern Nigeria. In order to cater to the urgent demand for low-cost and sustainable shelter options, according to Omolola, 2014, it becomes very important that laterite be considered in the formulating or implementation of housing rules.

The findings by Hamidu, 2022 reinforce the quality of good laterite as a material in the building industry, especially in Plateau State and generally in Northern Nigeria, where huge deposits of lateritic soils are found. In his assertion, Hamidu said that structures possessing long service life and being structurally sound would be assured by having proper laterite quality control measures and correct application. The building research institute in Nigeria has also been emphasizing a scheme whereby they have schemes of building laterite houses, an example can be seen Figure 4.4.

Study on the practical application of laterite in road construction exemplifies the usability and versatility of the material outside the housing sector. For example, Madu provides an example of how sand may be added to laterite to improve its qualities. It thus became clear

how laterite can be used for infrastructure development projects in creative and efficient ways.



Figure 4.4: Laterite CSLB Bungalow NBRRI (Edited by Author 2024).

4.2 COMPARATIVE ANALYSIS OF SANDCRETE HOLLOW BLOCKS AND COMPRESSED STABILIZED LATERITE BRICKS FOR CONSTRUCTION OF A THREE-BEDROOM HOUSE IN NIGERIA (GOMBE)

The choice of construction materials is very germane to the sustainability and affordability of residential buildings in a country like Nigeria, where the Construction Industry seems to hold the key to any substantive economic growth and development. There is now greater sensitivity to environmental impact and cost-effectiveness, which places a corresponding quest on the part of the builder or home owner in procuring materials that will effectively balance durability, affordability, and eco-friendliness.

This paper presents a comparison between two of the most commonly used construction materials in Nigeria: sandcrete hollow blocks and compressed stabilized laterite bricks. The former, sandcrete hollow blocks, had been widely adopted due to the low cost and ease of production. The latter, compressed stabilized laterite bricks, comprising blocks made of lateritic soil stabilized with cement or lime, has attracted worldwide interest today as a sustainable and durable building material.

The analysis draws on insights from the literature review and data collected from local suppliers of construction materials and construction experts. It sets out an attempt to gain in-depth understanding of the material properties, cost considerations, and sustainability aspects that surround these two construction materials.

Background Information of SHB in Nigeria

According to, Sandcrete hollow blocks have been used for so many decades in Nigeria because it is the most prevalent and easily produced material written by Popoola et al., (2018). To be basic, blocks are made from a mixture of sand, cement, and water mixed together and molded into form, usually allowed to cure. Although very popular, sandcrete hollow blocks have been criticized lately over their relatively low quality, durability, and susceptibility to weathering, especially in the humid and high rainfall areas.

Interest in the use of substitute construction materials with improved sustainability and durability has been on the rise over the last few decades. Compressed stabilized laterite bricks are one such prospective alternative. The common laterite soil abounding in many regions of Nigeria could be stabilized with cement or lime and then compressed at high pressure into bricks. These bricks represent excellent thermal properties, resistance to weathering, and an increase in structural strength compared to traditional sandcrete blocks.

The adoption of Compressed Stabilized Laterite Bricks marks a turning point in very sustainable and environmentally friendly construction methods within Nigeria. With the main constituents sourced from local materials—laterite soils—and reduced use of cement, a critical source of greenhouse gases in building, the bricks are more environmentally friendly compared to conventional construction.

4.2.1 Production Process of Sandcrete Hollow Block (SHB)

Sandcrete hollow blocks are among the most commonly used materials in Nigeria and are relatively inexpensive, highly producible. Producing the blocks, according to studies involves a few critical stages that must be followed religiously toward ensuring quality and uniformity.

First, there's the gathering of the raw materials—cement, sand, and water—and their preparation for mixing. The mix ratio normally assumes a standard building code of 1:9 for

solid blocks and 1:8 for hollow blocks (Nigerian Industrial Standard, 2017). Once the raw materials are brought together, they are mixed well so that the mixture attains a homogeneous consistency to ensure proper bonding between sand and cement particles.

After mixing, the sandcrete mixture is poured into moulds of the desired shape and size. These blocks would usually be dimensioned by moulds—usually wood or steel—mostly of multiple compartments for instantaneous block making. Vibration is often applied to the moulds for compacting the mixture and ensuring adhesive bonds and dense, uniform blocks with no air-voids. The minute moulded, blocks undergo a curing process to enhance their strength and durability. Following the recommended standard building code, it is suggested that sandcrete blocks be provided with a curing period of at least 14 days (Nigerian Industrial Standard, 2017). Curing is done by allowing the blocks to get exposed to a moist environment, thereby hydrating the cement to continue forming stronger bonds within the mix. This may occasionally have to be promoted through spraying of water or dipping the blocks in water, or even covering them with such wet cloths to maintain adequate moisture levels. After adequate curing, the blocks are brought out of the molds and taken for drying. Here they may be air-dried or further cured if required. After that, the blocks are dried, quality-checked, and stacked in a store or bagged for transportation to the construction site.



Figure 4.5 Typical Sandcrete Hollow Block (Wikipedia, 2010).

4.2.2 Production Process of Compressed Stabilized Laterite Bricks (CSLB)

The compressed stabilized laterite bricks produced in Nigeria are made to conform with the Nigerian building codes and standards. This involved sourcing the right laterite soil, sieving to rid of impurities. This sieved soil mixed cement normally by weight of 5-10% by weight with water in a workable manner (Nigerian Standard for Compressed Earth Blocks, NIS 87:2004).

Next, the mixture is poured into a mould and compressed using a machine that applies pressure of between 2-5 MPa, significantly enhancing the bricks' density and strength (NIS 87:2004, Section 5.3). after the compression, the bricks are then subjected to a curing process. They are then covered with a plastic sheet, trampoline, or stored in a humid environment to prevent rapid drying, which usually lasts between 14 to 28 days, allowing for full development of strength (NIS 87:2004, Section 5.4).

Again, Quality control is an important aspect of this process. The bricks then undergo various tests, including compressive strength and water absorption tests, to ensure they meet the standards specified in the building codes (Nigerian Building Code, Section 4.2.5). Once the bricks pass these tests, they are stored in a dry place until required for construction, ensuring they maintain their structural integrity (NIS 87:2004, Section 6).

Table 4.1 Showing the Weight of CSLB and SHB.

Type	Dimension (mm)	Volume (m ³)	Density (kg/m ³)	Weight (kg)
Laterite Brick	113	0.00144367	1800	2.60
Stabilized Soil Block (SHB)	255	0.016581375	2000	33.16
Stabilized Soil Block (SHB)	115	0.001521875	2000	3.04

4.3 COSTING OF CSLB AND SHB

According to data gathered from local suppliers and construction companies as of May 2024 which (1USD = NGN1400), (Structure ville, 2024) and (AY homes, 2024) in the North-East region, the prices of sandcrete hollow blocks range from “NGN400-500” and “NGN320-420” per block, for 225mm and 150mm respectively. While the prices of compressed stabilized laterite bricks range from “NGN70-100” per brick This price variation can be attributed to several factors, including differences in transportation costs, availability of raw materials such as sand and cement, and competition among suppliers.

In Borno State, for example, where the availability of raw materials may be limited due to the ongoing conflict and displacement of populations, the prices of sandcrete hollow blocks tend to be higher compared to other states in the region. Construction companies operating in Borno often face logistical challenges and increased production costs, which are reflected in the prices of building materials, including sandcrete blocks.

Conversely, in states like Adamawa, Taraba and Gombe where raw materials are more readily available and infrastructure is relatively better developed, the prices of sandcrete hollow blocks are comparatively lower. Construction companies in these states benefit from easier access to raw materials and lower transportation costs, resulting in more competitive prices for building materials.

It's essential to note that while price variations exist across different states in the North-East region, the average price of 225mm and 150mm sandcrete hollow blocks in the region falls within the range of “NGN490” and “NGN390” per block, while stabilized laterite fall NGN90 This average price serves as a reference point for construction projects and budget planning in the region (Okay.Ng 2024).¹

4.3.1 Cost Per Square Meter of SHB and CSLB

To calculate the cost per sqm we will need to include labour and also mortar for joints. According to the Nigerian Building and Road Research Institute (NBRRI), labour costs in block laying typically range from 30% to 40% of the total cost of block and mortar (NBRRI, 2006). This would include the cost of skilled Labour to lay the blocks and any other additional labour for mixing mortar, transporting the material, and cleaning up the site.

As for the mortar percentage based on the block quantity, this can also vary depending on factors such as block size, mortar thickness, and construction practices. However, a typical guideline for mortar quantity in block laying is to use around 0.4 to 0.5 cubic meters of

¹ On-site production of construction materials can also impact prices significantly. Companies that produce compressed stabilized laterite bricks or sandcrete hollow blocks directly at construction sites can reduce transportation costs and minimize reliance on external suppliers. This on-site production model often results in lower prices for construction materials, making building projects more cost-effective, particularly in remote or resource-constrained areas.

However, it's essential to consider the initial investment required for on-site production equipment and the expertise needed to ensure quality control and efficient operations. While on-site production can lead to cost savings in the long run, careful planning and investment are necessary to achieve optimal results.

mortar per thousand blocks. This translates to approximately 40% to 50% of the total volume of the blocks (NBRRI, 2006). Again, these percentages may vary depending on specific project requirements and local practices.

Cost per square meter of SHB

To calculate the cost/sqm, first we will need to find the elevation area, and the number of blocks is needed per square meter, which will be found through the calculation in Table 4.2 and

Table 4.3 for 225mm and 150mm SHB respectively.

Table 4.2: Cost Per Square Metre of 225mm SHB.

Elevation area of Sandcrete hollow block	0.450m x 0.22m	0.01013m ²
Number of Sandcrete hollow block per sqm	$\frac{1.00 \text{ m}}{0.1013 \text{ m}}$	= 9.87 approximately 10 blocks
Cost of 225mm SHB/sqm	10(225mm) x NGN460	NGN 4,600
40% cost of mortar for laying blocks		NGN 2,208
15% cost of labour for laying blocks		NGN 700
Total cost for 225mm SHB (1m ²)		NGN 7,508

Table 4.3: Cost per Square Meter of 150mm SHB.

Elevation area of Sandcrete hollow block	0.450mx0.15m	0.01013m ²
Number of Sandcrete hollow block per sqm	$\frac{1.00 \text{ m}}{0.1013 \text{ m}}$	= 9.87 approximately 10 blocks
Cost of 150mm SHB/sqm	10(150mm) x NGN390	NGN 3,900
40% cost of mortar for laying blocks		NGN 1,560
15% cost of labour for laying blocks		NGN 820
Total cost for 150mm SHB (1m ²)		NGN 6,610

Cost per square meter of CSLB

To calculate the cost/sqm, first we will need to find the elevation area, and the number of bricks is needed per square meter which will be found through this calculation in

Table 4.4 and also, for the mortar and labour cost CSLB is higher due to high professionalism and extra labour required in relation to the SHB.²

Table 4.4: Cost per Square Metre of CSLB.

Elevation area of compressed laterite brick	0.230m x 0.115m	= 0.02645m ²
Number of compressed laterite brick per sqm	$\frac{1.00 \text{ m}}{0.02645 \text{ m}}$	= 37.81 approximately 38 bricks
Cost of 115mm CSLB/sqm	38(CSLB) x NGN95	NGN3,610
40% cost of mortar for laying bricks		NGN 1,444
20% cost of labour for laying bricks		NGN 1,010
Total Cost for 115mm CSLB (1m ²)		NGN 6,054

² In this comparison study, the different wall sizes between CSLB (Compressed Stabilized Laterite Bricks) and SHB (Sandcrete Hollow Blocks) are the result of realistic factors impacted by market availability and the natural characteristics of the materials. Even though efforts were made to keep wall dimensions consistent, changes had to be made in order to ensure a fair comparison of prices between the two building methods due to the unavailability of particular block sizes. These differences in wall sizes represent the practical limitations that arise in building projects that use CSLB and SHB, not the integrity of the cost analysis. And also, in case of laterite interlocking bricks cost of mortar is excluded which will add extra difference in cost.

4.4 COST OF SHB AND CSLB FOR A THREE-BED BUGALOW

Cost of SHB for a Three-bed Bungalow

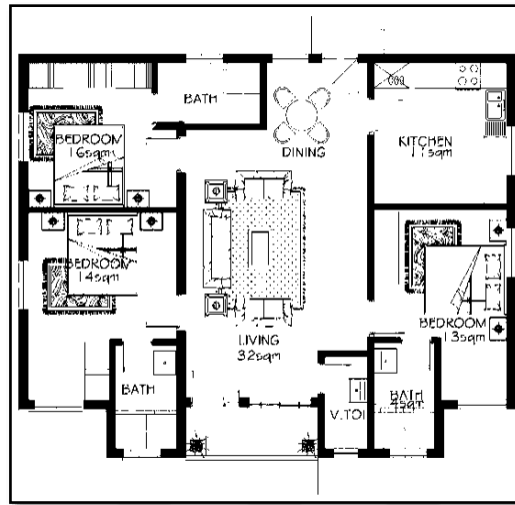


Figure 4.6: A Three-bedroom Bungalow (Designed by Author).

For the three-bedroom bungalow above in Figure 4.6 the cost can be determined through multiplying the total area of wall by the total cost of SHB/sqm, for both external wall and internal wall, which 225mm and 150mm SHB are to be used respectively.

Where 158sqm is built with 225mm and 96sqm to be built with 150mm

$$\text{NGN}7,508 \times 158\text{sqm (225mm)} = 1,186,264$$

$$\text{NGN}6,610 \times 96\text{sqm (150mm)} = 634,560$$

$$\text{Total} = \text{NGN}1,820,824 \text{ (USD1,600)}$$

Cost of CSLB for a Three-bed Bungalow

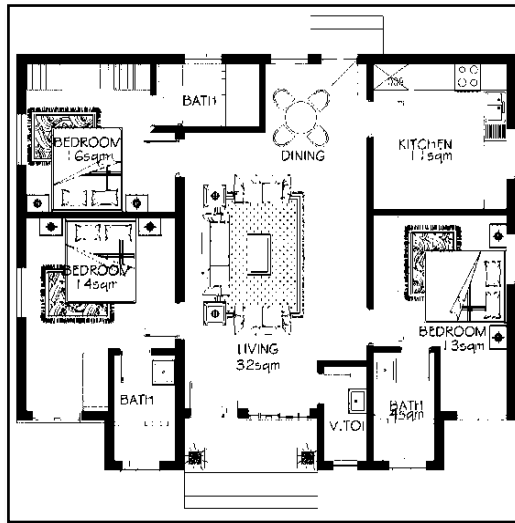


Figure 4.7: A Three-bedroom Bungalow (Designed by Author).

For the three-bedroom bungalow above in Figure 4.7 the cost can be determined through multiplying the total area of wall by the cost of CSLBs/sqm: which can be seen in

Table 4.5

Where the whole 256sqm is to be built with 115mm stretcher bond.

NGN6,054 x 256sqm

Total = NGN1,549,824 (USD1,360)³

Table 4.5: Summary of Wall Comparison Using CSLB and SHB.

TYPE	3 - BEROOM (256m ²)	TOTAL
Total cost using CSLBs	4,446 x 256sqm	NGN1,549,824
Total cost using SHB	7,508 x 158 sqm for 225mm 6,610 x 96sqm for 150mm	NGN1,820,824 NGN634,560
Total cost difference	1,820,824 – 1,549,824	NGN271,000
Total % saved	NGN271,000	16.01%

³ The calculations used in this thesis were conducted in 2024, and they are dependent on the state of the economy at that time. After 2024, adjustments to inflation rates or other economic variables could affect how accurate these estimates are.

4.4.1 Material Cost Evaluation (Affordability)

First of all, SHBs. A lot like the trusty workhorse of construction materials, sandcrete hollow blocks are made up of a mixture of sand, cement, and water (NBRRI, 2006). It is the fallback position for many builders in that they are inexpensive and very accessible. However, the quality of SHBs is really dependent on certain factors, like the ever-changing price of cement and the quality of laborers. While SHBs offer an economical solution upfront, their life and integrity are not without risk.

Contrasting this, CSLBs offer a much more environmentally friendly alternative. Basically, these bricks are produced from locally available laterite soils, pressed and then stabilized with cement or lime as the case may be. Other than their eco-friendliness, the CSLBs display extreme properties for thermal insulation, which guarantees building comfort and energy efficiency. The production process for CSLBs is, however, time-consuming and labor-intensive compared to that of SHBs, as described in the National Building Code of Nigeria 2019. By comparison, while CSLBs may be more expensive at the outset, their proponents say they pay back extra cost with many times longer life.

Basically, it comes down to the fundamental trade-off between immediate affordability and long-term sustainability considerations for choosing SHBs over CSLBs. SHBs offer a more budget-friendly solution with variable quality outcomes, while CSLBs present a more environmentally considerate alternative but at higher upfront costs. Compared to the cost of the material, it shows that CSLBs can save up to 16% of the total cost of buildings. It is further evident in other research that it saves up to 30% according to NBRRI 2023. After all, this remains upon the decision of every project priority: what should be first, the immediate saving of finances or durability and environment costs in the future.

4.5 A SIMULATION ANALYSIS COMPARING THE THERMAL PERFORMANCE OF SANDCRETE HOLLOW BLOCKS AND COMPRESSED STABILIZED LATERITE BRICKS

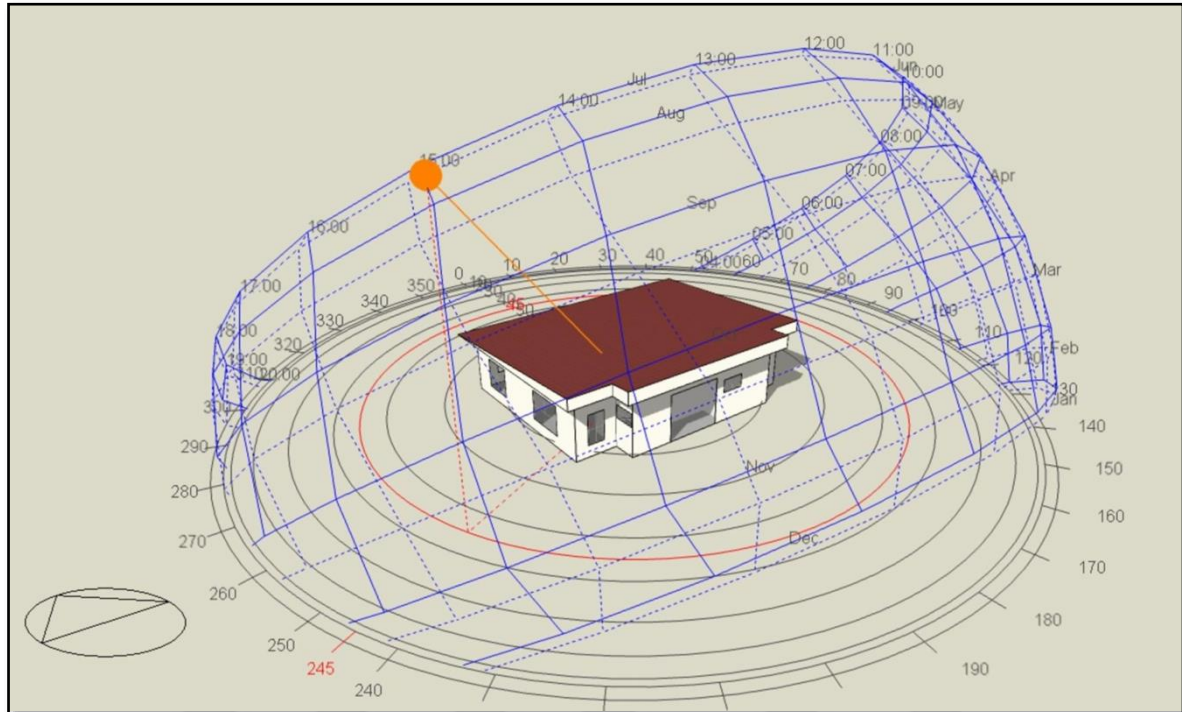


Figure 4.8: Solar Study of Proposed Building Site, Gombe, Nigeria, (Simulation Report).

4.5.1 Simulation Methodology

This section presents an overview of the steps followed in conducting simulations. It is a structured way to understand and replicate real-world scenarios within a controlled environment.

Step 1: Model Creation

The first step for the simulation process was to generate a rough model of the 3-bedroom bungalow in Design Builder, Figure 4.8, after importing the dxf.2D file. The living, service and sleeping zones were generated within a software as shown. Also, defining geometry, layout and dimension of spaces; including space details like walls and windows

Step2: Material and Construction Assignments

The different components that made up the model had to be assigned with materials and construction properties. This included the setting of wall constructions as medium weight

Sandcrete, glazing properties as single-pane, roof materials as concrete, floor constructions as concrete with rug finish. These inputs determine the thermal behavior of building elements with their interaction in surroundings.

Step3: Climate Data

There is a need to select appropriate weather data for simulation in order to reproduce real-world scenarios. DesignBuilder allows entering weather files, which it uses to represent the local climate at the site. In this case, Gombe, a city in northeast Nigeria with a weather file was used. Normally, these files will have in them information, usually on an hourly or sub-hourly basis, about dry bulb temperature, relative humidity, wind speed, and solar radiation.

Step4: Occupancy and Activity Profiles

This step helps build up the real thermal conditions that building occupants go through by defining plausible occupancy and activity profiles. Particular aspects include the number of occupants, behavior patterns, and time span of activities associated with them. These profiles determine internal heat gains and the resultant activity-linked thermal comfort requirements.

Step5: Simulation Settings

Setting up the correct simulation parameters and options within DesignBuilder is important in receiving results accurate and reliable. In this, setting of the correct Simulation Engine, time-step resolution was kept in months, and defining the duration of a simulation map out the way forward.

Step 6: Running the Simulation

After all the inputs and settings had been well defined, the simulations were run in DesignBuilder. The software uses advanced algorithms and calculation methods to compute, for a user-specified time period, heat transfer and parameters of thermal comfort within the zones. Multiple simulations were performed with different scenarios to compare thermal conditions when using either of the compressive-earth bricks and Sandcrete hollow blocks.

Step7: Analysis and Interpretation

After the simulations were completed, the results were analysed and interpreted to assess the comfort conditions of the overall zones including the heat loss due to external infiltration. This involved examining parameters such as Relative Humidity, Air Temperature, Radiant Temperature, Operative Temperature, Discomfort hours (all clothing), and Outside Dry-Bulb Temperature. Statistical analysis and visualization tools provided by DesignBuilder 6.1.0.6. aided in understanding the variations and trends in the results.

4.6 SIMULATION RESULT

Wall Construction Assembly

OPTION SHB 225mm +, Cement plaster 15mm (In and out)



Figure 4.9: SHB Wall (Simulation Report).

OPTION 2 CSLB 115mm +, Cement plaster 15mm (In and out).

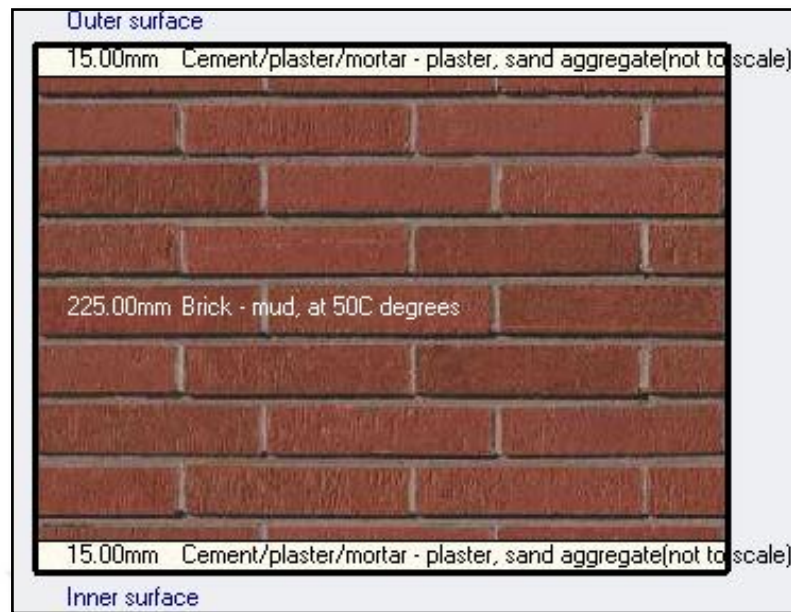


Figure 4.10: CSLB (Simulation Report).

Table 4.6: Wall Assembly Detail.

S. No	Construction	U-value (W/m ²)	Cement Plaster (mm)	CSLB (mm)	SHB (mm)	Wall Thickness
1	CSLB + Plaster	0.719 W/m ²	30	115	0	115
2	SHB + Plaster	1.974 W/m ²	30	0	225	255

To evaluate the comfort data for Sandcrete Hollow Blocks (SHB) and Compressed stabilized laterite Bricks (CSLB) as construction methods according to current ASHRAE standards for overall comfort, we need to compare the comfort parameters provided for both construction types, which is provide in

Table 4.6 The key parameters for evaluation are Relative Humidity, Air Temperature, Radiant Temperature, Operative Temperature, Discomfort hours (all clothing), and Outside Dry-Bulb Temperature.

In the comparison of comfort data (Figure 4.11 and **Error! Reference source not found.**), Sandcrete Hollow Blocks exhibit relative humidity levels ranging from 15.54% to 53.47%, whereas Compressed Earth Blocks range from 22.15% to 65.62%. SHB generally shows higher air, radiant, and operative temperatures, varying from 36.44°C to 45.80°C, compared to CSLB with temperatures ranging from 31.83°C to 39.72°C. Both methods exhibit similar

discomfort hours, ranging from 244.22 hours to 270.48 hrs, and similar outside dry-bulb temperatures ranging from 23.84°C to 32.14°C.

Comfort - Comparative Study - Laterite CEBs to SHBs, 3 Bedroom Bungalow													
EnergyPlus Output	1 Jan - 31 Dec, Monthly											Licensed	
	Month												
Air Temperature (°C)		35.95	37.75	39.12	39.72	38.38	36.26	32.55	31.83	33.06	36.22	38.28	36.30
Radiant Temperature (°C)		36.00	37.79	39.13	39.70	38.36	36.23	32.49	31.76	33.02	36.22	38.32	36.34
Operative Temperature (°C)		35.98	37.77	39.12	39.71	38.37	36.25	32.52	31.80	33.04	36.22	38.30	36.32
Outside Dry-Bulb Temperature (°C)		23.84	27.25	30.55	32.14	30.21	28.46	25.75	25.22	25.58	26.88	26.57	24.46
Relative Humidity (%)		22.15	21.49	24.35	32.66	45.79	52.48	64.35	65.62	63.75	50.34	28.92	24.06
Discomfort hrs (all clothing) (hrs)		270.40	244.22	270.32	261.78	270.32	261.62	270.48	270.32	261.70	270.40	261.62	270.48

Figure 4.11: Comfort Data for CSLB, (Simulation Report).

Upon analysis, SHB tends to offer higher temperatures and lower humidity levels compared to CSLB. However, both methods show similar discomfort hours and outside dry-bulb temperatures. The higher temperatures and lower humidity levels in SHB construction suggest potentially better comfort conditions according to ASHRAE standards. Overall, based on the provided data, Sandcrete Hollow Blocks may offer slightly better comfort conditions in terms of temperature and humidity levels compared to Compressed Earth Blocks.

Comfort - Comparative Study - Laterite CEBs to SHBs, 3 Bedroom Bungalow													
EnergyPlus Output		1 Jan - 31 Dec, Monthly											Licensee
	Month												
Air Temperature (°C)		44.16	45.08	45.20	45.19	43.81	41.61	37.55	36.44	38.06	42.02	45.80	44.40
Radiant Temperature (°C)		44.35	45.24	45.30	45.26	43.89	41.69	37.59	36.47	38.12	42.12	45.96	44.59
Operative Temperature (°C)		44.25	45.16	45.25	45.22	43.85	41.65	37.57	36.46	38.09	42.07	45.88	44.50
Outside Dry-Bulb Temperature (°C)		23.84	27.25	30.55	32.14	30.21	28.46	25.75	25.22	25.58	26.88	26.57	24.46
Relative Humidity (%)		15.54	15.01	18.01	24.60	34.49	39.91	51.26	53.47	50.54	37.76	19.67	16.63
Discomfort hrs (all clothing) (hrs)		270.40	244.22	270.32	261.78	270.32	261.62	270.48	270.32	261.70	270.40	261.62	270.48

Figure 4.12: Comfort Data for SHB, (Simulation Report).

To analyse and discuss the heat loss due to external infiltration for buildings constructed with Sandcrete Hollow Blocks (SHB) and Compressed stabilized laterite Bricks (CSLB), external infiltration readings for both construction types throughout the year will be examined.

For Sandcrete Hollow Blocks (SHB), the external infiltration readings range from -81.31 kWh in January to -79.70 kWh in December. These negative values indicate heat loss due to infiltration from the external environment into the building. The highest heat loss occurs in the colder months, such as January and December, which could be attributed to larger temperature differentials between the indoor and outdoor environments, driving increased

infiltration. Overall, the annual heat loss due to external infiltration ranges from -44.67 kWh to -81.31 kWh.

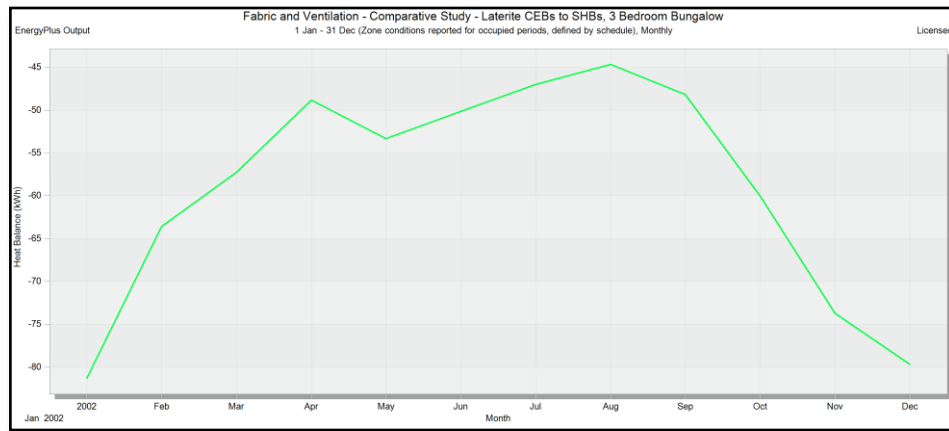


Figure 4.13: Heat Loss due to External Infiltration using SHB, (Simulation Report).

Similarly, for buildings constructed with Compressed stabilized laterite Bricks (CSLB), the external infiltration readings range from -48.61 kWh in January to -47.40 kWh in December. While the absolute values of heat loss due to infiltration are lower compared to SHB, the overall pattern remains consistent, with higher heat loss occurring in the colder months. The annual heat loss due to external infiltration for CSLB ranges from -26.33 kWh to -48.61 kWh.

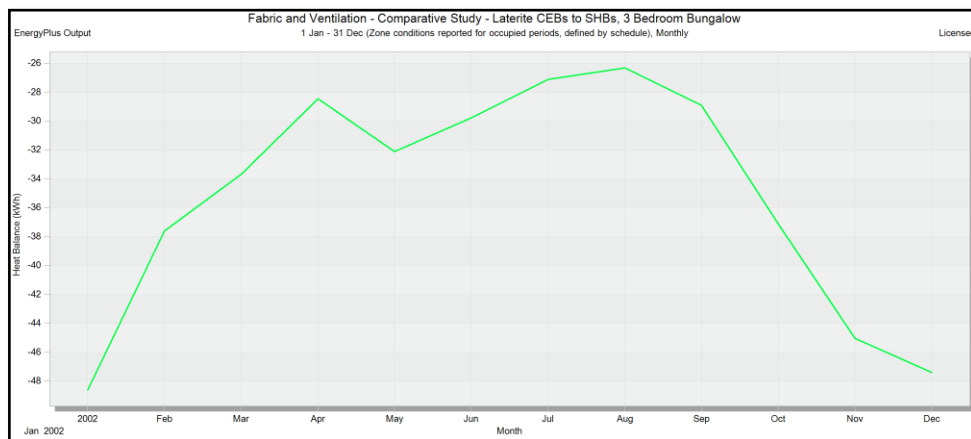


Figure 4.14: Heat Loss due to External Infiltration using CSLB, (Simulation Report).

Comparing the heat loss due to external infiltration between SHB and CSLB, it's evident that SHB generally experiences higher heat loss throughout the year. This could be attributed to differences in thermal conductivity and insulation properties between the two construction materials. SHB may have higher thermal conductivity, leading to increased heat loss through

infiltration compared to CSLB. However, it's essential to consider other factors such as building design, construction techniques, and environmental conditions, which can also influence heat loss through infiltration.

Material evaluation

Having met all the international building codes requirement i.e. ASHREA and LEED and also Based on the simulation report generated using DesignBuilder software, analyse closely at how Compressed Earth Blocks (CSLB) and Sandcrete Hollow Blocks (SHB) stack up as building materials, keeping in mind both comfort and heat loss due to external infiltration.

When it comes to comfort, both CSLB and SHB seem to offer similar conditions in terms of discomfort hours and outside temperatures, meaning occupants would likely feel about the same in either type of building (Simulation Report). However, SHB tends to give off a bit more warmth and has lower humidity levels compared to CSLB, suggesting that the people inside SHB buildings might feel a bit cosier overall (Simulation Report).

And also, on examination of the heat loss. The report shows that SHB buildings tend to lose more heat throughout the year compared to CSLB buildings. It seems like during the colder months, especially in January and December, SHB lets more heat slip out into the great outdoors, likely because of differences in how the materials handle temperature changes (Simulation Report).

Findings reveal that SHB generally exhibit higher air, radiant, and operative temperatures compared to CSLB, with temperatures ranging from 36.44°C to 45.80°C for SHB and 31.83°C to 39.72°C for CSLB. However, CSLB demonstrate lower relative humidity levels ranging from 22.15% to 65.62% compared to SHB, which range from 15.54% to 53.47%. (Simulation Report).

So, in a nutshell, while both CSLB and SHB have their pros and cons, it looks like SHB might offer a slight edge in terms of comfort, thanks to its warmer temperatures and lower humidity levels. However, when it comes to keeping the heat inside, CSLB seems to have the upper hand. Of course, there's more to consider, like building design and environmental factors, but based on this simulation, it seems like a pretty close call to the SHB.

FINDINGS

In a nutshell Simulation results reveals that CSLB buildings maintain more favourable indoor temperatures compared to SHB buildings. SHB buildings exhibit higher air, radiant, and operative temperatures, ranging from 36.44°C to 45. 80°C.

CSLB buildings exhibit lower temperatures, ranging from 31.83°C to 39. 72°C. Relative humidity levels in CSLB buildings are generally lower (22.15% to 65.62%) compared to SHB buildings (15.54% to 53.47%), enhancing indoor comfort.

The simulation also demonstrates the thermal Performance of CSLB contribute to better regulation of indoor temperatures, reducing the need for artificial cooling and heating.

The lower temperatures and reduced humidity levels in CSLB buildings result in fewer discomfort hours for occupants, improving overall living conditions.

5. DISCUSSIONS AND CONCLUSIONS

Mainly on this thesis's scope, which is focused on North East Nigeria, it can be concluded that the study offers a deeper understanding of the implications, prospects, and much more that compressed stabilized laterite bricks (CSLB) present in this specific region, and Nigeria at large.

Environmental Benefits

By lowering reliance on imported materials and limiting the impact on the environment (CO₂ emission), the usage of CSLB encourages sustainable building and construction practices. By using low-energy manufacturing and leaving a small carbon footprint, CSLB shows that it is dedicated to resource conservation and environmental care. Also, CSLB's durability and thermal stability, comfort occupancy, support long-term sustainability and energy efficiency in the building of houses and communities.

Economic Viability & Socioeconomic Empowerment and Community Development

Sandcrete Hollow Blocks (SHB), an alternative building material, are more? Slightly? Plaster cost? More expensive than CSLB, thereby making the material cost comparative in its favor. This much cost differential towards its favor proves that CSLB will be able to offer housing at affordable costs without compromising on the structure or its quality. Of course, with such a big cost advantage, CSLB presents itself as a robust choice for any developer, legislator, or generally any homeowner seeking low-cost, green housing options.

This conclusion opens up possibilities of socioeconomic empowerment and community development through the use of CSLB in North East Nigeria. Production of CSLB develops social cohesion and economic resilience because it creates jobs while encouraging local skill development. Besides, housing is made accessible to low-income families and other groups like the internally displaced persons by being affordable with the use of CSLB.

As continues the discourse on socio-economic empowerment and community development, it becomes incumbent to evaluate the massive impact that adoption of compressed stabilized laterite bricks may have on North East Nigeria's individual and community life.

Consider a lively community in north-eastern Nigeria built by residents who have been persistently perplexed by problems associated with substandard shelter and a lack of decent jobs for years. Now, with the arrival of CSLB as green building material, everything changes. Community people pool resources to acquire the skills in CSLB production and express excitement about the rare opportunity to be part of history. During the training courses and practical workshops, participants are trained to mix stabilizing chemicals, make bricks, and build solid structures. In working together, relationships develop and a feeling of group pride starts to grow.

Now that CSLB production has begun, there are numerous job opportunities. Competent laborers are employed within brick manufacturing factories, and businessmen take the advantage to establish businesses associated with the production of raw materials or construction companies. It is through this increased income levels and booming economic activities in this area that the community begins to enjoy a newly developed prosperity. But it does not stop at economical empowerment; CSLB gives the opportunity to have better housing conditions for those who are really in dire need. These are the very people who, some time ago, could not afford decent shelter but now can enjoy safe and resilient homes built with locally sourced materials. Internally displaced persons find refuge in CSLB-built communities that offer them a fresh start and provide opportunities to belong once again.

In addition, CSLB nurtures a green and sustainable society. Through effective management of natural resources and waste minimization, it would reduce community ecological footprints, thereby guaranteeing a better world for future generations.

Basically, the use of CSLB in North East Nigeria acts as a stimulant to overall development. It satisfies not only shelter needs but also brings social, economic, and environmental benefits to respective communities. This way, with shared collaboration and vision, CSLB transforms from mere building material into something that symbolizes resilience, hope, and empowerment for all concerned.

Case Study Insights & Occupancy Comfort

On indoor comfort levels, CSLB performed well, according to occupancy comfort simulations done in DesignBuilder as part of the study. Though the number of discomfort hours in CSLB and SHB was the same, occupant satisfaction and thermal comfort in CSLB

were high—with a difference of up to 6 degrees Celsius in favour of CSLB—thereby suggesting it is more suitable for Nigeria's varied climate.

The case study analysis gave an insight into the sustainable building practices that CSLB offers over SHB, which is in wide use internationally and locally in Nigeria. Examples of successful CSLB projects showcased its versatility, durability, and adaptability to local contexts, and also emphasizing strongly on its comfort for occupants and its potential in reducing energy usage, thereby reinforcing its potential as a viable solution for affordable housing initiatives.

Handling Regional Housing Challenges & Contribution to Sustainable and affordable Housing

It is impossible to overestimate the importance of CSLB as a sustainable and affordable housing solution in North East Nigeria, where housing challenges are made worse by elements like rapid population growth, internal displacement from conflict, and restricted access to building materials and high rate of unemployment. In addressing these issues, the conclusion stresses the part played by CSLB in offering an affordable, indigenous substitute for conventional building materials like sandcrete hollow block.

Based on the study, CSLB has a lot of potential to be used as a sustainable building material that can help with both the pressing need for affordable housing solutions and environmental concerns. Through utilization of locally available laterite soil and stabilizing agents, CSLB provides an economical alternative for conventional building materials, thereby helping in the achievement of Nigeria's objectives towards affordable housing.

Leveraging International Best Practices

The conclusion again shows the applicability of best practices and lessons gained to the context of North East Nigeria by drawing on global examples of successful CSLB projects, such as those from India, Peru, Haiti, and so on. Through the customization of well-known building methods and design concepts to suit regional conditions, stakeholders may make the most out of CSLB's utilization and optimize its influence on the affordability and sustainability of housing in the region.

Questionnaire survey Findings and Conclusion

Section 3. 3.2: What challenges do you foresee in the widespread adoption of laterite as a building material? (Open text response)

Feedback from stakeholders in the building industry reveals that widespread use of laterite as a building material confronts major obstacles, especially in terms of professionalism and expertise. Respondents expressed concern about construction workers' and experts' lack of knowledge and abilities in proper laterite procedures. They indicated that what is really needed are specialized training programs, capacity-building initiatives, and regulatory frameworks to ensure improvement of technical competence, promotion of best practices, and assurance of the structural integrity and safety of laterite-based construction works. It shall be very critical to give attention to such issues if laterite, in its full potential, has to contribute to the building industry.

Section 5: Other comments Try to include below any other thoughts or comments that you think of with regard to laterite as a building material for sustainable, low cost housing in the North-East of Nigeria. free text question

The responses clearly show that most of the stakeholders are of the view that laterite use will make for more affordable and sustainable housing within Northeastern Nigeria. It's important to observe, nevertheless, that a small portion voice worries about the resource's possible depletion. These different points of view highlight how crucial it is to weigh the advantages of laterite as a building material against sustainable methods for resource management in order to reduce environmental worries and guarantee long-term survival.

General conclusion

The value of this compressed stabilized laterite brick investigation for a sustainable approach to affordable housing underlines the revolutionary possibilities that this line of innovation on construction materials holds. CSLB does not just present a way to solve housing difficulties in NE Nigeria; by combining affordability, sustainability, and occupant comfort, it is an important architect for inclusive and resilient communities. Moving forward, to optimize the advantages of CSLB and accelerate its adoption and implementation in the Nigerian housing sector.

5.1 RECOMMENDATIONS

In light of the research findings, it is recommended that future studies delve deeper into the nuanced effects of socioeconomic empowerment initiatives.

a. Promotion and Adoption of CSLB: collaborating and engaging government agencies, policymakers, and developers to champion CSLB as the go-to option for housing. explain its cost-saving advantages and eco-friendliness can spark interest and prompt its widespread adoption in construction projects.

b. Investment in Research and Development: It's high time to invest in further researches and developments to boost CSLB's quality, durability, and thermal performance. By exploring innovative manufacturing techniques and testing with different stabilizing agents, CSLB can be an even stronger contender in the construction industry.

c. Capacity Building and Training: Roll out training programs and capacity-building initiatives for stakeholders, that is, architects, engineers, and builders on the CSLB's ins and outs. Feedback from building industry stakeholders reveals that mass use of laterite as a building material is plagued by serious challenges. The most significant challenges that were to be addressed were on professionalism and expertise. The respondents decried construction workers' and experts' poor knowledge and abilities in proper laterite procedures. They pointed out that specialized training programs, capacity-building initiatives, and regulatory frameworks on technical competency, good practices, structural integrity, and safety are all needed to raise laterite-based construction projects. In the absence of these steps, in the event that laterite would really make it big in the building industry, such needs would remain as issues.

d. Incentives and Subsidies: The announcement of incentives and subsidies to builders and developers who use CSLB can be a game-changing factor. Many huge initial investments

may lessen with tax breaks, grants, and low-interest loans, encouraging more usages associated with house construction.

e. Public Awareness Campaigns: Merge with public awareness campaigns for the word of mouth on the benefits of CSLB homes. This would go a great way in debunking myths, capitalizing on comfort, affordability, and sustainability, generating demand for this housing solution from the communities at large and homeowners.

f. Collaboration and Partnerships: Collaboration among government agencies, academic institutions, industry stakeholders, and community organizations to drive innovation and scale up CSLB production and use. By joining forces with the government, we can tackle challenges and make the way for CSLB to flourish nationwide.

END NOTES

The information we got from these sources gives us a good idea of how much construction materials cost and what the real estate market is like in Nigeria in 2024. But it's important to note that this information might mostly relate to the North-Eastern part of Nigeria only, and things might be different in other regions. Also, because the market is always changing, condition and prices can vary a lot depending on where you are. So, while these sources are helpful, it's essential to keep in mind the specific regions and the facts that things might have changed since the information was gathered, to fully understand the construction and real estate situation in Nigeria.

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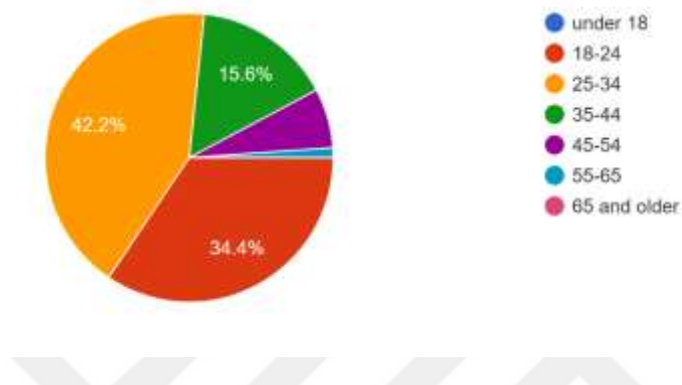
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APPENDIX A

A.1 SURVEY QUESTIONNAIRE: STAKEHOLDER PERSPECTIVES ON COMPRESSED STABILIZED LATERITE BRICKS (CSLB) AS BUILDING MATERIAL.

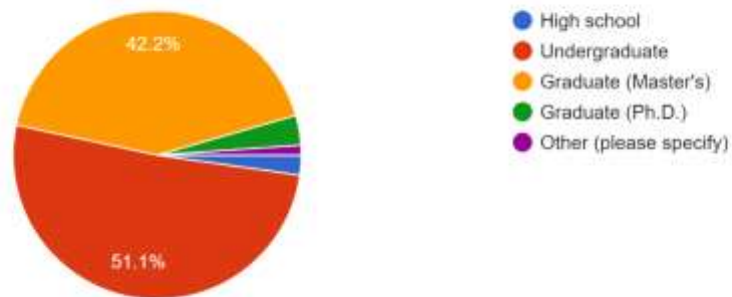
Section 1: Demographic Information 1.1. What is your age range?

90 responses



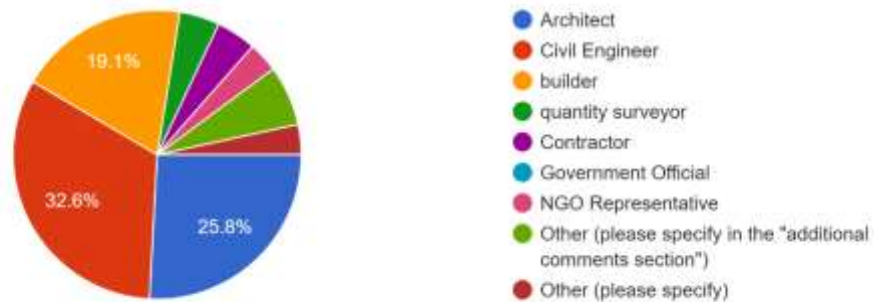
1.2. What is your level of study?

90 responses



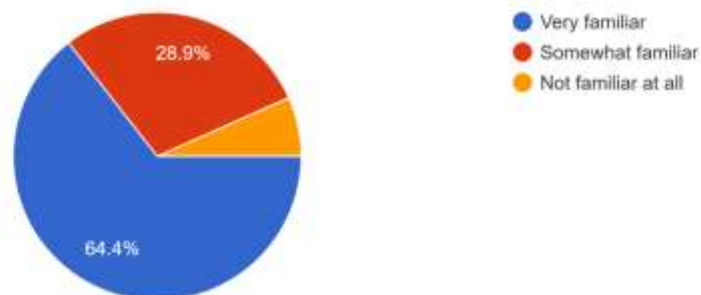
1.3. What is your role in the construction industry?

89 responses



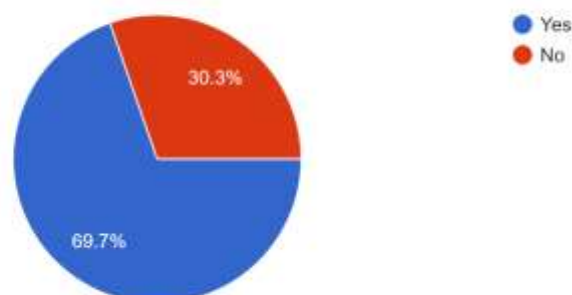
Section 2: Knowledge and Perception of Laterite 2.1. How familiar are you with laterite as a building material?

90 responses



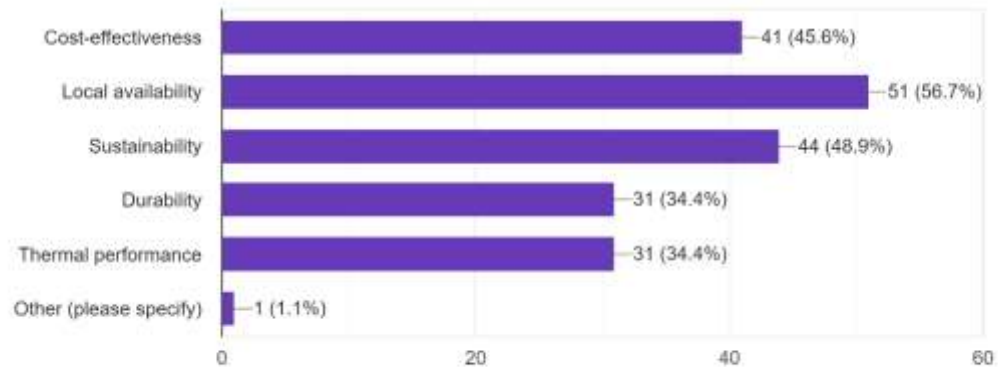
2.3. Have you worked on any projects involving laterite construction?

89 responses



Section 3: Benefits and Challenges 3.1. In your opinion, what are the main benefits of using laterite in construction? (Check all that apply)

90 responses



Section 4: Usage and Recommendation 4.1. Would you recommend the use of laterite in future construction projects?

91 responses

