ACHIEVING SUSTAINABLE LOCAL BUILDING WALL MATERIALS IN ONDO STATE, NIGERIA: USING LATERITE STABILIZED WITH CEMENT AND BONES ASH-POWDER

Abstract

Shelter is an integral part of human needs. It has been adjudged second to food in the ranking of human needs. However, the provision of shelter for the Nigerian populace remains low despite various policies and efforts from both governmental and private agencies to provide desirable housing for citizens. This study seeks to introduce the use of laterite soil, which is a common natural material in most Nigerian environments, with ordinary portland cement and cow bone ash powder to achieve affordable, eco-friendly, and tropical compliance materials for building wall construction in Nigeria. The study investigates the existing mud bricks and sandcrete (hollow) blocks for wall construction. It conducts a thorough test of the laterite soil composition with respect to its compressive strength and cohesive compatibility with cement and bone ash powder to form solid and desirable stabilized bricks for building walls. The resultant bricks show that ordinary portland cement and cow bone ash powder exhibit significant stabilization potency on laterite to attain high compressive building wall material. The cow bone ash powder reduces the percentage of cement used for stabilization of the laterite bricks and enhances its sustainability and affordability for housing delivery in Nigeria.

Keywords: Housing delivery, Local building materials, Laterite, Cow bone ash-powder, Ordinary portland cement.

Introduction

Nigeria is making high use of foreign building materials. Thus, the cost of building materials and construction increases annually in Nigeria, noting the constant increase in the exchange of currency (i.e., the US dollar to Nigerian naira). This study aimed at providing affordable and effective use of local materials via the use of laterite soil to achieve sustainable building wall construction as a formidable means of housing delivery in Nigeria. In Africa, laterite soil stabilized with ordinary Portland cement was used, particularly in Sudan, for the mass production of housing, and its sustainability was attested to (Adam E. A, 2001). However, researchers have posited that laterite stabilized with cement has demonstrated good performance in building and pedestrian road construction (Ola S. A, 1974., Osinubi et al, 2007).

The continued usage of non-local material for building construction in Nigeria is partially responsible for the poor provision of housing to rural and sub-rural dwellers, which constitute a higher population percentage in Nigeria and are primarily agriculturally dependent. Sandscrete blocks and other non-locally available materials, such as glass ,fiber vibers, synthetics, etc., have become major building wall materials in Nigeria with their high cost and low strength properties. Hence, the cost of the materials became unbearable for the common man to afford, and it called for an alternative local building material that’s readily available and affordable. Thus, in time memorial, laterite soil has been adjudged traditionally in most Nigerian villages and communities as the primary basic wall materials for the building construction in Nigeria, stabilized with grass and agricultural produce (Aguwa ,2010). But, the advancement in the building industry introduces the use of cement for its stabilization based on different ratios and percentages of laterite quantities and molding sizes.

Literature Review

The importance of environmental sustainability and an eco-friendly built environment has thrown attention into a study geared towards the use of natural earth materials for building construction purposes. The aforementioned was combined with the high cost of building construction, which resulted in the use of foreign building materials, which led to the non-affordability of the building materials, which poses difficulties in housing delivery in Nigeria. The use of earth materials supports building sustainability as it encompasses resource efficiency in construction processing (Alam et al., 2015). Building supports human well-being, reduces emissions, eases maintenance, and promotes health construction. The use of laterite has the tendency to reduce the human environmental impact of building construction on nature.

It has been reported that much effort should be made to minimize the cost of building construction in Africa via material domestication to achieve housing affordability (Aguwa J.S 2010; Jayasinghe & Kamaladasa, 2006). Thus, laterite as an earth material is naturally available in Nigeria in large quantities. Laterites are formed via the weathering process, as they undergo both physical and chemical weathering. It mostly contains aluminum oxide, iron, and quarts. The weathering process spans several years. Numerous studies have defined laterite in terms of its physical nature and chemical composition (Amadi & Okeiyi, 2017; Obianyou et al., 2020). Laterite varies in color; its resemblances or variances are influenced by its chemical composition and physical properties. It abounds more in the wet-tropical region (Oluremi, et al., 2012).

Laterite soils are commonly found in tropical and sub-tropical regions; the soils are the by-products of chemical weathering. It has a poor loading strength capacity and properties due to its long weathering process, which affects its chemical composition and the characteristics of its morphology that differentiate it from its parent strong strength properties (Oluremi, et al., 2012). Stabilization of laterite soil has been done by numerous researchers in the building construction industry to improve the laterite soil strength for construction purposes (Oluwatuyi et al., 2018). According to the available research, the major means of stabilizing laterite soil have been the use of cement, bitumen, and lime, which are all conventional, costly, and uneconomical. However, the efficacy of lime as a stabilizer of lateritic soil has been recognized (Ajayi, 2012; Akoto & Singh, 1981; Alavéz-Ramírez et al., 2012; Amadi & Okeiyi, 2017; Obianyo et al., 2020). Larger clay contents in laterite soil constitute its poor loading bearing capacity (Gidigasu, 1976), but conventional stabilizers such as cement, bitumen, and, more importantly, lime have made the products of laterite bricks expensive and uneconomical for the citizen (Tesfaye, 2001, Nebro, 2002). Lime as a laterite stabilizer was said to be specifically uneconomical (Joel & Edeh, 20113). Therefore, there's a need to look into the use of more affordable and available stabilizing materials on laterite soil to achieve better strength properties and be more economical (Osinubi 2000).

To achieve stabilized laterite bricks for building construction, adhesive can be added (Obianyo, Onwualu et al., 2020; Ola, 2013; Malkanthi et al., 2020; Rao & Shivananda, 2005). Therefore, this study adds ordinary Portland cement and bone ash powder to improve its stability and strength. Cement and bone ash powder have high adhesive features and properties that are capable of achieving high laterite compressive stability and strength. The objectives are to identify the properties of the available laterites used in the study area and determine their strength properties using ordinary Portland cement with cow bone ash powder as stabilizer for effective building wall of high economic and affordable value.

This study looks into the vast availability of laterite in Ile Oluji, Ondo state, Nigeria and the tendency to strengthen the stabilization strength of the laterite with the use of cement and bone ash powder to achieve desirable bricks for building wall construction. The bellow properties of the laterite found in the study area (Ile Oluji, Ondo State, Nigeria) are shown in Table 1. Dried cow bones were collected from a cow abattoir in Ondo township, Ondo State, Nigeria. The dried bones were burned and crushed to a powdery substance termed cow bone ash powder, a residual that's primarily hydroxyapatite's $(Ca_2(PO_4)_2OH)$ ash's chemical composition as posited by Ayininuola and Sogunro (2013). Grain size analysis and Atterberg test were done in line with BS 1377(1990).

Table 1. Properties of the Natural Laterite soil used

S/no	Property	Laterite
1	Natural moisture content (%)	3.11
2	Optimum Moisture content (%) 14.73	13.46
3	Percentage passing BS No 200 sieves (75µm) (%)	32
4	Specific Gravity	2.71
5	Plasticity Index (%)	23
6	Linear shrinkage	10.5
7	Plastic Limit (%)	30.7
8	AASHTO classification A-2-6	A-2-7
9	Maximum Dry Density (Kg/m3) 2011	2010
10	Liquid Limit (%) 54.34	53.8
11	Condition of sample	Air-dried
12	Color	Brownish-red

Problem Statement

Shelter has been adjudged second to human need in the scale of preferences after food. However, the provision of shelter to the Nigerian populace becomes an individual's responsibility as the fewer housing units provided by the government could not accommodate the citizen couple with the non-sustainability of the foreign materials. Thus, building construction material has increased tremendously in recent years. Hence, we are searching for substituting materials to mitigate the increased cost of these building materials, mostly cement, which has been used as a stabilizer and binder among the aggregate in Mortar and Sand Creed Block Productions. This research recognizes the use of cow bone ash powder (CBA) to partially replace ordinary Portland cement (OPC) to stabilize laterite as a potential material in building construction. Oyelami and Van Rooy (2016) posited that lateritic soil is a sub-tropical leftover soil that is solidified and enriched with many ions, commonly used in the foundation of buildings.

According to Afrin (2017), laterite stabilization is very relevant using different techniques for changing its deceptive properties and improving its engineering qualities for execution. Stabilization has been employed mostly in road construction, dams, and other related earthworks and utilized for different engineering works, with the fundamental goal of achieving the strength of the soil and reducing the cost of construction by using locally readily available materials (Chukwutem, 2020). On this note, this study investigates the potential of laterite soil with the combination of ordinary Portland cement and bone ash powder to produce a building wall that will exhibit good strength, be affordable, and uphold building construction and maintenance sustainability.

Methodology

A sample of laterite will be collected in the Ile-Oluji area of Ondo State, Nigeria. It will be sieved with 300pm B.S Sievers in which a laboratory test was carried out for the laterite stability (compressive test) in accordance with Nigerian building code regulations for brick testing and curing. The laterite mixed with cement and bone ash powder undergoes a sieving method to establish the distribution patterns of the particles. The laterite mixed with cement and bone ash powder undergoes a similar test after its compaction. The compressive strength test was done with an electrical Seidner compressive machine at the curing age of 7 and 28 days using six blocks of bricks. The blocks were positioned to allow the axis of the trust of the compression machine for uniform loading during the curing, and the blocks underwent crushing each day of the curing age, respectively, while the laboratory average compressive strength was measured accordingly in line with previous study (BS 1377,1990; BS 1881,1983 Neville A.M,2000).

Results and discussion

Table 2:Values of 7 Days Average Compressive Strength Brick Test

OPC (%)	*Laterite Soil (%)*	*Weight of bricks (kg)*	*Density of brick (kg)*	*Load at failure (N)*	*Compressive strength (N/mm^2)*
0	100	11.50	111.1	10.50	0.99

10	90	11.38	109.5	12.60	1.19
30	70	10.81	104.4	13.10	1.67
OPC/CBA (%)	Laterite Soil (%)	Weight of bricks (kg)	Density of brick (kg)	Load at failure (N)	Compressive strength (N/mm^2)
5/10	85	11.41	110.2	14.08	2.08
20/10	70	11.46	110.7	27.06	4.00

Table 3:Values of 28 Days Average Compressive Strength Brick Test

OPC (%)	*Laterite Soil (%)*	*Weight Of Bricks (Kg)*	*Density Of Brick (Kg)*	*Load At Failure (N)*	*Compressive Strength (N/mm^2)*
0	100	11.46	110.7	12.06	1.75
10	90	11.42	110.3	12.62	1.82
30	70	10.98	106.1	12.02	1.74
OPC/ CBA (%)	*Laterite Soil (%)*	*Weight of bricks (kg)*	*Density of brick (kg)*	*Load at failure (N)*	*Compressive strength (N/mm^2)*
5/10	85	11.51	111.2	14.19	2.06
20/10	70	11.67	112.8	29.06	4.20

In this study, a wooden mold of 460 mm x 150 mm x 150mm size was prepared to produce laterite-Cement-Cow Bone Ash-Power (LCCBA) block as a sustainable building wall material in building construction. Laterite soil was air dried, and the unwanted particles were removed from the soil prior to the mix. The cow bone ash powder CBA was obtained from the production factory in a dried-off white color, including ordinary Portland cement OPC of the BUA brand that was used as the admixture to produce LCCBA block. Laterite soil was later prepared in different proportions of 100%, 90% and 70% mixed with OPC of 0%, 10% and 30%. 25.3 water-to-cement ratio was obtained. The homogeneity mixture of the aggregates yielded a proper semi-dried laterite cement for the molding of laterite cement blocks cured for 7 days and the compressive strength was determined and summarized in Table 2. From Table 2, result of the specimen increases when the laterite stabilizes with OPC and CBA after attaining the curing age of 7 days with 85% of laterite soil against 5% of OPC and 10% of CBA also, 20% of OPC and 10% CBA against 70% of laterite soil The crushing efforts were recorded to be 2.06 N/mm^2 for 85% of laterite soil against 5 – 10% of OPC- CBA and 4.20 N/mm^2 for 70% of laterite, as shown in Table 3.

The curing age of bricks and its effects on their compressive strength, mainly on earth-based materials such as bricks, clay, and concrete, have been considered to have significant effects on their compressive strength (Chen et al., 2019; Johnson et al., 2014). The bricks underwent a basic curing age, and the findings indicate that stabilized laterite soil compressive strength increases as the curing age increases. The experimental result shows that as the curing age increases for laterite stabilized with OPC and CBA to produce blocks that are made up of LCCBA, the compressive strength increases with a decrease in the volume of the laterite, therefore reducing the quantity of cement used for the laterite stabilization as the cow bone ash powder takes 10% off the cement quantity.

Conclusion

This study conducted a comprehensive test and analysis of the natural laterite soil available in the study area to achieve good compressive strength, taking into consideration the economic value and the affordability of the product for effective use. The strength of the laterite increases in proportion to the cement (Metcalfe J.B, 1977). In this study, the increase in the cement ration or percentage increases the bonding strength of the laterite bricks, but the addition of cow bone ash powder averagely makes the laterite bricks maintain a good compressive strength of 4.2N/mm2 which in turn reduces the quantum of cement and, as such, reduces the laterite production cost. Despite the natural availability of laterite soil in the tropical region, the higher cement contents as stabilizers will have a high-priced cost effect on the products. Therefore, the use of bone ash powder as an additional stabilizing element, particularly cow bone, to partially replace ordinary Portland cement as a major stabilizer is economical, gives good compressive strength to the laterite, and exhibits a high affordability value. The laterite brick products have a higher tendency to minimize cracks and excessive dampness on laterite walls. The use of cow bone ash powder will eradicate cow bone heaps on Nigerian abattoir sites and waste pits and enhance healthy living and a pleasant built environment.

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