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Application of Rice Husk Ash and Laterite Interlocking Bricks Sandcrete Blocks for Affordable Housing Delivery in Nigeria - A Review

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Abstract. Nigeria's housing affordability necessitates innovative and sustainable building materials. Sandcrete block, being commonly used for load bearing and non-load bearing walls in building construction has been seriously affected by the high cost of its ingredient. The search for alternative materials to sandcrete block with the intent of reducing the cost of conventional materials has led to investigating the use of laterites blended with agricultural residues as supplementary cementitious materials thus complementing the cement. Effective use of these materials is a way of advocating for the green method of disposal of large quantity of waste, which would have caused environmental nuisance. An overview of studies carried out on laterite interlocking bricks and rice husk ash (RHA) sandcrete blocks is presented in this paper. The review considered the utilization of RHA as partial substitution for cement in sandcrete block and laterite interlocking bricks with the aim of reducing cost of conventional materials for affordable and sustainable housing unit. The chemical, physical, and mineralogical properties of these materials were described based on findings reported in previous studies, rather than through direct analysis in the present work. Also, their influence on the characteristics of sandcrete block and Laterite interlocking bricks such as; water absorptions, compressive strength, and durability (acid attack and abrasion) were discussed in details. The findings suggest that these materials can contribute to sustainable and affordable housing delivery in Nigeria, depending on project-specific requirements.

1. Introduction

The housing sector significantly drives economic growth by influencing factors like employment, savings, and investment, and it also impacts health through quality housing [1]. Affordable housing, which is essential for human needs, should be practical, affordable, and well-maintained [2] It accounts for 10–20% of a country's economy and is the largest household asset [1]. Rapid urbanization poses significant challenges to developing countries, including Nigeria, in providing adequate housing, infrastructure, and services for the growing urban population. [3]. According to Lee [4], since the COVID-19 pandemic, housing affordability has declined, with more households, especially renters and mortgage owners, spending over 30% of their income on housing. The high cost of building materials inhibits housing affordability. Sandcrete blocks, made from sand, cement, and water, account for about 22% of building expenses for load-bearing and non-load-bearing walls and depend on factors like cost and climate [5]. Rising demand for sandcrete blocks increases interest in local materials like Rice Husk Ash (RHA) and Laterite Interlocking Bricks [6]. Nigeria's Raw Materials Research and Development Council cites local materials like laterite soil and rice husk ash as affordable, sustainable options [6, 7]. Studies have looked at using rice

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husk ash to partially replace cement in hollow sandcrete blocks and laterite bricks for cost savings [8]. This review discusses properties and performance of sandcrete block blended with RHA and laterite bricks blended with cement, amongst are water absorption, strength, and durability.

2. Rice Husk Ash (RHA)

Rice husk, a byproduct of rice processing, is removed during harvest. According to Jalam et al[8], up to 78% of rice and 22% of rice husk are produced during milling. It is abundant in Asia and parts of Africa due to favorable conditions [9]. (RHA) is formed by burning rice husk, which increases silica reactivity at a temperature of 700°C [10,11,12]. RHA's chemical, morphological, and physical properties have been studied.

2.1 Physical, Chemical Composition and Morphology of RHA

The physical properties of rice husk ash (RHA) are influenced by various processing factors such as combustion method, temperature, duration, separation, and grinding, all of which collectively determine its effectiveness as a pozzolanic material [10]. The chemical composition of RHA after cooling is provided in Table 1. X-ray fluorescence analysis was used to determine the chemical composition. The silica content in the rice husk ash (RHA) is higher, averaging 82% among other chemical constituents, as indicated by researchers. This suggests a high potential reactivity of RHA as a pozzolanic or cementing agent [11,12]. The microstructure of RHA depends on incineration, processing, and grinding methods [37,60,62]. Scanning Electron Microscope (SEM) images, (Fig. 1), typically show that RHA particles are irregularly shaped and have a micro-porous cellular surface. Meanwhile, the XRD pattern displays both crystalline and amorphous regions with peaks between 10° and 70°. The main phases include quartz (Q), cristobalite (Cr), and tridymite (Tr). Peaks at approximately 26° and 20° indicate quartz's crystalline structure, which is a stable silica phase [37]. This study focuses on evaluating the structural integrity of RHA as a partial replacement for cement in sandcrete blocks, focusing on characterization, water absorption, compressive strength, and durability for construction purposes. This approach aims to reduce material consumption, address RHA waste disposal, conserve resources, and lessen environmental harm from improper disposal and cement emissions.

Table 1. Chemical composition of RHA

Chemical Constituent	Authors	[11]	[12]	[13]	Average (%)
SiO_2		81.04	86.51	78.87	82.14
Al_22O_3		1.80	0.61	1.61	1.34
Fe_2O_3		1.01	0.60	2.20	1.27
CaO		1.60	0.71	1.33	1.21
MgO		2.25	1.53	2.11	1.96
Na_2O		0.45	0.02	0.03	0.17
K_2O		2.35	1.89	2.03	2.09
P2O5		5.26	4.20	9.87	6.44
Total SO_2 + Al_2O_3 + Fe_2O_3		83.85	87.74	82.86	84.75

2.2 Rice Husk Ask Sandcrete Block.

The most common use of sandcrete blocks is as walling material in buildings, drainage, and other masonry projects. Over 95 percent of all walling materials consists of sandcrete blocks [15,16]. These blocks are usually rectangular hollow units with typical dimensions of 450 × 225 × 225mm and 450 × 150 × 225mm [15]. The quality of sandcrete blocks depends on several factors, including

the quality of materials, the manufacturing process, the curing period, water absorption, compressive strength, and durability, especially when used for load- bearing walls [16].

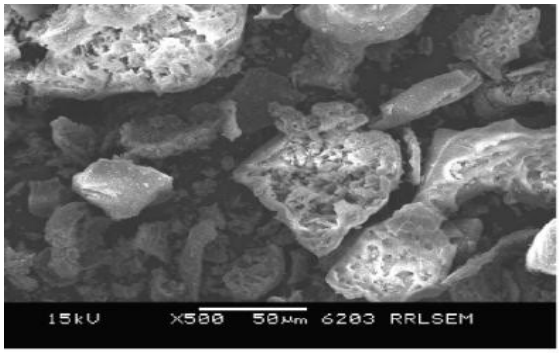


Figure 1: SEM image of RHA. Source: [14]

Researchers have shown that replacing cement with RHA can significantly lower building costs and reduce greenhouse gas emissions from cement production. According to Anifowose and Raheem [17], they compared conventional sandcrete blocks with RHA sandcrete blocks, focusing on specific gravity and compressive strength. [18] studied using rice husk ash to create low- cost sandcrete blocks in Nigeria. The study concluded that compressive strength increased over time during curing and decreased as RHA percentage increased there by, recommending 20% RHA as the optimal cement replacement level. Additionally, [18] suggested replacing 17. 5% of cement with RHA for sandcrete blocks used as building units. [18] also recommended 30% RHA for cement replacement in the production of hollow sandcrete blocks in Nigeria. Meanwhile, Mayowa et al., [19] concluded that 10% rice husk ash replacement met the strength requirements for building construction and reduced costs by 5.3%. Conversely, in corresponding [20] recommends an optimal cement replacement level of 15-20% with RHA in sandcrete blocks. Furthermore, [21] evaluated how RHA impacts the water absorption properties of the blocks. Results indicate that water absorption increased with higher RHA content, correlating with increased porosity. In addition, [22] examined the water absorption coefficient of sandcrete blocks incorporating wastepaper ash (WPA) as a partial cement substitute. The density ranged from 1682 to 1872 kg/m ^{3}, while water absorption varied between 27.49 to 27.04 %, with significant values ($p< 0. 05$) (Fig. 2). Whereas [23] investigated the cost benefits of using agricultural waste materials like RHA. Their results showed that the costs of RHA in sandcrete blocks are based on actual material prices and volumes, leading to approximately 24% savings in total material costs. This paper will focus on using 15% Rice Husk Ash replacement of cement based on previous research, while comparing RHASB with that of conventional Blocks in terms of strength, water absorption, density and durability.

3. Laterite

Laterite consists of residual sedimentary rocks that are reddish or brownish, soft, highly porous, and have worm-like structures. According to [24], Laterite is locally available, and its use in civil engineering, such as road construction and landfilling. Its primary industrial use is as a filling material. Since it is abundant, expanding its application could reduce building costs and promote affordable housing [25]. Additionally, laterite can serve as an eco-friendly, cost-effective fine aggregate for brick manufacturing, which can decrease block costs and support building development in Nigeria [26].

3.1 Application and use of Laterite.

According to [34] Laterite interlocking bricks, is mortar-free with dry-stack grooves, enable quick, cost-effective, eco-friendly dry stacking for low-rise load-bearing walls, suitable for two stories in residential, educational, and community buildings without cement mortar. [35].

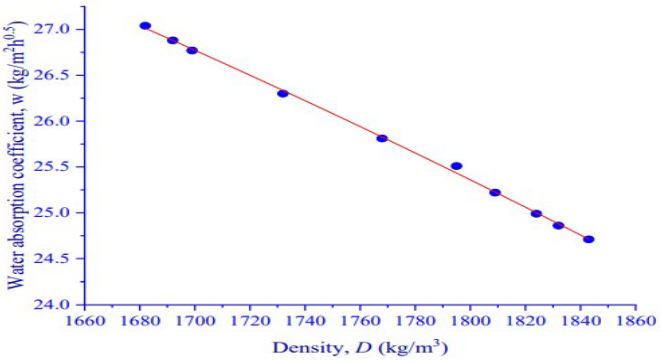


Fig. 2: Water absorption coefficient on density of the block samples [22]

3.2 Chemical properties of Laterite

Many researchers [38,39,49] state that laterites mainly contain iron, aluminum, silica, titanium, and water, with low levels of alkali and alkaline earth metals. They include water and Al_2O_3 (50-60%), the most common element. Iron and quartz levels vary inversely with alumina. TiO_2 is minor; oxides make up over 70%, sometimes around 92±5%. [24,26] suggested that laterite soil is slightly acidic, rich in iron, and amorphous, forming cementitious phases in alkaline media. According to [41], the main strategies to enhance the characteristics of laterite soil is to use an effective soil stabilizer (i.e., chemical stabilization). Previous studies have demonstrated that the strength of laterite soil has been significantly increased through the use of effective soil stabilizers in various applications.

3.3 Laterite Interlocking Bricks

The choice of walling material depends on cost, availability, durability, aesthetics, and climate [27]. Laterite bricks can be stabilized with small amounts of cement, lime, or pozzolans, and help reuse waste like rice husk ash and fly ash. They offer excellent fire and heat resistance, ideal for hot climates with interlock mortar free shown Fig 3. Lateritic bricks are durable and affordable. Several researchers [26,27,28,29] have studied Laterite Interlocking Bricks' mechanical properties, including water absorption, density, compressive strength, and durability.

3.4 Water Absorption of LIB:

Water absorption is a critical parameter for Interlock Compressed Earthen Bricks because it directly affects their durability, weather resistance, and overall performance. Generally, the less water the material absorbs, the better its quality and performance [28]. Low water absorption is preferred because it shows the material is less prone to moisture ingress, which reduces the risk of damage such as cracking, efflorescence, and freeze-thaw issues [29]. In construction materials like bricks, too much water absorption can cause structural weaknesses and aesthetic problems over time. For interlock compressed earthen bricks, only about 4% water absorption is notable, while previous studies reported a minimum of 13.20% [30]. According to [31], low absorption is due to decreased porosity from the compaction pressure during production. The compaction process reduces voids within the material, making it less permeable. Additionally, cement helps lower porosity, further increasing ICEBs' resistance to water absorption [32].



Fig 3: showing image of Laterite Interlocking Bricks.

Whereas [33] Investigate the water absorption of interlocking compressed earth brick (ICEB) units and beam bricks. ICEB units absorb water at 15.09% and 17.18%, with the half brick at 15.87% and beam brick at 13.20%. ICEBs absorb more water than normal bricks but stay below the maximum rate of 21%.

3.5 Compressive strength of Laterite Interlocking Bricks:

The mechanical properties of Laterite bricks are essential. [27] examined a comparative study of cement and lime stabilized lateritic interlocking blocks produced with laterite samples. The Nigeria Building and Road Research Institute (NBRRI, 2006) specified that the minimum 28-day strength should not be lower than 2 N/mm². Only cement-stabilized blocks satisfied this requirement at 10% and above stabilization levels. It was concluded that cement stabilized interlocking blocks are of better quality and cheaper than those stabilized with lime. Meanwhile, [33] used laterite as a partial replacement for fine aggregate at different percentages in interlocking blocks. The results revealed that the interlocking bricks exceeded the NBRRI standard.

3.6 Durability of LIB

According to Mohammadi et al [33,36], 28-day abrasive test results for cement and lime stabilized bricks are presented in Tables 2. The results showed that resistance to abrasion increases with both stabilizers. Unstabilized laterite interlocking blocks (the control) had a high percentage of material abraded, indicating stabilization is essential to improve durability. Cement-stabilized blocks performed better than lime-stabilized ones, reflecting higher durability. [33] Further observed that the cost of stabilizing with cement is cheaper than the cost of stabilizing with lime. This is due to the high cost of lime per bag, [33] Recommends 10% cement stabilization to meet the minimum strength. However, despite prior research on Laterite Interlocking bricks, these units haven't been used for model buildings, nor has their cost per unit meter been studied.

Table 2: Showing results of abrasiveness test for cement and lime stabilized lateritic bricks [36]

Cement Stabilization(%)	**0**	**5**	**10**	**15**	**20**	**25**
Average abraded away(%)	1.26	0.61	0.52	0.39	0.18	0.11
Lime Stabilization(%)	0	5	10	15	20	25
Average abraded away(%)	1.26	0.98	0.86	0.78	0.52	0.35

4. Conclusion

- This study concludes that RHA sandcrete blocks and LIBs can be viable for affordable housing in Nigeria, depending on context and needs. Using local materials and innovative tech can lower costs, speed up construction, and improve sustainability [25].
- RHA sandcrete blocks and LIBs serve as environmentally sustainable alternatives to conventional building materials, thereby decreasing the ecological footprint of construction endeavours. The use of indigenous waste materials such as rice husk ash and laterite further encourages sustainable construction practices and reduces waste generation [32].
- The utilisation of local materials and innovative technologies in RHA sandcrete blocks and LIBs can significantly decrease construction expenses. Additionally, LIBs, featuring their interlocking design, facilitate expedited building processes, thereby reducing both construction duration and labor costs [32].

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