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Effect of Rice husk ash on the compressive strength of eco-friendly compressed Lateritic Earth Blocks

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ABSTRACT: Blocks and cementitious materials are the major construction materials that determines the overall construction cost of buildings. The use of agricultural waste materials in brick production helps in enhancing properties of Blocks and reducing the depletion of natural resource and the resulting environmental impacts. The aim of this research is to develop an eco-friendly and resilient brick for low-cost housing using laterite and Rice Husk Ash (RHA). The effect of blending rice husk ash with a lateritic soil on the strength characteristics of low-cost eco-friendly Blocks will be investigated through laboratory and field experiments. The compressive strength of RHA-Laterite block increase with increase in RHA up to 8 %. However, a higher percentage of RHA beyond 8 % decrease the compressive strength. The compressive strength increased by 10.8 %, 26 %, 44.1 %, 67.6 % and 27.9 % compared with the control mixture. At higher temperature the strength of the block decreases significantly. Microstructural examination revealed that brick sample produced with 8% RHA exhibits a uniform and dense microstructure, thus, resulting in a higher strength.

I. INTRODUCTION

Shelter is one of the basic human needs after food and clothing. Housing in most of the developing countries are not adequate and its inadequacy is always increasing rapidly due to population growth. Meeting the need for adequate housing of the world's population requires sustained investment and continued innovation, particularly in appropriate technologies that lower the cost of construction and the cost to the environment. For sustainable to development to succeed in the industry, there must be an efficient collaboration among all the stakeholders in the construction industry [1]. The building industry is constantly embracing the use of supplementary cementitious materials and environmental wastes in concrete, owing to the emergence of sustainable technologies, which is largely driven by regulations and increasing demand for innovations and cost reduction, international organizations, a shortage of landfills and a scarcity of natural aggregates, and environmental issues [1, 2].

Burnt clay Blocks are a popular building material all over the world. In general, the properties of clay Blocks are determined by the raw material composition, the burning temperature, and the manufacturing method. The quartz in clay softens at high temperatures and forms a bond between clay particles after cooling. Blocks contain additives to improve the bond between clay particles [3]. At low melting temperatures, the additives act as a flux and aid in bond formation. Many parts of the world have naturally emerging clay deposits. However, the excessive use of clay in the production of Blocks has resulted in a scarcity of natural clay resources. Traditional Blocks are made from clay and fired at high temperatures in a kiln, or from ordinary Portland cement (OPC) concrete. Quarrying processes for clay are energy intensive, have a negative impact on the surrounding, and produce a high level of waste.

Laterites are the most common surface deposits in the world's tropical and subtropical regions, enriched in iron and aluminum and formed by extensive and long-term weathering of the underlying parent rock [4]. Laterites are found to be an excellent building material in developing countries especially in highway construction, embankment construction, and as a concrete ingredient [5]. The use of laterite in various research studies, particularly in concrete production, has been shown to significantly increase the strength properties of concrete. Lingling et al. [6] investigate the effect of blending fly ash with clay Blocks. They have reported that fly ash used as a raw material instead of clay to make fired Blocks is an effective way of conserving land and reducing pollution. They further reported that fired Blocks with a large - volume ratio of fly ash had a high compressive strength, no lime cracking, low water absorption, high resistance to efflorescence, no frost, and high resistance to frost-melting. Chean et al. [7] concluded that it was feasible to produce Blocks with hematite tailing. Blocks made with hematite tailing exhibits high compressive strength.

The use of agricultural waste materials as an additive in brick production not only helps to enhance the properties of Blocks, but it also helps to resolve natural resource scarcity and the related environmental impacts. The use of supplementary cementitious materials and the recycling of environmental wastes contributes to green concrete, helps to reduce global warming, and has been found useful in both structural and non-structural applications. Furthermore, there have been organized calls for increased use of local materials in construction, which are abundant, readily available, and less expensive than traditional materials [1].

Energy conservation is a high priority in the world today due to environmental and economic concerns [8]. Buildings in developed countries consume 40% of all energy for heating and cooling. One-twelfth of this amount is consumed solely by building walls [9]. The development of energy-efficient buildings is critical. Improving the thermal performance of walls is one of the most effective ways to make a building more energy efficient. Sutcu [9] reported that the formation of micro pores in Blocks can help to improve the thermal performance of walls, resulting in more energy-efficient buildings. Thermal resistance of Blocks can be improved by creating pores, resulting in more energy-efficient buildings. Despite the fact that laterite is recognized as a good construction material, literature results show that there have been few studies on the durability properties of lateritic Blocks modified with a rice husk ash. The use of pozzolanic materials in Blocks, is intended to reduce the reliance on cement as the sole binding agent.

Raheem *et al.* [10] considered the production and testing of sandcrete hollow blocks and laterite interlocking blocks with a view to comparing their physical characteristics and production cost. The blocks were tested to determine their density and compressive strength. Then, these results were compared with the specification of Nigerian Building Code 2006. They found from their study that all the blocks produced satisfied the minimum requirements in terms of compressive strength, by all available codes. In term of cost, they found that it was ₦2,808:00 and ₦2,340:00 per square meters of 225mm and 150mm sandcrete hollow blocks respectively. While, the cost was ₦2,121:20 for laterite interlocking blocks. The main conclusion for this study is the recommendation of using laterite interlocking blocks in the building construction.

This research is aimed to experimentally investigate the properties of lateritic brick blended with rice husk ash for the production of low-cost eco-friendly Blocks. Thermal properties of the Blocks also have to be investigated. The use of such local materials in construction increases self-sufficiency, lowers construction costs, and speeds up the achievement of sustainable development, particularly in developing countries with abundant local materials. In addition, the use of Lateritic brick has so far been neglected due to its lower strength and durability. In dealing with these challenges, rice husk ash which is an abundant agricultural waste will be used in addition to the lateritic material in brick making. The combined use of these materials in construction of houses will ensure an economic use of the waste while reducing its effect on environment.

II. MATERIALS AND METHODS

The laterite used in this research was collected from the Janguza borrow pit in Kano, Nigeria. Rice Husk was sourced from Kano State in Nigeria. The Rice Husk was thoroughly washed with water to remove stones and other solid debris. Rice husk was air-dried at room temperature for a week and then burnt to collect the RHA. The rice husk was burnt in a furnace at 750 ºC. The resulting Rice Husk Ash (RHA) is allowed to cool down and sieved through BS sieve size 75µm and its color was grey. Figure 1 presents the schematic diagram illustrating the production process from rice plant to RHA. X-ray fluorescence (XRF) analysis was performed to obtain the chemical and oxide composition of the Rice Husk Ash (RHA). The chemical compositions of RHA as measured by X-ray fluorescence (XRF) are presented in **Table 1**. The time frame of the burning process, the temperature at which it occurs, and the rate and duration of cooling all have an impact on the quantity and kind of silica, carbon, and LOI in RHA. These factors also have an impact on the material's physical and chemical characteristics [11, 12].

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Table 1. Oxide composition of RHA.

Oxides	Weight (%)
SiO_2	80.722
Al_2O_3	2.363
P_2O_5	8.109
Fe_2O_3	1.103
CaO	1.394
MgO	2.721
SO_3	0.675
K_2O	2.341
MnO	0.233
Na_2O	0.056
Others	0.283

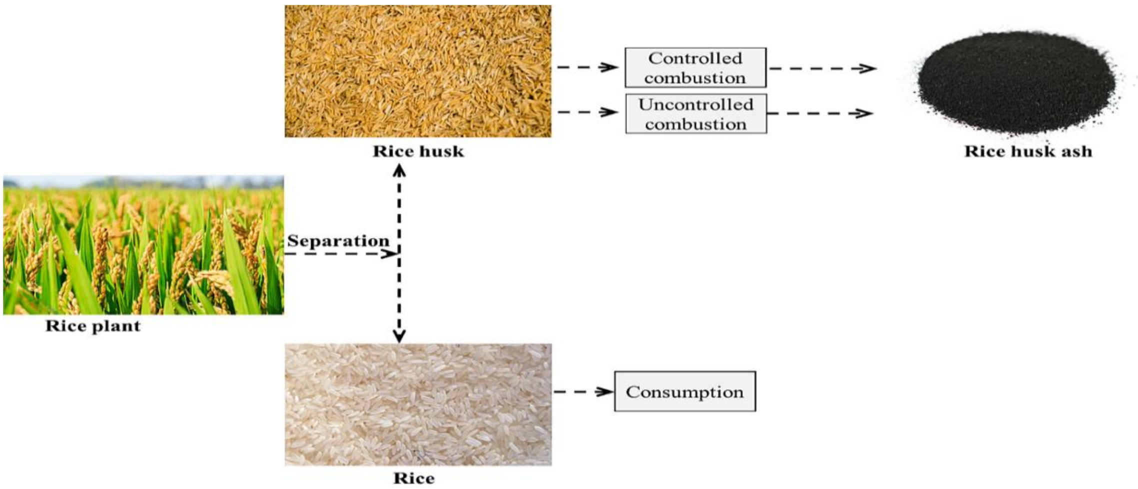

Fig. 1 Visual, representation of the production of rice husk ash [12].

The distribution of laterite particles used is shown in Figure 2. It shows from Figure 3 that the coarse to fine laterite comprise of about 58 %, coarse to fine gravels is 40 %. While the fines are around 2 % of the laterite used. The particle size distributions provide a good gradation for lateritic soil used for the block making.

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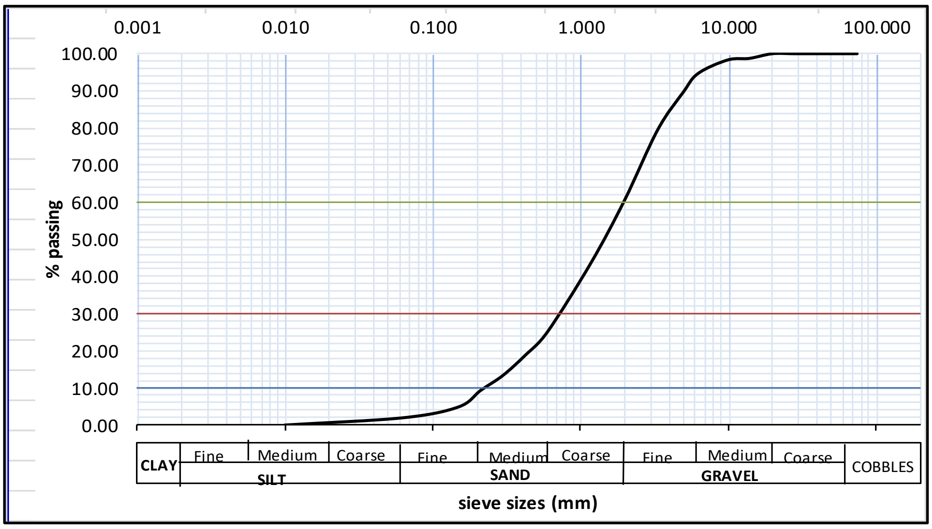

Fig. 2 Particle size distribution of the laterite.

III. MIX DESIGN AND BLOCK PREPARATION

Table 2 shows the proportions of the raw material combination. The control sample is a sample without RHA in it. The percentage RHA added in to the block mix was 0, 2, 4, 6, 8 and 10 % respectively. Laterite block samples were cast and cured at ambient temperature for 28 days before testing. To produce the block the laterite was dry mixed with RHA for about 5 minutes, then water was added to the dry mixture and continue mixing for another 5 minutes until consistent mixture was reached. The fresh mixture was then placed in the mould of size 235 mm x 115 mm x 100 mm and compressed with the aid of the block machine as shown in Figure 3. Typical samples of the produced lateritic blocks are shown in Figure 4. The block specimens were then dried for 28 days and tested.

Fig. 3 Laterite block machine

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Fig. 4 Laterite block samples.

Table 2. Mix proportions of lateritic blocks.

Mixtures ID	Laterite (%)	RHA (%)
Control	100	0
LR2	100	2
LR4	100	4
LR6	100	6
LR8	100	8
LR10	100	10

IV. RESULTS AND DISCUSSIONS

A) Compressive strength

One of the key variables in quality control and one of the most significant mechanical characteristics of construction Blocks is compressive strength. The strength of laterite RHA-laterite block was determined by testing the compressive strength of the blocks after for 28 days of ambient curing. Figure 5 shows the compressive strength against percentage RHA replacement. As demonstrated in Figure 4, the compressive strength of RHA-Laterite block increase with increase in RHA up to 8 %. The compressive strength of the 2% RHA, 4% RHA, 6% RHA, 8% RHA and 10% RHA increased by 10.8 %, 26 %, 44.1 %, 67.6 % and 27.9 % compared with the control mixture. It is interesting to note that the presence of RHA filled the pores inside the blocks filled over time, thereby producing a more dense and compact blocks. likewise, a higher percentage of RHA beyond 8 % affects the mixture's rheology, thus, producing a non-homogeneous mixture that has a negative effect on the compressive strength. It was consistent with earlier research finding of Hwang and Huynh [13]. The strength of the block deteriorated beyond 8% of RHA. It is worth noting that even though the strength reduces at 10% RHA addition, it is still better than the control mixture. Thus, the optimum value of percentage RHA replacement was found to be 8%.

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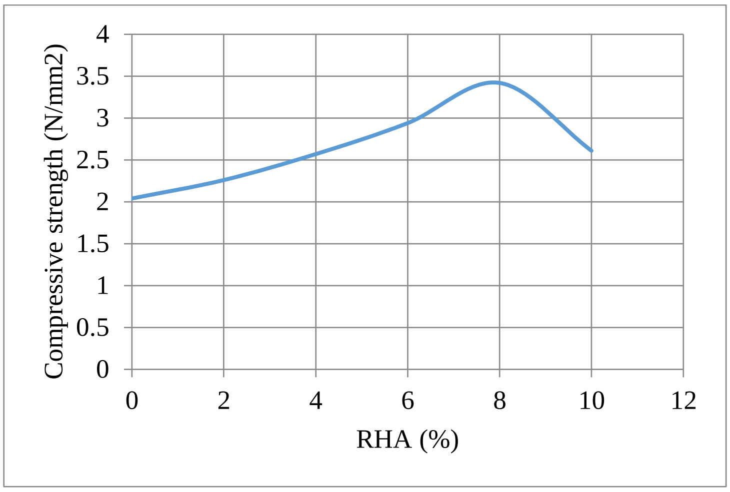

Fig. 5 Compressive strength of RHA-blended blocks

B) Residual compressive strength after fire exposure

Compressive strength test was performed to ascertain the resistance of the RHA-Laterite block to fire. The lateritic block samples were tested in a furnace at 100˚C, 200˚C and 400˚C for 1 hour. The result shows that high temperature decreases the strength of the blocks. The optimum value of the RHA replacement was obtained at 8% for all the elevated temperatures considered as shown in Figure 6. The compressive strength of mix containing 8% RHA reduces by 21.6 %, 45.9 %, and 76.9 % at 100˚C, 200˚C, and 400˚C respectively. For LR10 mix, the decline in strength observed was 24.5%, 46.1 %, and 91.9 %. It was observed that for all the mixes considered (0%, 2, 4, 6, 8, and 10 % RHA), the strength loss is much more pronounced at higher temperatures. The significant reduction in strength could be attributed to the loss of plasticity and porosity of the lateritic material at elevated temperature. It is worth to mention that at 400˚C, the compressive strength loss of more than 70 % was observed for all the mixtures.

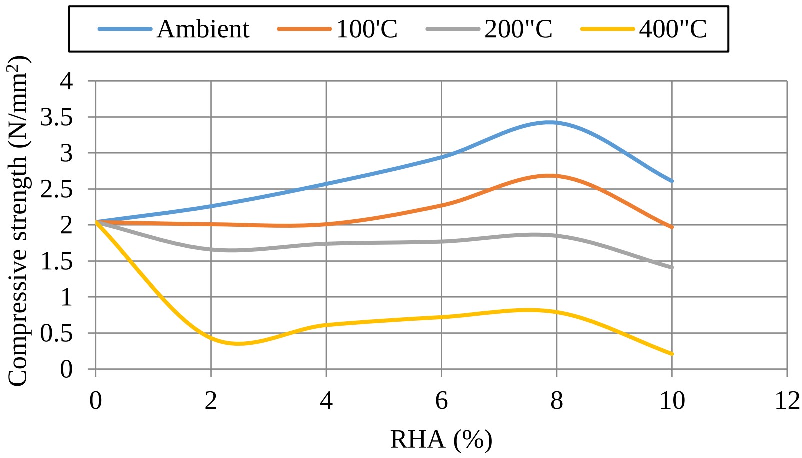

Fig. 6 compressive strength against %RHA at elevated temperature

C) SEM microstructural analysis

Figure 7 displays SEM pictures of a few specimens of geopolymer paste. The microstructure of the lateritic block specimens was determined using scanning electron microscope. The images presented are for 0%, 2% and 8% addition of RHA. Compared to control brick samples, LR0 and LR2 brick samples had increased porosity. Brick sample produced with 8% RHA exhibits a uniform and dense microstructure as shown in Figure 7(c). Figure 7(a) shows the micrograph of the control block consisting of only laterite. In the brick samples with 2% and 8% RHA, a significant quantity of irregularly shaped and linked pores is also apparent. The compressive strength of the brick samples examined in this study is supported by the SEM pictures.

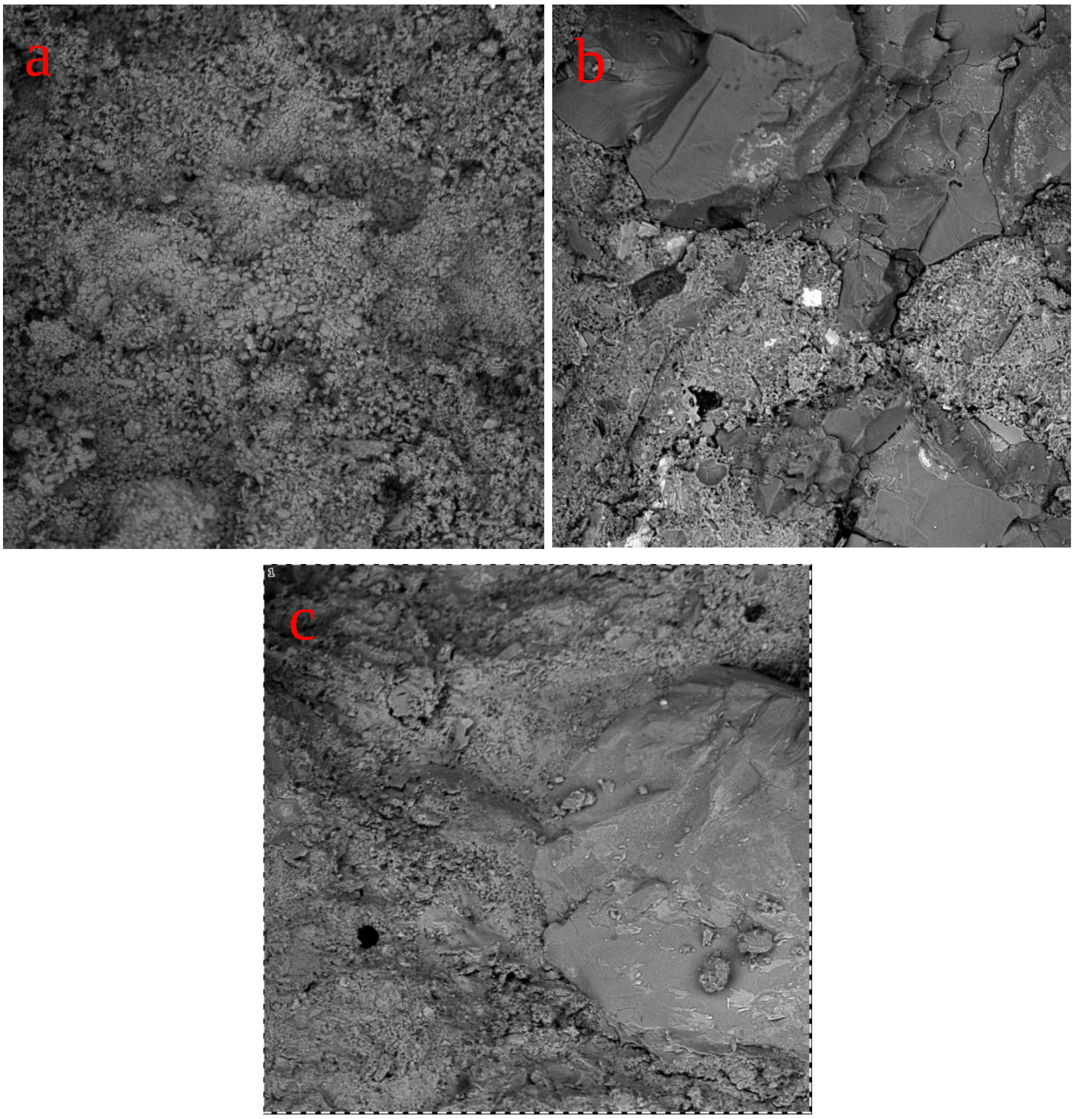

Fig. 7 SEM micrograph of block samples (a) control (b) LR2 (c) LR8

V. CONCLUSION

This research leverages on the availability of lateritic soils and its traditional application in building across the urban and rural areas to produce RHA-Lateritic Blocks that could be used in low-cost housing. Based on the findings of this research, the following conclusions can be drawn:

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1. The compressive strength of RHA-Laterite block increase with increase in RHA up to 8 %. However, a higher percentage of RHA beyond 8 % decrease the compressive strength. The compressive strength increased by 10.8 %, 26 %, 44.1 %, 67.6 % and 27.9 % compared with the control mixture.
2. The result shows that high temperature decreases the strength of the blocks. The optimum value of the RHA replacement was obtained at 8% for all the elevated temperatures.
3. The cementitious properties of RHA may promote its usage in Lateritic brick there by supplementing additional binding effect within the Lateritic brick material and as such reduces its devastating effect on the environment.
4. Microstructural examination revealed that brick sample produced with 8% RHA exhibits a uniform and dense microstructure, thus, resulting in a higher strength.

VI. ACKNOWLEDGMENTS

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