

Application of Agro-Waste for Sustainable Sandcrete Block Production in Tropical Ecology: A Review



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ABSTRACT: The built environment is currently confronted with several challenges, primarily due to urbanization, the depletion of natural resources required for construction materials, and the complexity of waste management. In addition, a greater awareness of climate change is prompting the construction sector to reassess its intentions for developing more environmentally friendly building materials. In fact, various agro-waste products, such as rice husk ash (RHA), eggshell powder (ESP), sawdust ash (SDA), coconut husk ash (CHA), and palm oil fuel ash (POFA), have been discovered to be beneficial in the manufacture of sustainable construction materials. This review paper investigates the utilization of various agricultural wastes in the manufacture of long-lasting sandcretes. Studies were conducted on the mechanical and physical characteristics of the by-products and sandcretes. The utilization of waste agricultural produce as a substitute material in sandcrete blocks is examined, along with trends, innovations, and potential hurdles. The review's findings revealed that employing agro-waste to create sustainable sandcrete blocks was successful because the materials produced satisfied recognized building criteria. These products have the capability to replace conventional construction materials, achieving lasting financial, ecological, and social sustainability. Consequently, it offers a means to conserve energy and natural resources.

KEYWORDS: Agricultural wastes, Sustainable sandcretes, Tropical masonry, Walling materials, Recycled materials.

[Received Sept. 15, 2024; Revised July 8, 2025; Accepted July 26, 2025]

Print ISSN: 0189-9546 | Online ISSN: 2437-2110

I. INTRODUCTION

The use of healthy and sustainable building materials is currently gaining popularity in both developed and developing countries. Traditional building materials, such as concrete and sandcrete blocks, are expensive to produce and have negative environmental effects due to high energy consumption and greenhouse gas emissions (Danso et al., 2021; Ibeabuchi et al., 2022; Latawiec et al., 2018). Concerned about the potential dangers that current CO₂ and other greenhouse gas emissions pose to upcoming generations, governments and corporations are lending their support to efforts aimed at cutting down these emissions worldwide (Imbabi et al., 2012). Furthermore, cost of building and construction materials plays a crucial influence in deciding the price of every housing project worldwide. As a result, increased costs for items such as cement and aggregates, among others, will raise the cost of housing. The vast volume of materials in a building project makes it a major issue with a significant impact on the entire cost of the project (Danso et al., 2021; Gunasekaran et al., 2015; Musarat et al., 2020). One approach is to use alternative resources as building materials in the construction sector, such as waste materials and byproducts (Akinyemi et al., 2020; Gunasekaran et al., 2015). However, due to concerns about the economics and the environment, the use of agricultural byproducts as an alternative building material has piqued the

interest of the construction industry (Eziefula, 2018). In addition, the growing agricultural industry throughout the world produces a substantial amount of agro-waste annually, and the accumulation of unmanaged residue, especially in developing countries, has raised environmental concerns.

In recent years, researchers have attempted to find new uses for agricultural waste in order to reduce its environmental impact. Numerous studies have shown that using agro-waste in the production of alternative construction materials will explicitly emphasize energy savings and waste management issues (Al-Fakih et al., 2020; Jannat et al., 2020; Laborel-Préneron et al., 2016). Numerous upcycled materials used in eco-friendly construction are predominantly sourced of agro byproducts. In general, a wide range of green assessment methods are used to determine the sustainability of infrastructure and building projects. Over the last decade, green assessment of systems has increased in popularity, and one factor used to measure building sustainability is the construction material. According to studies, utilizing agro-waste as a stabilizer in the construction of masonry units is more beneficial than using man-made materials with regard to the environment (saving energy), the economics (reducing prices), and ecology (saving resources) (Maraveas, 2020).

Sandcrete blocks are a composite material made by compacting sand, cement, and water mixture, with cement serving as the binder. They are commonly employed in constructing buildings and various infrastructure for human

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comfort (Awolusi et al., 2021). Composite nature enhances properties and additives are occasionally used to increase strength (Esonye et al., 2022; Onyia et al., 2022). Most often, these sandcrete blocks are used as walling materials for building houses, particularly in developing countries (Robert et al., 2021b).



Figure 1. Freshly made hollow sandcrete blocks (Ikeagwuani et al., 2020)

Studies (Al-Fakih et al., 2019; Jannat et al., 2020; Robert et al., 2021b) has demonstrated that incorporating agro-waste into sandcrete blocks often results in better qualities. The extent to which they are utilized as a walling material in Nigeria and other developing nations cannot be overemphasized. They are available in both hollow and solid forms (Sholanke et al., 2015). Figure 1 demonstrates freshly made hollow sandcrete blocks. Sandcrete blocks are utilized to construct nearly 90% of the walling units in Nigerian dwellings and infrastructure, according to Oladeji and Awos (2013). This highlights the importance of sandcrete blocks in building construction. Figure 2 depicts a typical commercial building in Nigeria made of sandcrete blocks.

Consequently, it is not surprising that the strong demand for these masonry units eventually leads to overexploitation of aggregate natural resource reserves in the ecosystem (Ibeabuchi et al., 2022b). The mission of conscientious development is to protect the planet's reserves and keep the ecosystem balanced. Agro waste has been utilized to enhance the quality of building materials in several parts of the world. Geographically, it is more cost-effective to use locally accessible vernacular agro-wastes because they require little processing and entail low shipping expense (Ibeabuchi et al., 2023; Morel et al., 2001).



Figure 2. A typical commercial building made of sandcrete blocks in Nigeria (Wenapere & Ephraim, 2009)

Researchers have used agricultural waste to partially substitute traditional aggregate (sand) and cement for manufacture of sandcrete blocks. The features of the newly developed green masonry units were evaluated against the characteristics of conventional (control) masonry units. Additionally, certain byproducts have been recognized as potential lightweight aggregates for creating light-weight sandcretes (LWS). The advantages that lightweight sandcrete block has over conventional sandcrete block (CSB) are lighter dead weights, greater durability, enhanced acoustic performance, lower hauling expenses, as well as improved thermal insulation. Using agricultural solid waste instead of conventional materials (cement and sand) can help conserve natural resources, save money on energy, enhance waste management techniques, and reduce construction costs.

The past decade has seen numerous experiments focused on the use of maize cob (MC), rice husk (RH), palm kernel shell (PKS), coconut shell (CS), breadfruit stem (BF), cassava peel (CP), and palm kernel shells (PKS) as alternative materials in the composition of sandcrete blocks. This comprehensive review emphasizes on current advances in the utilization of these wastes as binder and aggregate in sandcrete blocks. The study investigates the features of agro derived by-products and the qualities of sandcrete blocks formed from them, both when newly made and after hardening. Recommendation for upcoming investigations are also suggested.

II. THE IMPORTANCE OF RESEARCH

The utilization of agro waste in the manufacturing of sandcretes for constructions is essential for ecological and cost benefits. As a result, production of green masonry units, the conservation of finite natural resources, the preservation of the environment, energy conservation, and the promotion of appropriate waste management will all contribute to the sustainability of the building industry. The information in this paper is designed to pique the attention of stakeholders in further developing masonry units made from agricultural leftovers and wastes. The built environment can be produced in a sustainable manner by recognizing and utilizing the aforementioned by-products as substitute materials in the construction of blocks.

III. METHODOLOGY

This study presents a structured review of original research articles on the utilization of agricultural waste in sandcrete block production. A comprehensive search was conducted using Scopus and Google Scholar to identify peer-reviewed publications from 2000 to 2023, guided by keywords such as agricultural waste in concrete, sustainable sandcrete blocks, rice husk ash (RHA), eggshell powder (ESP), sawdust ash (SDA), corn husk ash (CHA), and palm oil fuel ash (POFA).

Initial screening was based on titles and abstracts to exclude irrelevant studies, followed by full-text reviews to confirm eligibility. Only experimental and technical studies published in academic journals and conference proceedings

were included, resulting in a total of 98 unique sources. This review analyzes original research articles and selected technical documents published between 2000 and 2023. However, earlier foundational references—such as a 1989 book describing the engineering properties of agricultural wastes—have been included to provide historical context and trace early material development.

The analysis employed a qualitative and thematic approach, focusing on the types of agricultural by-products used, their regional distribution, impacts on material properties such as compressive strength and durability, and broader sustainability implications. Foundational information not available in journal literature was supplemented with technical reports, academic books, and credible digital sources. The reviewed studies span multiple countries, with a concentration of research efforts in Nigeria, Ghana, Malaysia, and Indonesia, reflecting both regional material availability and growing interest in sustainable construction alternatives.

IV. AGRO WASTE MATERIALS INCORPORATED INTO SANDCRETE BLOCKS

A. Coconut Husk and Shell Ash

The coconut tree is a tropical plant that grows year after year. Indonesia, Philippines, India, and Sri Lanka are important coconut producers. It is most abundant between the latitudes of 20° N and 20° S (Nagaraj, 2021). According to 2015 data on the world's ten biggest coconut producers as given in (Eziefula, 2018), global coconut production is approximately 59,977,668 tonnes, with the Philippines accounting for 32.5% of this value, making it the highest producer (see Fig 3).

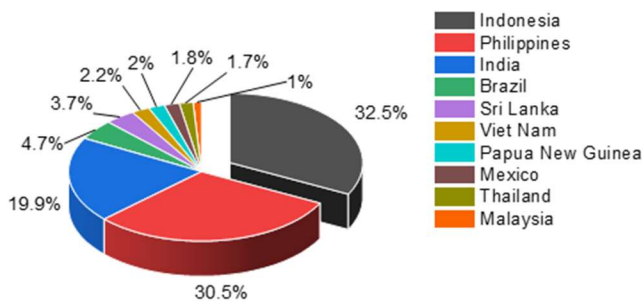


Figure 3. Ten top producers of coconut

Coconut husk is an agricultural waste product comprised primarily of the coconut's outer shell. About 75% of the coconut coir fibers are found in the coconut husk (Harish et al., 2009) and the reddish-brown material known as coconut coir is composed of pectin, cellulose, hemicellulose, and lignin (Kosseva, 2017). Research indicates that the low bulk density of coconut coir can lower a composite's heat conductivity and produce a lightweight products (Asasutjarit et al., 2007; Khedari et al., 2001). According to Panyakaew and Fotios (2011), numerous researchers have looked at the usage of coconut coir in the manufacturing of different building materials, including stabilizing soft soil and insulating board (Babu & Vasudevan, 2008), concretes reinforced with fiber (Ali et al., 2012; Ramli et al., 2013).

Other applications include the manufacturing of unfired earth brick as well as fired bricks (Purnomo & Arini, 2019).

B. Properties of Coconut husk and shell ash Sandcretes

In their study, Robert et al. (2020) explored how sandcretes performed when coconut husk (CH) was used to partially replace sand at weights ranging from 10% to 40%. The results showed that there was a rise in percentage water absorption and a drop in bulk density for both untreated and treated samples, while compressive strength improved. The best range for strength performance, according to the study, is between 20 and 30%. Ettu et al. (2013a) determined the compressive strength of ternary blended cement sandcrete using plantain leaf ash (PLA) and coconut husk ash (CHA) with a percentage replacement range of 5 to 25 and an incremental value of 5. CHA and PLA were substituted equally by weight for each percentage of cement replacement considered. According to the findings, the use of these composites enhanced the compressive strength of the sample sandcrete. The standard mix ratio for blended cement and sand was 1:6, while the water/cement ratio was 0.6. After 90 days of curing, the sandcrete incorporating agricultural waste demonstrated higher compressive strength than the control, which measured 9.90 N/mm²; the corn husk ash (CHA) mixes achieved peak strength at 5% replacement (11.50 N/mm²), followed by 10% (11.10 N/mm²), 15% (10.80 N/mm²), and 20% (10.40 N/mm²).

Ikeagwuani et al. (2018) studied the impact of end-web and center-web ratios (1:1 and 1:2) while utilizing coconut shell ash (CSA) to replace cement in sandcrete block manufacturing. There were five cement replacement percentages: 0, 10, 15, 20, and 25%. It was discovered that adding more CSA to the mix produced sandcrete blocks with lower densities, resulting in low density sandcretes. For instance, the average density decreased from approximately 2,125 kg/m³ at 0% CSA to around 2,010 kg/m³ at 25% CSA, confirming the production of lower-density sandcretes with higher CSA content. This increase in strength is most likely due to the formation adequate quantities of calcium aluminate hydrate (CAH) and calcium silicate hydrate (CSH) through the pozzolanic reaction between coconut shell ash (CSA) and the calcium hydroxide released during cement hydration. The reactive silica and alumina in CSA combine with calcium hydroxide to generate additional CSH and CAH. CSH is the main binder responsible for long-term strength and durability, while CAH contributes to early strength development and enhances resistance to chemical attack. When sorptivity was compared to the Control, an overall decline was observed. Ikeagwuani et al. (2020) employed the Taguchi Optimization technique to predict the characteristics of CSA sandcretes once more. Although the tendency to absorb water is slightly greater than with the typical block with a ratio of 1:1, new sandcretes block mold with a ratio of 1:2 was important for manufacturing blocks with high strength and density. Given casting surface of the sandcretes as if it were a beam and the web as supports, larger reactions at the center-web are reasonable. As a result, increasing the thickness of the central web will improve the compressive strength of the block. This explains why the strength values of blocks with a 1:2 end-

web-to-center-web ratio were greater. Properties of coconut shell are described in Table 1.

Table 1. Physical and mechanical properties of PKS, CS and ES

| Property | PKS | CS | ES (Jannat et al., 2022) |
|-----------------------------------|--|---|-----------------------------|
| | (Alengaram et al., 2008; Aslam et al., 2017; Gibigaye et al., 2017; Ndoke, 2006; Teo et al., 2006) | (Bari et al., 2021; Gunasekaran et al., 2011; Mathew et al., 2020; Nadir & Sujatha, 2018; Prusty & Patro, 2015) | |
| Shell thickness (mm) | 0.5–3.0 | 2.0–8.0 | - |
| Fineness modulus | 6.08–6.41 | 5.50–6.78 | - |
| Specific gravity | 1.17–1.62 | 1.05–2.33 | 1.74 |
| Bulk density (kg/m ³) | 500–740 | 550–650 | 1170 |
| Porosity (%) | 28.00 | 8.0–25.0 | 0.56 |
| Moisture content (%) | 8.0–9.0 | 2.04–4.20 | 0.31 |
| 24 h water absorption (%) | 9.02–32 | 8.0–27.65 | 39.42 |
| Aggregate impact value (%) | 2.03–7.51 | 3.84–8.15 | - |
| Aggregate crushing value (%) | 0.20–8.00 | 0.98–2.58 | - |
| Los Angeles abrasion value (%) | 3.60–5.70 | 1.63 | - |

PKS– Palm kernel shell, CS– Coconut shell, ES – Eggshell

C. Palm Oil Wastes

The oil palm (*Elaeis guineensis*), is a tree that can produce 4-6 tonnes of oil per hectare. It is commonly consumed all around the world. Oil palm offers a wide range of applications. Originating in Africa's wet tropical climates, it may survive in areas up to 150 degrees on either side of the equator (Nagaraj, 2021). Over a lifetime of 100 years or more, it has the potential to reach heights of as much as fifteen meters. Its commercial viability extends over a period of twenty to thirty years, after which harvesting becomes increasingly laborious and yields gradually fall (Jones & Hughes, 1989). Palm oil production has increased as a result of recent research initiatives on turning it into biodiesel (Ishola et al., 2020; Kareem et al., 2017). About 62,390,000 tonnes of oil palm were produced worldwide in 2015; 92% of that amount came from Nigeria, Indonesia, Malaysia, Thailand, and Columbia (Eziefula, 2018). Nigeria leads the continent of Africa in output with over 940,000 tonnes, while Indonesia leads Asia with roughly 33,400,000 tonnes (Fig. 4).

Many Sandcrete and masonry blocks are made from waste and byproducts from oil palm. Palm Kernel Shells (PKSs) are by-products of agriculture that are extracted while making palm oil. The mechanical and physical properties of PKSs are listed in Table 1. Normal weight aggregate (NWA) typically has a specific gravity of 2.6 to 2.7 (Neville & Brooks, 2010), however Table 1 shows that PKSs have a specific gravity that ranged between 1.17 – 1.62 which is significantly lower than what obtains with NWA.

Researchers have looked into the properties of PKS-incorporated sandcrete masonry blocks (Jaji et al., 2017a). In this investigation, different replacements of sand with PKS were accomplished, and volume of the samples determined the

batching, with mix ratios of 1:4, 1:5, and 1:6. According to their research, sand has a specific gravity that is twice as much as PKS, and neither the 1:5 mix with a 50% PKS replacement nor the 1:6 mix with 40% or 50% PKS replacement achieved the necessary compressive strength for load-bearing and non-load-bearing blocks. Table 1 contains PKS's detailed properties. The range of the shell's 24-hour water absorption capability is 21–33%. Given that traditional gravel aggregates typically have a water absorption of less than 2%, this value suggests that PKS have a high-water absorption rate. This could be because of the large pore content (Dadzie & Yankah, 2015).

Rahman et al. (2014) explored the use of Palm Oil Fuel Ash (POFA) as a partial substitute for cement in the manufacture of masonry blocks, aiming to keep the blocks' preferred attributes intact. According to their research, compressive strength decreases as the fraction of POFA replacement rises. Even so, it satisfies the load-bearing masonry block standards for Class 1 and Class 2 as defined by Malaysian Standard MS76:1972. Water absorption for each masonry block meets the criterion for durability of the masonry block. Masonry blocks made from cement and sand, with 20% and 40% POFA substitution, based on density, fall under the category of conventional masonry blocks weight as stated in ASTM C55-22 (2022). On the other hand, a masonry block with 60% POFA substitution is classified as medium weight. Masonry blocks with a larger POFA substitution percentage weigh less.

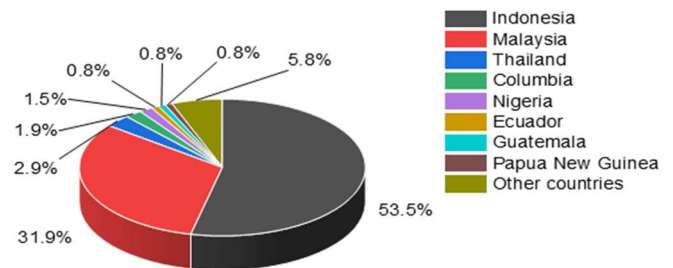


Figure 4. Report on Global Palm Oil Production

Using the optimization approach of Taguchi-grey relational analysis (T-GRA). Taguchi-grey relational analysis (T-GRA) optimization technique, Onyia et al. (2022) examined the impact of adding processed wastes from pressed palm oil fruit fiber (PPOFF) as an addition on the mechanical properties of sandcrete blocks. PPOFF was added to the cement mass at percentages of 0.00%, 0.25 %, 0.50 %, 0.75 %, and 1.00 %. T-GRA optimizing approach yielded data indicating peak response values for compressive strength, bulk density, and water absorption capacity of the manufactured samples as 4.58 N/mm², 2066 kg/m³, and 4.12%, respectively, for the tested properties. The optimal parameters for achieving the highest response values in the evaluated properties were found to be 0.25 percent treated PPOFF, a 0.65 W/C ratio, and a mold value of 0.0101 m³, which, according to Onyia et al. (2022), demonstrate that the resulting sandcrete blocks possess the requisite quality for use as load-bearing walls in the construction sector.

D. Rice Husk Ash

Rice husk ash (RHA) is made by separating husks from rice grains during milling and processing of rice. Rice mills, agro-based companies, and biomass power plants produce it. RHA is also available from local markets, traders, and online providers. Rice cultivation and processing operations have an impact on its availability. Notably, RHA has emerged as a promising contender for improving the qualities of numerous building materials while addressing environmental issues (Taiwo et al., 2022). RHA has a specific gravity of about 1.54 and a moisture content of about 1.18% (Okpala, 1993). Researchers have explored the effect of RHA on the qualities of construction materials in the quest of sustainable building methods.

According to Utsev and Taku (2012), Rice husk, which pollutes the environment, is collected and burned at 600 °C to make rice husk ash (RHA), which is then utilized as pozzolana in the manufacturing of sandcrete blocks. Cisse and Laquerbe (2000) describe how the addition of RHA to sandcrete increased its physicomechanical performance. The use of ground ash resulted in unexpectedly high strengths, whereas the use of unground ash contributed to the manufacture of robust-sandcrete blocks—materials that, though lower in strength, were structurally stable, durable, and well-suited for practical applications due to their insulating capacity and cost-effectiveness. The economic competitiveness of RHA-enhanced sandcrete blocks, in combination with their attractive physical properties, underpins the viability of this strategy. Further studies were conducted by (Oyekan & Kamiyo, 2011; Sangeetha, 2016) on the complex impact of RHA on sandcrete block properties. Their results showed that while compressive strength decreased with increasing RHA content, the blocks became progressively lighter, indicating a reduction in unit weight and improved potential for easier handling and reduced dead load in construction applications. The addition of RHA enhanced the porosity, permeability, and thermal conductivity of the material. According to Oyekan and Kamiyo (2011), the thermal effusivity of most RHA-incorporated blocks exceeded that of the control, with the 15% RHA mix exhibiting the highest value, approximately 17.5% greater than the control. This increased thermal effusivity indicates an enhanced capacity of RHA-blended blocks to absorb and release heat, promoting faster conduction away from building interiors. Such behavior can reduce cooling loads and support extended periods of indoor thermal comfort. Another study Okpala (1993), examined RHA as substitute for cement in sandcrete blocks. The developed RHA satisfies the pozzolan criteria and contributes to increased strength and sound absorption capacity. The study also found that RHA has the ability to improve heat insulation qualities, which might reduce heat flow in hot conditions, and in cold conditions due to the loss of heat.

Agbede and Obam (2008) investigated the economic possibilities of RHA, focusing on its use by rural residents in the construction of hollow sandcrete blocks. The study demonstrated the feasibility of partially substituting RHA for cement, providing a cost-effective and green option. According to (Khan et al., 2021), extensive compression testing of sandcrete blocks with different. Their study showed

that compressive strength of sandcrete blocks declined with increasing RHA content. At all curing ages, higher proportions of RHA led to reduced strength; even so, blocks with a sand-to-binder ratio of 1:8 incorporating up to 40% RHA still exhibited higher compressive strength than commercially available concrete blocks in Pakistan. . Nonetheless, RHA's early-stage pozzolanic activity was visible, indicating that it may be able to support sustainable building practices by maximizing energy use. In a study by Ettu et al. (2013), binary and ternary blended cement sandcrete and soilcrete blocks with RHA studies were carried out. These blocks showed different patterns of strength as they cured, suggesting that RHA could improve strength at a later time. Additionally, RHA was contrasted with other pozzolans in the study, demonstrating its increased reactivity and its potential for ternary mixing to maximize block strength. Model of heat transfer in sandcrete blocks with RHA, reveals increase in thermal resistance and decrease in heat flow due to RHA addition which suggests that RHA could play a pivotal role in minimizing air-conditioning loads and contributing to energy-efficient building practices (Kamiyo, 2020).

E. Groundnut Shell Ash

Mahmoud et al. (2012) evaluated the feasibility of using groundnut shell ash (GSA) as a partial replacement for cement in the manufacturing of sandcrete blocks. The study shows that GSA has cementitious qualities, giving a new option for sustainable building methods. One of the important findings of Mahmoud's research is that GSA may be used efficiently to generate sufficient compressive strength at around 20% of the binder content. The compressive strength of the sandcrete blocks, on the other hand, decreased as the GSA concentration increased. This highlights the significance of tailoring the ash-to-cement ratio to achieve a balance between target strength and replacement level. Moreover, the study revealed a relationship between GSA content and composite binder sandcrete block setting periods. The setting durations of the blocks lengthened as the ash concentration rose, which has consequences for construction scheduling and project schedules. Furthermore, the study discovered that as GSA amounts grew, water requirement for appropriate workability of the mix increased. This study implies that when selecting the proper water-cementitious material ratio for the combination, caution should be taken.

Importantly, Mahmoud's research emphasizes the importance of quality control and standardization in the use of GSA as a substitute material. The study stresses the importance of making additional efforts to improve the quality of GSA in order to obtain appropriate strength levels at maximal replacement levels. Furthermore, the study emphasizes the importance of raising public knowledge and education about the possible benefits of GSA consumption while maintaining quality standards, particularly among sandcrete block makers. Another contributing study by (Ketebu & Farrow, 2017) explores the utilization of plantain peel ash (PPA) and groundnut shell ash (GSA) as cement replacements in sandcrete blocks. The study emphasizes the cementitious properties of both waste ashes, implying their applicability as cement substitutes. The compressive strength of the generated blocks, however, was shown to diminish with

increasing waste ash proportions, indicating the need of controlled ash-to-cement ratios. Notably, the ternary blend of GSA and PPA outperformed separate binary mixtures in compressive strength, indicating the possibility of synergistic benefits when combining diverse waste materials. The study also emphasizes the importance of water absorption qualities, warning against the use of plantain peel ash-based blocks in moist areas.

F. Eggshell Powder (ESP)

Eggshells, which are mostly produced by the food and poultry sectors, are regarded as waste materials. Approximately 110 billion metric tons of eggshells are produced worldwide, and most of them wind up in landfills (Waheed et al., 2020). Eggshells have significant calcium content, ranging from 94% to 98%, according to observations (Philippe et al., 2020; Shwetha et al., 2018). Additionally, calcium from eggshells is more easily absorbed than calcium from coral or limestone sources (King'ori, 2011) which strengthens the material bonding (Adogla et al., 2016; Hamza et al., 2023) and because of this quality, chicken eggshells are a desirable option for natural reinforcing material. Nigeria produces 10.3 billion eggs a year, making it the largest egg producer in Africa (Kubkomawa & Kenneth-Chukwu, 2019), this figure is a little lower than Pakistan with annual estimation of 18 billion. China has the highest value of 458 billion with percentage global share of 48.94%. Fig 5 provides data on the top egg-producing nations and their associated waste estimates. Researchers are looking into how eggshells might be used to create inexpensive adsorbents for treating waters tainted with metals (Mignardi et al., 2020), several kinds of useful and valuable products (Hamideh & Akbar, 2018; Waheed et al., 2020) as well as sandcrete blocks (Afolayan et al., 2017; Commey, 2019). The specific gravity of eggshell is roughly 1.74, and its water absorption during a 24-hour period is 39.42%.

Table 1 provides additional information about eggshell powder's attributes. The shell is primarily composed of CaCO_3 , which is likewise the primary component of sea shells. According to research, the percentage of cement replacement ranged from 5 to 40%. (Afolayan et al., 2017; Commey, 2019). Chemical compositions of eggshell powder are shown in Table 3. The dry density of the samples improved with the addition of eggshell. Additionally, tests revealed that samples with 15% eggshell outperformed others in strength, wear resistance, and water retention. Results also show that strength increases up to 15% and then declines after that when replacement cement percentages with eggshell powder increase.

When comparing the compressive strengths of the 15% cement replacement to the control's 0% over seven, fourteen, and twenty-one days, respectively, the results show increases of 21.16%, 11.77%, and 26.59%. Because the eggshell powder contains a certain amount of calcium carbonate, which fills the mixture's numerous holes, the strength of the mixture has increased (Commey, 2019).

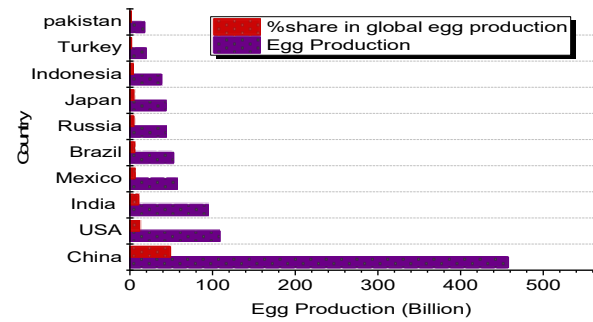


Figure 5. Leading Egg-Producing Nations and Estimated Eggshell Waste (Waheed et al., 2020)

G. Saw Dust Ash

Conversely, sawdust, also known as wood dust, is a fine wood particle that is left over from the wood and forestry industries. Sawdust generally resembles wood, albeit its particle nature has changed some of its structural qualities. Different tree species have different dry wood chemical compositions. Lignin (18–35%) and carbohydrates (65–75%) make up the majority of sawdust's chemical composition, with trace amounts of other elements (4–10%) present as well. It is discovered that sawdust has a very low bulk density ($150\text{--}200\text{ kg/m}^3$) (Jannat et al., 2022a), it also has a very low thermal conductivity, making it an excellent insulation material. Table 2 outlines the chemical constituents of sawdust ash (SDA), with average percentage composition of $\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$ meeting the ASTM C 618 (Raheem & Sulaiman, 2013) minimum percentage criterion of 70% for pozzolanas

Researchers experimented with producing various building materials out of sawdust (Ibeabuchi, 2025; Mwango & Kambole, 2019). Among the materials that have been built are sandcrete blocks, fired and unfired clay bricks, insulating material, particleboard, and landcrete interlocking blocks (Akinyemi et al., 2016; Assiamah et al., 2022; Chemani & Chemani, 2013; Ouattara et al., 2016; Robert et al., 2021; Zou et al., 2020). Adebakin et al. (2012) evaluated the strength of sandcrete blocks created by substituting sawdust in various amounts (10%, 20%, 30%, and 40%) for some of the sand. They observed that compressive strength reduces with increasing percentage substitution and that weight reductions of around 10% and production cost reductions of 3% occur with 10% sawdust replacement. According to (Raheem & Sulaiman, 2013), the strength of blocks with 5% and 10% SDA replacement, measured at 2.33N/mm^2 and 2.04N/mm^2 after 56 days, exceeded the National Building Code's required standard of 2.00N/mm^2 (Raheem & Sulaiman, 2013). It was shown that increase in SDA substitution decreases density. Robert et al. (2021) conducted experiments on the hygrothermal properties of sandcrete blocks made partially from sawdust instead of sand. On an annual value of 10%, their SDA replacement ranges from 0 to 40%. Their research demonstrates that sawdust improves building envelope energy efficiency and reduces the burden on walls that transmit heat.

H. Other Agro Waste

Research has examined the integration of several agricultural waste materials and revealed their impact on the qualities of sandcrete blocks, such as their compressive strength, water absorption capacity, as well as durability. A notable development in this field results from a study by (Tijani et al., 2020), which examined sorghum husk ash's (SHA) potential as a pozzolanic material in the manufacturing

of sandcrete blocks. Important parameters including compressive strength, density, and water absorption were carefully studied by the researchers. According to their research, SHA is a suitable pozzolanic material that can be used to increase the compressive strength of sandcrete blocks.

Table 2. Chemical composition of some natural cement and sand replacement materials.

| | SiO ₂ | CaO | Al ₂ O ₃ | MgO | Fe ₂ O ₃ | Na ₂ O | K ₂ O | SO ₃ | P ₂ O ₅ | LOI |
|--|------------------|-------------|--------------------------------|-----------|--------------------------------|-------------------|------------------|-----------------|-------------------------------|-------------|
| RHA | 8.33–10.85 | 41.13–47.61 | 1.34–2.03 | 0.73–7.13 | 0.72–1.13 | 0.08–0.13 | 0.17–0.24 | 0.33–0.50 | 0.02–0.03 | 38.76–40.08 |
| CSA (Robert et al., 2020) | 43.5 | 3.25 | 15.2 | 5.01 | 12.6 | 0.47 | 8.49 | - | 0.40 | 10.39 |
| GSA (Mahmoud et al., 2012) | 26.96 | 9.50 | 5.82 | 5.60 | 0.50 | 1.15 | 20.02 | 1.86 | 2.00 | 22.00 |
| ESP (Adogla et al., 2016; Commey, 2019) | 0.08-0.79 | 52.1-64.83 | 0.03-0.13 | 0.01-0.29 | 0.02-0.06 | 0.15-1.48 | 0.08 | 0.06-0.62 | - | 45.42 |
| SDA (Raheem & Sulaiman, 2013) | 65.31 | 4.21 | 6.09 | 3.39 | 3.49 | 1.00 | 11.09 | 2.89 | - | - |
| SHA (Tijani et al., 2020) | 55.30 | 10.40 | 10.10 | 1.20 | 11.90 | 0.70 | - | 0.50 | - | 6.10 |
| MCA (Anowai et al., 2020; Oyebisi et al., 2018) | 55.50-61.53 | 3.03-16.23 | 8.78-18.28 | 2.23 | 7.13-8.67 | 0.90 | - | 1.75 | - | 6.55 |

LOI– loss, CSA– Coconut shell ash, GSA– Groundnut shell ash, ESP– Eggshell Powder, SDA– Saw Dust Ash, SHA– Sorghum husk ash, MCA– Maize Cob Ash

Even though the water absorption increased as the SHA content increased, the values stayed within acceptable bounds, indicating that SHA could serve as an agricultural residue to bolster the longevity and structural integrity of sandcrete blocks. Olawale and Tijani (2019) looked at how different fine aggregate sources affected the production of sandcrete blocks. In order to get the best block performance, the study highlighted the crucial role that aggregate selection plays in reflecting local conditions. It also highlighted the significance of ensuring compatibility between aggregates and cement. This study emphasizes how important it is to choose materials carefully in order to incorporate agricultural waste materials into sandcrete blocks and achieve the desired qualities.

Aginam et al. (2013), examined the possibility of using breadfruit stem ash (BSA) in place of some cement in the manufacturing of sandcrete blocks. Even while BSA showed pozzolanic properties, the study revealed drawbacks from using a lot of BSA, which led to reduced compressive strengths. This finding emphasizes how exact optimization and cautious material selection are necessary to maintain the intended sandcrete block qualities while adding BSA. Cassava peel ash (CPA) as a cement substitute in sandcretes was investigated by (Abubakar et al., 2021). The study proved that sandcrete blocks with 5% CPA supplementation met the necessary compressive strength requirements in addition to promoting the environmental benefits of reusing agricultural waste. This study demonstrates how CPA can be used to

improve block qualities and manage environmental issues related to trash disposal at the same time.

In an evaluation of maize cob ash (MCA), identified in some study as Corncob ash (CCA) (Oyebisi et al., 2018) for use as a substitute material, (Anowai et al., 2020), examined its pozzolanic qualities and suitability for partial cement substitution in the manufacturing of sandcrete blocks. The study emphasized how important it is to use the right replacement percentages in order to provide the required strength and durability. Adding MCA turned out to be a viable way to improve block attributes and deal with waste management issues at the same time.

Mama and Osadebe (2009) provided a thorough model with the goal of integrating agricultural waste materials into sandcrete blocks to maximize their compressive strength through a variety of criteria. The study used Scheffe's simplex theory to show how adding the right elements to a partial cement replacement can cause pozzolanic reactions that increase compressive strength. This study sheds light on the complex interactions that exist between block performance and material composition. Another potential agro material is the Guinea corn husk ash (GCHA). Chemical compositions of these materials as well as the compressive strength of their composite sandcrete is given in Tables 2 and 3.

Table 3. Characteristics of Sandcrete blocks incorporating agro by-products.

| Mix Design Proportion | | | Size (mm) | Bulk Density (kg/m ³) | Comp. strength (N/mm ²) | Reference |
|--|-----------|-----------|---|--|---|-------------------------|
| % replacement | Mix ratio | w/c ratio | | | | |
| 0.25%PPOFF | 1:6 | 0.65 | | 2066 | 4.58 | (Onyia et al., 2022) |
| 0%PKS 20%PKS 40%PKS | 1:4 | 0.55 | 230X110X110 | | 5.54 4.91 2.31 | (Jaji et al., 2017b) |
| 0%PKS 20%PKS 40%PKS | 1:5 | 0.55 | 230X110X110 | | 4.98 3.54 2.24 | (Jaji et al., 2017b) |
| 0%PKS 20%PKS 40%PKS | 1:6 | 0.55 | 230X110X110 230X110X110 230X110X110 | | 4.60 2.33 1.76 | (Jaji et al., 2017b) |
| 0%CPA 5%CPA 10%CPA 15%CPA 20%CPA | 1 :6 | 0.6 | 450X225X150 450X225X150 450X225X150 450X225X150 450X225X150 | | 2.67 2.52 2.42 2.30 2.16 | (Abubakar et al., 2021) |
| 0%GCHA 5%GCHA 10%GCHA 15%GCHA 20%GCHA | 1:6 | | 450X225X225 450X225X225 450X225X225 450X225X225 450X225X225 | 1971.6 1985.9 1964.5 1936.2 1929.1 | 2,16 2.30 1.73 1.59 1.35 | (Alkamu et al., 2018) |
| 0%GCHA 5%GCHA 10%GCHA 15%GCHA 20%GCHA | 1:8 | | 450X225X225 450X225X225 450X225X225 450X225X225 450X225X225 | 1993.0 2000.0 1971.6 1943.3 1922.0 | 1.53 1.64 1.51 1.42 1.30 | (Alkamu et al., 2018) |
| 0%ESP 5%ESP 10%ESP 15%ESP 20%ESP 25%ESP 30%ESP | 1:3 | 0.5 | 100X50X70 100X50X70 100X50X70 100X50X70 100X50X70 100X50X70 100X50X70 | | 3.415 3.612 3.824 4.323 3.405 3.132 2.974 | (Commey, 2019) |

PPOFF– Pressed palm oil fruit fiber, PKS – Palm kernel shell, CPA – Cassava peel ash, GCHA – Guinea corn husk ash, ESP – Eggshell powder

V. CHALLENGES TO PROMOTING THE USE OF AGRICULTURAL BYPRODUCTS AS ALTERNATIVE MATERIALS IN SANDCRETE MASONRY

Research on green concrete, which replaces some aggregate with byproducts from agriculture and aquaculture, began several years ago (Eziefula, 2018). This development has started reflecting in the manufacturing of sandcretes. The utilization of agro-waste in sandcretes offers a viable solution for handling agro wastes issues while also lowering the environmental impact of mining natural resources. Furthermore, using by-product materials can lower the cost of constructing sandcrete units, resulting in more affordable housing. However, there exist obstacles that limit the use of

these by-products. Among these impediments are the following:

1. **Availability as well as Accessibility:** Depending on whether substantial amounts of the by-product are accessible and available nearby, by-products may be used as building materials in a given location. The amount of by-products that are accessible at a specific place might or might not be sufficient to serve as a sustainable substitute. The handling, processing, and transportation systems will be impacted by the importation of byproducts from remote areas. Where natural resources are extremely hard to come by or where environmental constraints drive up the cost of building, the utilization of waste materials can significantly lower the cost of concrete construction (Onyia et al., 2022). However, using

byproducts in sandcrete units might not be more cost-effective in locations of abundance traditional natural materials. Utilization and development of by-product aggregates will probably be severely restricted by the accessibility of traditional materials over short transportation distances.

2. **Extra cleaning:** Because agricultural by-products contain contaminants that weaken sandcrete, they may need to be cleaned (Adebakin et al., 2012). Various cleaning techniques have been described, such as immersing items in hot, soapy water followed by clean water rinse, washing with water followed by air-drying, using an oven at 105–135°C for periods ranging from thirty minutes to four hours, and heat treatment at 250–300°C (Eziefula, 2018). However, some authors neglected to mention purification and decontamination of by-products in any way. Agricultural by-product materials must be cleaned in order to reduce the concentration of chloride ions and organic contaminants. Agro-waste with a high impurity level will adversely affect the performance of sandcrete units. Compared to typical materials, cleaning agricultural byproducts might be more expensive. This is due to the fact that the majority of natural, conventional materials used in sandcretes typically merely need to be washed and dried—extra or intricate cleaning is rarely needed.
3. **Transporting and handling:** The assessment of by-products as substitutes for aggregates in sandcrete should take the distance between the waste source and the construction site into account. In order to compete with traditional construction materials, the transportation distances required should be fair. It is not cost-effective to carry concrete across long distances.

VI. FURTHER INVESTIGATION

This section identifies gaps in the available literature and offers future study possibilities. The constraints of the current technology are illustrated here. From the evaluation of current research, the subsequent recommendations for future investigation are presented:

- The qualities of agro by-products, which are of natural source, typically change with species, age, and climate. The age of the byproduct has not been reported in the literature. It would be beneficial to look into the effects of aggregates made from agricultural by-products' age on the durability and physico-mechanical characteristics of sandcrete. Furthermore, the effects of species and conditions of by-product exposure on the characteristics of sandcretes needs be ascertained.
- The examined agricultural by-product materials' mechanical, chemical, and physical characteristics point to some behavioral variances. To enhance the use of these novel by-products in the manufacturing of sandcretes, an international standard ought to be established. The following should be included in specifications for various agricultural by-products in international standards: The acceptable ranges for by-product qualities depending on environmental situations, the intended age, and the species.
- More experimental research is necessary to definitively determine the behavior of sandcretes made using cement replacements such as SHA, BSA, MCA, GSA and GCHA. For fine aggregate materials, use CS, PKS, and CH. In concrete made from these agricultural byproducts, strength properties as well as density are the most investigated characteristics.
- Further research on the structural behavior of sandcrete units, such as fire resistance, sound absorption, heat transfer, and abrasion resistance, should be done due to the lack of research on optimizing and modeling sandcrete blocks that include agro waste for optimum evaluation. There should be a number of formulas and correlations need to be established for the parametric properties.
- Research on the effect of climate change on the properties of agricultural by products will give more insight on integrity as well as sustainability subjects.
- There aren't many studies that examine the immediate advantages of using agriculture byproduct materials in sandcretes in terms of the environment and economical costs. It is important to conduct further research to find out how much cost may be saved and how much CO₂ can be avoided when producing sandcrete from agricultural byproducts.
- In general, durability is a crucial factor to consider while designing and building concrete structures. Biological materials, such as agricultural wastes and by-products, are easily impacted by natural and biological elements like heat, precipitation, organic matter, and material property fluctuations. More research is required to accurately forecast the durability of by-product sandcrete, even though some publications have noted durability features, particularly for sandcrete made using SDA. Thus, it is important to research the durability characteristics of sandcrete made from agricultural byproduct materials. Water absorption, sound absorption, thermal resistance, concentration gradient of chloride, resistance to high temperatures, color shifts, durability against sulfate assault, and resistance to acid attack are a few of the durability attributes.

VII. RESULTS AND DISCUSSION

This review primarily covers published research from 2000 to 2023 on the use of agricultural waste materials in sandcrete block production. However, selected foundational literature, including a key source from 1989, was referenced to provide historical context and trace early material development. The selected literature spans over three decades and includes 98 peer-reviewed sources, technical reports, and academic texts. A thematic and qualitative synthesis of the data was conducted, focusing on material types, replacement levels, mechanical performance, and sustainability benefits. The most commonly studied agricultural wastes include rice husk ash (RHA), eggshell powder (ESP), palm kernel shell (PKS), groundnut shell ash (GSA), sawdust ash (SDA), coconut husk ash (CHA),

and palm oil fuel ash (POFA). Their application spans two major functions:

- as supplementary cementitious materials (SCMs)
- as partial replacement for fine aggregates (e.g., sand)

Studies show that ESP and RHA are predominantly used as cement replacements, while PKS, SDA, and CSA are commonly used as sand replacements. Their chemical compositions vary but typically contribute beneficial silica, calcium oxide, or alumina needed for pozzolanic activity.

➤ *Effects on Compressive Strength*

Most studies confirm that partial replacement levels between 5% and 25% yield acceptable or improved compressive strength:

- i. ESP: Strength increases up to 15% replacement, with a decline beyond that due to excess porosity (Commeey, 2019).
- ii. RHA: Enhances long-term strength due to pozzolanic reactions (Cisse & Laquerbe, 2000; Ettu et al., 2013).
- iii. PKS: Shows reduced strength at high replacement levels but still meets non-load-bearing requirements (Jaji et al., 2017).
- iv. GSA & PPA: Require optimal mix designs to avoid low early strength; ternary blends often yield better results (Mahmoud et al., 2012; Ketebu & Farrow, 2017).

➤ *Density and Thermal Performance*

Almost all agro-waste inclusions result in lower bulk density, contributing to lightweight sandcretes. For example:

- CSA reduces density due to its low specific gravity (~1.1–1.6 g/cm³) and helps enhance thermal insulation (Ikeagwuani et al., 2018).
- SDA and RHA improve thermal resistance and may help lower energy demands in tropical structures (Kamiyo, 2020; Robert et al., 2021).

➤ *Durability and Absorption Properties*

Water absorption generally increases with agro-waste inclusion due to higher porosity, but most replacements remain within acceptable durability limits:

- POFA and RHA blends meet Malaysian and ASTM durability standards (Rahman et al., 2014).
- SHA and MCA show pozzolanic potential but need more research on long-term exposure and moisture behavior (Tijani et al., 2020; Anowai et al., 2020).

➤ *Comparison of Key Mixes*

Table 3 highlights the best-performing mixes for each agro-waste material. While PPOFF at 0.25% shows the highest strength at 4.58 N/mm² (Onyia et al., 2022), 15% ESP gives ~26% higher strength than control after 21 days (Commeey, 2019). However, RHA at 20% improves thermal performance but reduces early strength (Sangeetha, 2016)

VIII. CONCLUSION

Agro-wastes offer promising potential as sustainable alternatives in sandcrete block production. The reviewed

literature from 2000 to 2023 indicates that, when properly processed and optimally dosed, materials such as rice husk ash (RHA), eggshell powder (ESP), and sawdust ash (SDA) can enhance or maintain the strength and durability of sandcrete blocks. Their application supports cost-effective construction, reduces environmental impact, and aligns with circular economy principles.

Recent studies show an increasing trend toward optimizing mix designs using statistical models such as Taguchi and regression analysis, particularly in Malaysia and Nigeria. There is also growing interest in combining multiple agro-wastes to achieve improved performance through material synergy. However, notable research gaps remain. The majority of studies have focused on compressive strength and density, with limited data on properties such as shrinkage, thermal conductivity, and acoustic insulation. Long-term durability indicators, including sulphate resistance and chloride penetration, are also underreported. Additionally, the influence of variables such as the age and origin of agro-waste materials and the impact of local climate conditions have not been thoroughly investigated. Addressing these gaps will be essential for the broader adoption and standardization of agro-waste-based sandcrete technologies.

AUTHOR CONTRIBUTIONS

V. T. Ibeabuchi: Conceptualization, Manuscript preparation, Software, Writing – review & editing, **C. U. Nwoji:** Supervision, Validation, Writing – review & editing, **A. A. Amin:** Visualization, Writing – review & editing.

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