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TREATMENT OF CLAY WITH OIL PALM FIBRE ASH AND RICE HUSK ASH MIXTURE FOR BURNT CLAY BRICKS PRODUCTION

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ABSTRACT: *The current study examines the use of oil palm fibre ash (OPFA) and rice husk ash (RHA) mixture in the treatment of A-6 Makurdi clay for burnt brick production. The results show that the compressive strength of 9.4 MN/m^2 for burnt untreated brick increased to 10.86 MN/m^2 for burnt 2%OPFA+2%RHA treated brick. The corresponding water absorption of 14.9% for the burnt untreated brick increased to 16.2% for burnt 2%OPFA+2%RHA treated brick. The strength value of 10.86 MN/m^2 is greater than 10.3 MN/m^2 which is the minimum strength value for negligible weather (NW) conditions. The water absorption of 16.2% is less than 17%, 22% and 'no limit' which are the maximum values for severe weather (SW), moderate weather (MW) and NW respectively. Based on combined strength and water absorption criteria, burnt bricks production with 2%OPFA+2%RHA treated A-6 Makurdi clay is adequate for use as a load-bearing brick in wall areas of NW condition.*

KEYWORDS: Burnt clay bricks, oil palm fibre ash, rice husk ash, compressive strength, water absorption.

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INTRODUCTION

There is an increasing cost of primary stabilizers (cement and lime) used in brick production (Ogunbiyi *et al*., 2014; Olutoge *et al*., 2018). Also, the production of cement and lime in itself generates high CO_2 emissions (Rubenstein, 2012; Stork *et al*., 2014). Mitigating the effects of increasing CO_2 and other greenhouse gases is another concern for the geotechnical engineers. In an attempt to provide cheaper walling bricks for affordable houses in growing population of developing nations, the use of cheaper and low CO_2 waste materials in bricks production is encouraged.

Previous studies have been conducted on the use of waste materials in burnt brick production. Some studies on burnt clay bricks made with rice husk ash (RHA) or oil palm fibre ash (OPFA) are presented in Table 1. Throughout this study, OPFA and palm oil fuel ash (POFA) are considered the same, since it refers to the same material. From Table 1, increased compressive strength of the burnt bricks has been achieved with low waste (OPFA or RHA) additions mainly between 1% and 2%. Higher additions of waste greater than 5% for OPFA or 4% for RHA resulted in decreased compressive strength (Kadir *et al*., 2017; Agbede & Joel, 2011). Also, higher water absorption has been reported in burnt bricks made with either OPFA or RHA than in the corresponding burnt untreated bricks. Although different studies on the treatment of clay with OPFA or RHA for burnt bricks production have been reported, the combined OPFA and RHA treatment of clay for burnt clay bricks production is lacking, therefore necessitating the current study.

The standard of burnt bricks for use in building construction has been established by ASTM C62-99 (2012). Some requirements are based on compressive strength and water absorption. The minimum compressive strength required for an average of 5 bricks in structural masonry work are: 20.7 MN/m^2, 17.2 MN/m^2 and 10.3 MN/m^2 for Grade severe weather (SW), minimum weather (MW) and negligible weather (NW) respectively. Also, the maximum water absorption requirements for an average of 5 bricks are 17%, 22% and 'no limit' for SW, MW and NW respectively.

Table 1: Previous studies on burnt clay bricks made with oil palm fibre ash or rice husk ash

Author	Topic	Waste and soil	Some improved properties
Kadir *et al*. (2017)	Study on fired clay bricks by replacing clay with palm oil waste (POFA): effects on physical and mechanical properties	POFA and clay from Yong Peng, Johor, Malaysia. The clay was treated with 0%, 1%, 5% and 10% POFA for burnt bricks production	The compressive strength of 20 MPa for fired untreated clay bricks increased to a peak value of 22.5 MPa for fired 1% OPFA treated clay brick. The corresponding water absorption of 12.9% for fired untreated clay bricks increased to 14.1% for fired 1% treated clay brick.
Djamaluddin *et al*. (2020)	Fired clay bricks incorporating palm oil fuel ash (POFA) as a sustainable	POFA and clay in Makassar, Indonesia. The clay was treated with 0%, 5%,	The compressive strength of 8.2 N/mm^2 for fired untreated clay bricks was reduced to 7.13 N/mm^2 for fired 5% POFA treated clay bricks, which is the highest strength in treated fired clay

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	building material: an industrial-scale experiment	10%, 15% and 20% POFA for brick production	bricks. The corresponding water absorption of 19% for fired untreated clay brick increased to 23% for fired 5% treated clay bricks
Agbede & Joel (2011)	Effect of rice husk ash (RHA) on the properties of Ibaji burnt clay bricks	RHA and Ibaji clay from Kogi State, Nigeria. The clay was treated with 0%-10%RHA at 2% RHA intervals for burnt bricks production	The compressive strength value of 17.60 MN/m^2 for burnt untreated clay bricks increased to a peak value of 18.64 MN/m^2 for burnt 2%RHA treated clay brick. The corresponding water absorption value of 16.8% for burnt untreated clay bricks was reduced to 14.8% for burnt 2%RHA treated clay bricks.
Khoo *et al*. (2013)	Influence of rice husk ash (RHA) on the engineering properties of fired-clay brick	RHA and clay supplied by Toh Hai Pin & Co. Butterworth, Malaysia. The clay was treated with 0%, 5%, 10%, 15%, 20% and 25% RHA for fired brick production	The compressive strength of 58.56 MN/m^2 for fired untreated sand-clay bricks decreased with RHA additions. At 15% RHA additions, the compressive strength of 28 MN/m^2 was achieved. The water absorption of 9.036% for fired untreated sand-clay bricks increased to 19.1% for fired 15% RHA-treated sand-clay bricks.
Kazmi *et al*. (2016)	Manufacturing of sustainable clay bricks: utilization of waste sugarcane bagasse (SBA) and rice husk ashes (RHA)	RHA or SBA and clay from Mirpur Azad Kashmir, Pakistan. As part of the study, the clay was treated with 0%, 5%, 10% and 15% RHA for brick production	The compressive strength of 8.4 MPa for burnt untreated clay brick was reduced to the strength value of 6.62 MPa for burnt 5%RHA treated clay brick. The corresponding water absorption of 17% for burnt untreated clay brick increased to 18% for burnt 5% RHA treated clay brick.

MATERIALS AND METHODS

Materials

The OPFA used in this study was obtained as follows: oil palm fibres were collected from Otukpo, Benue State Nigeria. It was burnt into ashes in an oven at the temperature of 800^{o}C to form OPFA. The OPFA passing through sieve No. 200 with a 0.075 mm aperture was used for the study in accordance with ASTM C311-11 (1994). RHA was obtained by incinerating rice husk at a temperature of 800 ^{o}C in an oven. The rice husk was collected from a heap of rice husk at Wurukum rice mill, Makurdi Benue State, Nigeria. The Makurdi clay used was

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collected from a pit 1.2 m deep at Uga Soja village, opposite Air Force Base in Makurdi, Benue State, Nigeria. Uga Soja is situated in Makurdi local government area, near the bank of River Benue at 2.9 km Northwards from Makurdi Airport Junction along Makurdi-Gboko Road. It is located on 7^{0}43’6.2’’N and 8^{o}36’56’’E on the geographical map of Nigeria (Makurdi, Wikipedia, 2022).

Methods

Geotechnical properties

The Makurdi clay was treated with 0%, 2%, 4% and 6% (by weight) each of OPFA and RHA as presented in Table 2. To determine Atterberg limits and shrinkage limit, plastic limit (PL), liquid limit (LL) and shrinkage limit were performed on untreated and OPFA-RHA treated Makurdi clay in accordance with ASTM D4318-10 (1994). The liquid limit test was determined using the Casagrande apparatus, while the PL test was performed using the PL equipment in accordance with ASTM D4318-10 (2010).

To determine optimum moisture content (OMC) and maximum dry density (MDD) of untreated and OPFA-RHA treated Makurdi clay, compaction was conducted using the standard Proctor compaction energy level. This involves a 2.5 kg rammer falling through 30 cm on three layers in the compaction mould with a 101.6 mm diameter and a height of 116.43 mm, each receiving 25 uniformly distributed blows in accordance with ASTM D698-12 (2021).

Table 2: Mix ratios of oil palm fibre ash plus rice husk ash for burnt clay bricks production

		RHA (%)			
	RHA OPFA	0% RHA	2% RHA	4% RHA	6% RHA
OPFA (%)	0%OPFA	✓	✓	✓	✓
	2% OPFA	✓	✓	✓	✓
	4% OPFA	✓	✓	✓	✓
	6% OPFA	✓	✓	✓	✓

Note: OPFA = Oil palm fibre ash, RHA = Rice husk ash, ✓ represents mix ratio used.

To prepare clay bricks, the clay was treated with 0%, 2%, 4% and 6% each of OPFA and RHA as shown in Table 2. The choice of 6% as the highest content of OPFA and RHA was due to the previous report which showed in separate studies that lower content of OPFA (1%) treated clay for burnt brick production resulted in peak compressive strength, while higher content of OPFA from 5% resulted in lower compressive strength (Kadir *et al*. 2017). Similarly, treatment of clay with lower RHA content (2%) for burnt bricks production resulted in higher compressive strength, while higher RHA content from 4% resulted in lower compressive strength (Agbede & Joel, 2011).

The untreated and OPFA+RHA treated clay was moulded each with a dimension of 200 mm x 100 mm x 100 mm in a cast iron mould cavity. The choice of the brick dimension was due to the size commonly available in the study locality (ASTM C62-99, 2012). A plywood sheet of 200 mm by 100 mm by 12·5 mm was placed on the soil in the mould and compacted in

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accordance with ASTM D698-12 (2021) to attain even distribution of energy in the mould. The compaction was achieved with a compression machine using 15 MN/m^2 pressure. The moulded brick was extruded by loosening the mould and the brick was removed. For each mixing ratio, five bricks were prepared. The bricks were cured/dried at room temperature (27 ^{0}C ± 2) for 14 days prior to firing.

The firing was performed in an electric furnace at 800 ^{0}C. This temperature was selected due to its preference for brick production (Agbede & Joel, 2011; Cultrone *et al*., 2020). Thereafter, the burnt bricks were preconditioned by immersion in cold water at room temperature (27 ^{o}C ± 2 ^{o}C) for 24 hours. The bricks were removed and all traces of water were wiped off, then stored under moist conditions for 24 hours for strength testing.

To determine the strength of the brick, the compressive strength of each brick was measured using the Testing Machine for Compressive Strength blocks in accordance with the specification of the Nigerian Industrial Standard (NIS 87, 2000). Each brick specimen was centrally positioned between the platens of the testing machine and the load was gradually increased until failure.

The durability of the bricks in the water environment was determined by the water absorption method in accordance with the Nigerian Industrial Standard (NIS 87, 2000). Five burnt bricks per mix ratio (Table 2) were used and their average result was considered the water absorption for the mix ratio. Prior to the durability assessment, the bricks were preconditioned by drying in a ventilated oven at 10^{o}C until they attained constant mass, then cooled to room temperature and weighed to note their initial weight Mi. The burnt bricks were immersed in cold water at room temperature (27^{o}C ± 2^{o}C) for 24 hours, thereafter traces of water were wiped off. Then, the bricks were weighed to note their final weight of Mf. The water absorption defined as the relative increase in brick weight between the initial and its final weight, with respect to initial weight was determined.

Mineralogical testing

To qualitatively determine the microstructural changes in the matrix of the bricks specimens, scanning electron microscopy **(**SEM) analysis was conducted on polished sections of burnt untreated and 2%OPFA+2%RHA treated clay bricks. The burnt untreated clay brick was selected to represent the control sample, while the burnt 2%OPFA+2%RHA treated clay brick represented the brick with the highest compressive strength.

SEM was conducted using the JOEL-JSM 7600F model. An energy dispersion X-ray spectrometer (EDX) was attached to the SEM to ascertain the changes in chemical composition owing to the treatment. Point elemental analysis was performed on the crystal grains within the sample using Rontec Quantax EDX to determine mineral elements.

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RESULTS AND DISCUSSION

Chemical Composition

The chemical composition of Makurdi clay, RHA and OPFA is presented in Table 3. The major contents of Makurdi clay are SiO_2 (51.29%), Al_2O_3 (24.30%), Fe_2O_3 (15.43%), K_2O (3.33%). For RHA, its main composition are SiO_2 (45.14%), CaO (22%), K_2O (6.65%), Al_2O_3 (3.95%), while for OPFA the dominant oxides are SiO_2 (28.40%), CaO (16.8%), K_2O (19.60%), SO_3 (7.95%), P_2O_5(6.41%). From Table 3, the high presence of CaO (22%) in RHA is greater than 20 %, thus an indication that RHA is a material with high reactivity and cementitious properties (Menendez *et al*., 2021). The low content of CaO (16.80%) in OPFA which is less than 20 %, indicates a material with low reactivity and cementitious properties (Menendez *et al*., 2021).

Table 3: Chemical composition of Makurdi clay, sawdust ash, and rice husk ash

Element	Makurdi clay (%)	RHA (%)	OPFA (%)
SiO_2	51.29	45.14	28.40
MnO	0.32	0.21	0.26
Fe_2O_3	15.43	3.37	5.30
P_2O_5	0.00	3.42	6.41
SO_3	0.07	3.23	7.95
CaO	0.41	22.00	16.80
MgO	0.00	0.00	-
K_2O	3.33	6.65	19.60
BaO	0.21	0.16	-
Al_2O_3	24.30	3.95	-
TiO_2	3.12	1.29	2.06
ZnO	0.03	0.20	0.17
Cl	0.81	1.45	5.59
Others	0.68	8.93	0.46
LOI		8.3	7.0

Note: RHA = Rice husk ash, OPFA=Oil palm fibre ash

Index Properties

The index properties of Makurdi clay, rice husk ash and oil palm fibre ash is presented in Table 4. Also, the particle size distribution of Makurdi shale is presented in Figure 1. The results of Atterberg limits for OPFA-RHA treated Makurdi clay are presented in Table 5. The Makurdi soil used in this study is classified as A-6 and CL based on AASHTO and USCS classifications respectively (ASTM, 1992; USCS, 1962).

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Table 4: Index properties of Makurdi clay, sawdust ash and rice husk ash

Index properties	Value
Percentage passing BS sieve No. 200	42.00
Liquid limit (%)	39.0
Plastic limit (%)	21.0
Plasticity index (%)	18.2
Linear shrinkage (%)	10.71
Maximum dry density (Mg/m^3)	1.45
Optimum moisture content (%)	23
Specific gravity (G_s) of clay	2.41
G_s of oil palm fibre ash	2.00
G_s of rice husk ash	2.05
AASHTO classification	A-6
USCS classification	CL

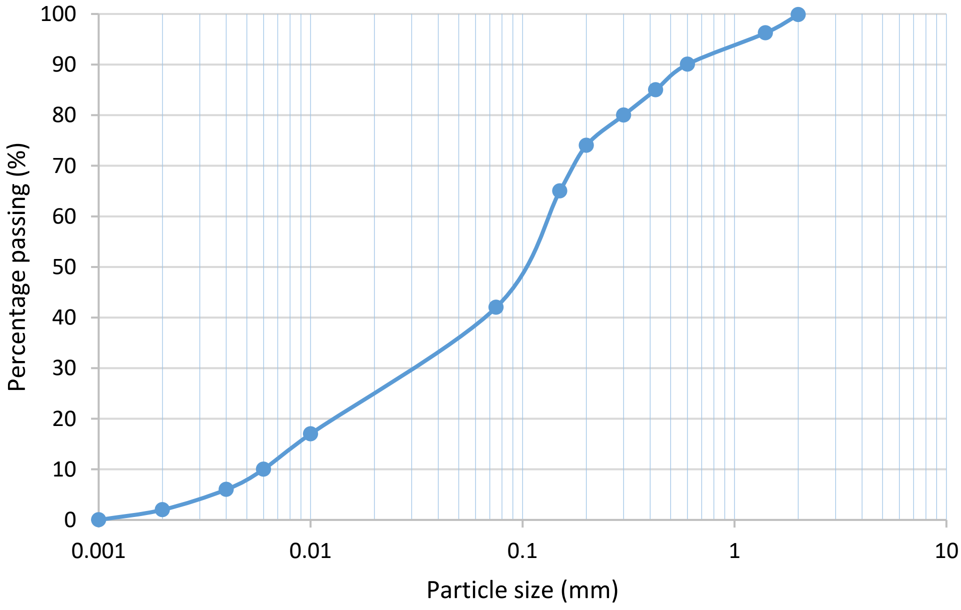

Figure 1: Particle size distribution of Makurdi clay.

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Table 5: Atterberg limits results of OPFA-RHA treated clay

OPFA (%)		0	2	4	6
0 % RHA	LL (%)	39	41	41	40
	PL (%)	21	23.6	24	24
	PI(%)	18	17.4	17	16
	LS (%)	10.71	10.5	10.2	9.4
2 % RHA	LL (%)	40.2	40	41	41
	PL (%)	22	23	24.6	25
	PI (%)	18	17	16	16
	LS (%)	10.21	10	9.6	9.3
4 % RHA	LL (%)	41.4	40	41	40
	PL (%)	23	24	25	25.3
	PI (%)	17	16	16	15
	LS (%)	10	9.7	9.4	9
6 % RHA	LL (%)	41	39.5	41	40
	PL (%)	23	24.4	26	26
	PI (%)	17	15.1	15	14
	LS (%)	9	8.6	8.4	8.1

Compaction Characteristics of OPFA+RHA Treated Makurdi Clay

The results of OMC and MDD for OPFA+RHA treated Makurdi clay are presented in Figures 2 and 3 respectively. The results show that the OMC increased with OPFA+RHA additions, while that of MDD decreased with OPFA-RHA additions.

The increase in OMC with OPFA+RHA additions could be due to the additional water required for hydration of OPFA and RHA. The decrease in MDD with OPFA-RHA additions could be due to flocculation and agglomeration of OPFA-RHA and clay mixture. This could have resulted from cation exchange between calcium ions (released from OPFA+RHA) with metal ions associated with the clay lattice. The OPFA+RHA clay agglomerates could occupy larger spaces and form higher voids content than those of the corresponding untreated (0%OPFA+0%RHA) clay. This could lead to the reduction of the mass-to-volume ratio, hence a decrease in dry densities (Vitale *et al*., 2020). The decrease in MDD with OPFA+RHA additions is similar to the decrease in MDD with OPFA-treated clay in the study by Kadir *et al*. (2017) and Djamaluddin *et al*. (2020).

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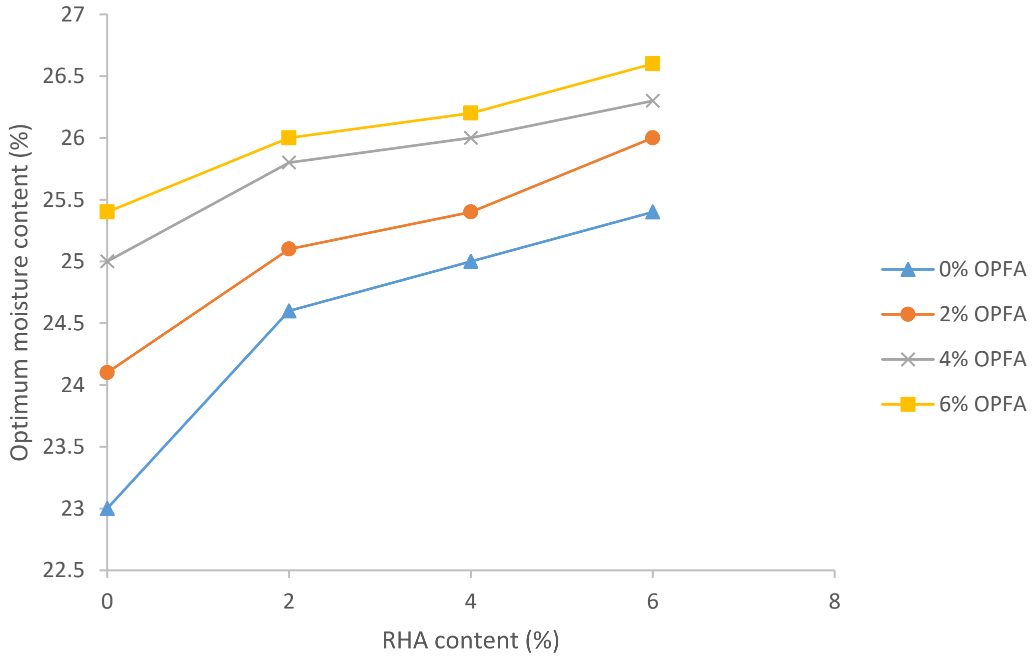

Figure 2: Variation of optimum moisture content with OPFA+RHA treated Makurdi clay. OPFA = Oil palm fibre ash, RHA = Rice Husk Ash.

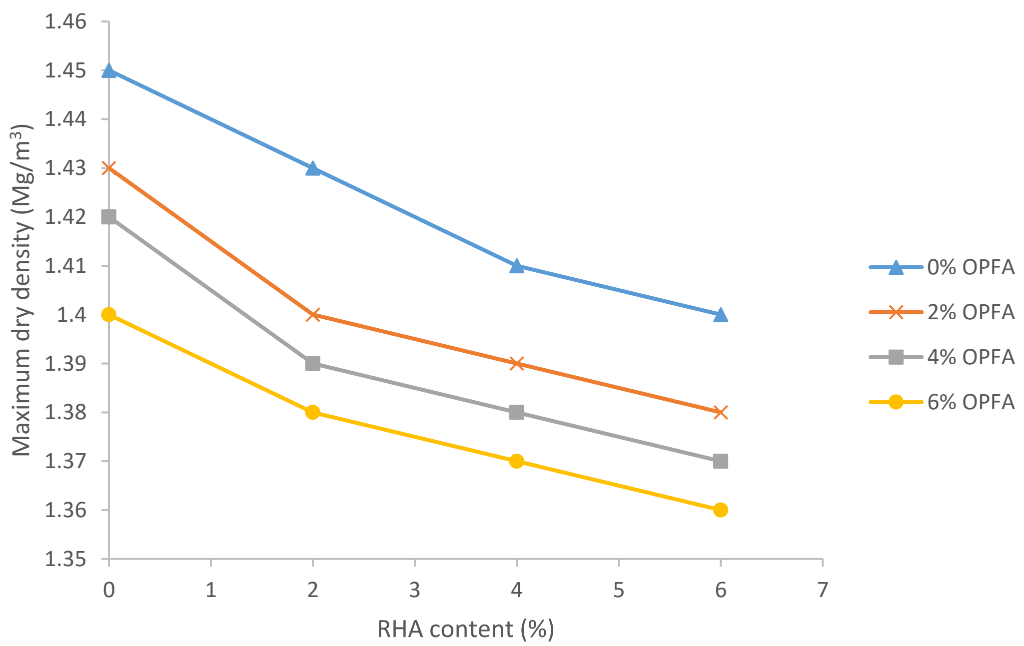

Figure 3: Variation of maximum dry density with OPFA+RHA treated Makurdi clay. Note: OPFA = Oil palm fibre ash, RHA = Rice husk ash

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Strength Development

The strength development of burnt untreated and OPFA+RHA treated clay bricks are presented in Figure 4. The compressive strength of 9.4 MN/m^2 for burnt untreated clay bricks increased to a peak value of 10.86 MN/m^2 for burnt 2%OPFA+2%RHA treated burnt clay bricks. However, higher additions of OPFA+RHA above 2%OPFA+2%RHA resulted in a strong reduction of the burnt bricks.

The peak strength of burnt clay bricks at low OPFA+RHA treatment is similar to that of a previous study on OPFA or RHA-treated clay brick. The study of burnt clay brick treated with 0%, 1%, 5% and 10% OPFA by Kadir *et al*. (2017) reported a peak compressive strength of 22.5 MPa at 1% OPFA treatment. Similarly, the study of burnt clay brick treated with 0%-10%RHA at 2% RHA intervals by Agbede & Joel (2011) found a peak strength of 18.64 MN/m^2 at 2%RHA treatment.

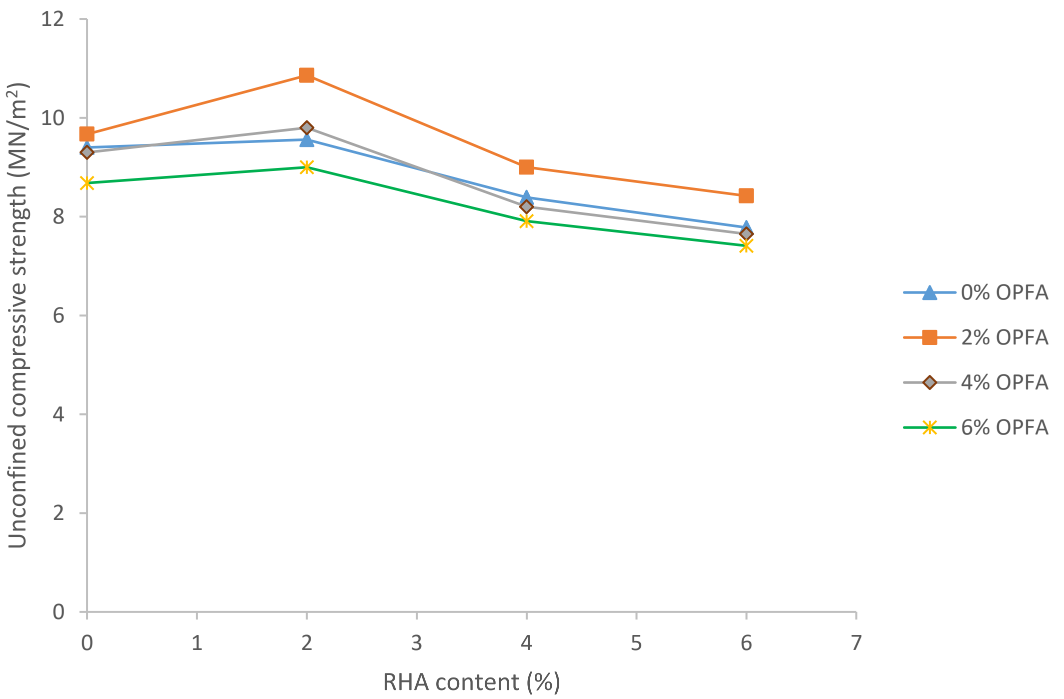

Figure 4: Compressive strength in burnt OPFA+RHA treated clay brick.

Note: OPFA=Oil palm fibre ash, RHA=Rice husk ash.

The increase in strength with OPFA and RHA additions could be due to the possible formation of calcium silicate hydrate (CSH) and calcium aluminate hydrate (CAH). This is expected owing to CaO content of 22% and 16.8% in RHA and OPFA respectively, which could react with Silica (51.29%) and alumina (24.30%) from the clay (Table 3) to form CSH and CAH respectively. This is further discussed in SEM Section 3.6. The peak strength at lower OPFA+RHA additions could be due to $SiO_2 + Al_2O_3$ content threshold, beyond which the

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content remains unreactive and undesirable. Previous studies showed that higher $SiO_2 + Al_2O_3$ content beyond 3.8% in burnt clay bricks could produce unreacted materials. Consequently, produces larger porosity of the brick leading to a looser brick structure (Hwang & Huynh, 2015; De Silva & Crenstil, 2008).

Strength property is one of the major criteria for bricks assessment and its suitability as a walling material in building structures. In the current study, the highest compressive strength of 10.86 MN/m^2 for burnt 2%OPFA+2%RHA treated clay bricks is higher than 10.3 MN/m^2 which is the minimum value for load-bearing brick walls in grade negligible weather (ASTM C62-99, 2012). Based on strength requirements, burnt Makurdi clay bricks treated with 2%OPFA+2%RHA is suitable for use as a load-bearing brick in walls of Grade NW condition.

Water Absorption

The results showing the effect of OPFA+RHA addition on the water absorption of burnt clay bricks is presented in Figure 5. The water absorption of the clay bricks increased with both OPFA and RHA additions. For example, the water absorption of 14.9% for burnt untreated clay bricks increased to the maximum value of 19.7% for burnt 6%OPFA+6%RHA treated clay bricks. The water absorption of 16.4% was observed in burnt 2%OPFA+2%RHA treated clay brick, which is the brick with the highest compressive strength.

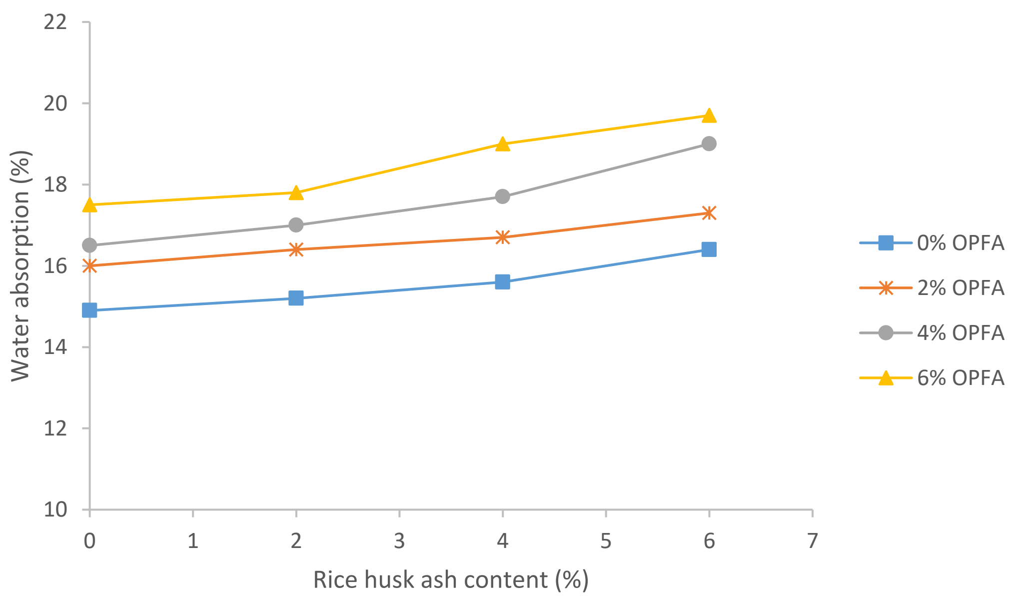

Figure 5: Water Absorption in burnt OPFA+RHA treated clay brick.

The results of increased water absorption in burnt clay brick with OPFA+RHA additions are similar to the previous study of burnt clay brick treated with OPFA by Kadir *et al*. (2017). The study showed that water absorption of 12.8% for burnt untreated brick increased to 17% for burnt 10%OPFA treated clay bricks. Similarly, the study on burnt RHA-treated clay bricks by Agbede & Joel (2011) reported the water absorption of 16.8% for burnt untreated clay bricks, which increased to a value of 19% for burnt 10% RHA-treated clay bricks.

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Water absorption is another important property for bricks assessment (ASTM C62–99, 2012). Water absorption determines the durability of bricks in the water environment. In the current study, water absorption of 16.4% was found in the burnt bricks (2%OPFA+2%RHA treated clay bricks) with the highest compressive strength. This water absorption is lower than 17%, 22% and 'no limit' which is the maximum required water absorption for SW, MW and NW respectively. Based on water absorption requirements, burnt 2%OPFA+2%RHA treated clay bricks is adequate for SW, MW and NW weather condition.

Scanning Electron Microscopy Analysis

The SEM micrographs from polished sections of burnt untreated and 2%OPFA+2%RHA treated clay bricks are presented in Figures 6a-b. As earlier stated, untreated burnt clay brick was selected to represent the control sample, while the burnt 2%OPFA+2%RHA treated clay brick represented the brick with the highest compressive strength. The corresponding EDX results of point elemental analysis on the bricks are also contained in Figures 6a-b.

The EDX results of burnt untreated clay brick (Figure 6a) show mainly the presence of Si (71%), O (11.74%), C (5.22%), and Al (4.33%), while the least element is Ca (0.05%). Similarly, the EDX results of burnt 2%OPFA+2%RHA treated clay brick (Figure 6b) show the presence of Si (73.03%), O (10.97%), Mg (3.76%), C (2.78%), Al (2.76%), Fe (2.69%), Ca (1.53%). The high composition of silica, oxygen and alumina in both burnt untreated and 2%OPFA+2%RHA treated clay brick is an indication of the presence of the clay. There is a remarkable increase in the Ca (1.53%) and Mg (3.76%) content in burnt 2%OPFA+2%RHA treated brick compared to the content in burnt untreated brick which is Ca (0.05%) and Mg (1.87%). The remarkable content of Ca, Si and Al in burnt 2%OPFA+2%RHA treated brick suggests the presence of cementitious compounds such as CSH and CAH (Bye, 2011). The formation of cementitious products in treated soil usually contributes to the increase in the internal friction and shear strength of the soil (Solanki & Zaman, 2012).

The remarkable presence of Ca, Si and Al in burnt 2%OPFA+2%RHA treated clay brick is consistent with the strength increase in the same brick (Section 3.4).

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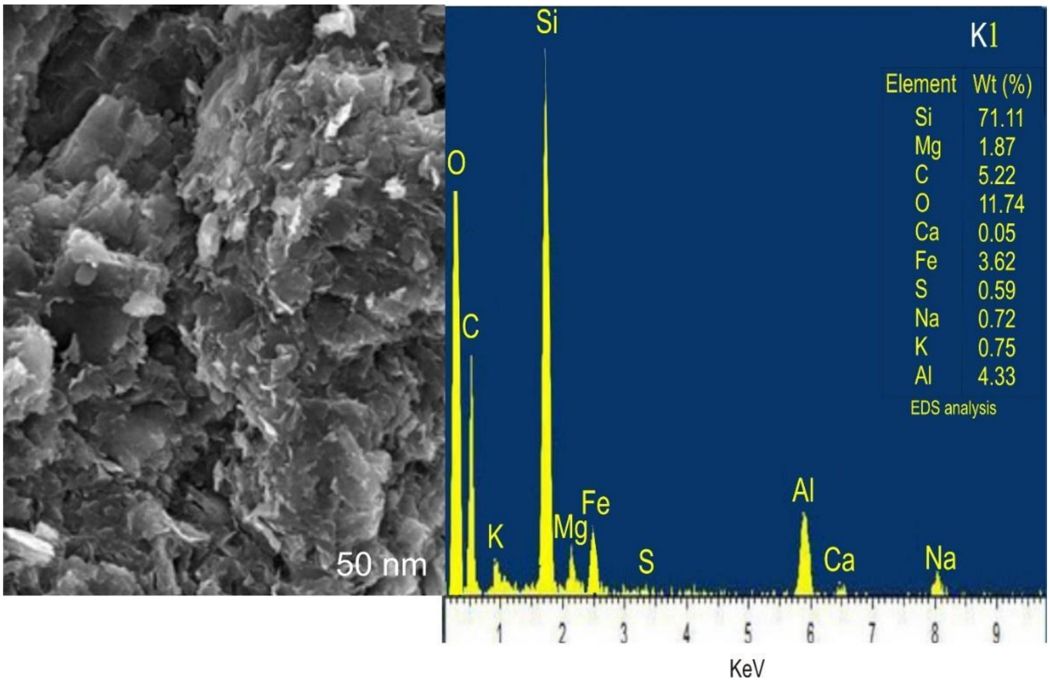
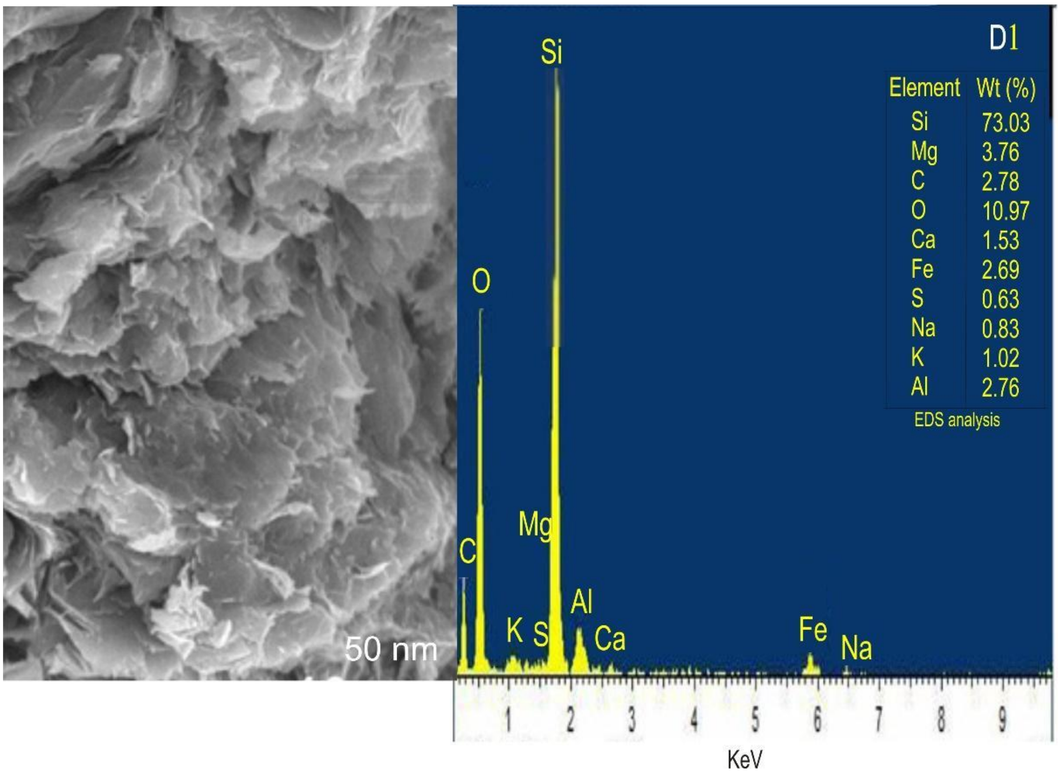


(a)



(b)

Figure 6: SEM Micrographs and corresponding EDX results of burnt brick (a) untreated burnt clay brick (b) 2%OPFA+2%RHA treated clay brick.

SEM = Scanning electron microscopy, EDX = Energy dispersion X-ray spectrometer.

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From the SEM micrograph (Figure 6a-b), there is no remarkable difference between burnt untreated and 2%OPFA+2%RHA treated clay brick. This could be due to the small composition of Ca (1.53%) in the EDX results of burnt 2%OPFA+2%RHA treated clay brick, and subsequent small formation of cementitious compounds of CSH and CAH.

CONCLUSIONS

The current study examined the effect of treating Makurdi clay with OPFA and RHA mixture for burnt bricks production. Based on the study, the following conclusions can be drawn:

- Makurdi clay used for bricks production in the current study is classified as A-6 and CL based on AASHTO and USCS classifications respectively (ASTM, 1992; USCS, 1962).
- The addition of 2%OPFA+2%RHA to A-6 Makurdi clay for burnt brick production resulted in a compressive strength increase. The compressive strength of 9.4 MN/m^2 for burnt untreated brick increased to a peak value of 10.86 MN/m^2 for burnt 2%OPFA+2%RHA treated clay brick.
- The compressive strength of 10.86 MN/m^2 for burnt 2%OPFA+2%RHA treated clay brick is greater than 10.3 MN/m^2, which is the minimum strength value for NW condition. Thus adequate for load-bearing brick walls in Grade NW condition.
- The water absorption value of 14.9% for burnt untreated clay brick increased to a value of 16.40 MN/m^2 for burnt 2%OPFA+2%RHA treated clay brick, which is the brick with the highest compressive strength.
- The water absorption value of 16.40 MN/m^2 for burnt 2%OPFA+2%RHA treated clay brick is lower than 17%, 22% and ‘no limit’. Therefore adequate for use in SW, MW and NW conditions.
- Based on EDX results, the remarkable presence of Ca, Si and Al were found in burnt 2%OPFA+2%RHA treated burnt clay brick, hence suggesting the presence of cementitious compounds such as CSH and CAH.
- Based on combined strength and water absorption requirements, burnt brick production with 2%OPFA+2%RHA treated A-6 Makurdi clay is adequate for use as load-bearing bricks in walls of Grade NW condition.

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