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Evaluation of Properties of Makurdi Lateritic Clay-Rice Husk Ash Bricks for Pavements.

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Abstract
This study was undertaken to investigate the effect of Rice Husk Ash (RHA) on the burnt properties of the Makurdi lateritic clay. Three (3) to 15 % RHA was blended with the clay. Compressive Strength and Water Absorption test were conducted on each admixture. The clay bricks were burnt at three different temperature levels 700^{0}C, 800^{0}C and 900^{0}C to ascertain the compressive strength property of the clay with temperature variation. The result showed that the plasticity index reduced gradually and had a minimum value of 19.23% at 9 % RHA. The average compressive strength and water absorption of burnt bricks at 700^{0}C attained a maximum value of 4.79 MN/m^2 and minimum value of 16.36 % at 0 % RHA.
Keywords: Rice Husk Ash, compressive strength, clay brick, water absorption.

1.0 Introduction

Lateritic soils or more precisely Ferralsols (FR) are usually the product of an in-situ (lateritic) weathering process of a basement rock, under tropical climate conditions. Lateritic soils are located in tropical regions, where they are used as construction material for embankment dams, roads, etc. In some cases the clay can remain in the foundation, whereas in other cases the dam engineer will require its removal prior to constructing the dam. In countries of the tropics and subtropics, lateritic soils are encountered in various engineering projects. In the Precambrian times, Nigeria consisted of uplifted continental landmass made up of basement sediments; this resulted in the formation of lateritic soils which are of relatively good quality for road construction works (*Kogbe, 1975*).

There are instances where a laterite may contain substantial amount of clay minerals that its strength and stability cannot be guaranteed under load, especially in the presences of moisture. These types of laterites are also common in many tropical regions including Nigeria where in most cases sourcing for alternative soil may prove economically unwise but rather to improve the available soil to meet the desired objective (*Mustapha, 2005*).

Rice husk ash (RHA) is an agricultural waste that originates from the combustion of the rice husk intended to produce energy for rice drying ovens. This ash is rich in silicon. Each ton of rice produces approximately 200 kg of husk, which when burned gives up to 40 kg of RHA (*Mehta, 1992*). Six hundred and sixty two (662) million tons of rice is produced globally every year. The husks represent 20% of this weight, which means that 132.4 million tons of wastes are generated annually (*FAO, 2008*). In Nigeria, there is few industrial scale applications directed towards managing RHA, a large part is used as agricultural compost or simply disposed on riverbanks, causing organic pollution.

According to Sear (2005), Portland cement, by the nature of its chemistry, produces large quantities of CO_2 for every tonne of its final product. Therefore, replacing proportions of the Portland cement in soil stabilization with a secondary cementitious material like RHA will reduce the overall environmental impact of the stabilization process. However, for the purpose of this project, rice husk ash (RHA) was used as a replacement for cement in enhancing the properties of clay in producing bricks. The waste product (rice husk) resulting from milling process of rice is found abundantly in some locations in Benue State especially in Makurdi the catchment area of this study. The useful adaptation of this available material in brick production (molding) and diminishing presence of bamboo which was formally used as reinforcement for a mud plaster in housing construction is the motivation for this research work and also to decongest the waste disposal problem in rice processing. Rice husk is a major agricultural byproduct obtained from the food crop of paddy. For every 4 tons of rice paddy 1 ton of rice husk is produced. The husk is disposed of either by dumping it in an open heap near the mill site or on the roadside to be burnt. In Nigeria, about 2.0 million tons of rice is produced annually. The annual production of paddy rice (*Oryza sativa*) globally was 579,500,000 tons in 2002 (FAO, 2002).

A number of researchers have studied the physical and chemical properties of rice husk ash. The properties of RH depend whether the husks have undergone complete destructive combustion or have been partially burnt. RHA has been classified into high carbon char, low carbon ash and carbon free ash. Meanwhile, the ash has been categorized under pozzolana, with about 67-70% silica and about 4.9% and 0.95% Alumina and iron oxides, respectively (*Oyetola and Abdullahi, 2006*).

According to Oyekan and Kamiyo, (2011), the result of the chemical analysis of the RHA and of is shown in Table 1. From the chemical analysis of RHA, the sum of SiO_2, Al_2O_3 and Fe_2O_3 is 79%. This satisfies the minimum percentage requirement for pozzolana when these constituents are added, which is 70% for ASTM C618 (American Society for Testing and Materials, 1978).The moisture content is less than 1.5% specified by BS 3892.

It therefore implies that the RHA is a good pozzolana since it meets the requirements of BS 3892 and ASTM C618 for pozzolana. The specific gravity of the soil is 2.46 and that of RHA is 2.04 which is less than 2.17 as obtained by Oyekan and Kamiyo, (2011).

Morel et al. (2007) reported that blocks are typically tested at oven dry or ambient air dry moisture conditions, reflecting that under service conditions. Walker (2004) also reports that under service conditions, earth blocks will necessarily remain largely dry. Testing blocks in a service or even in an oven-dry condition would therefore seem the most logical approach.

2 Materials and Methods

The lateritic clay sample was collected from a borrow pit of about 1m deep from Ikpayongo, Makurdi Benue State Nigeria. The rice husk ash used as additive was collected from a heap of rice husk dumped by the river side close to Rice mill at Wadata, Makurdi, Benue State. The Rice Husk collected was carbonated before it was used as additive.

2.1 Experimental Procedure

Test was performed on the natural sample and the clay-rice husk treated sample at various percentages. Test was also carried out on Atterberg limits, grain size, specific gravity, compaction, water absorption and compressive strength. All soil classification tests were performed in accordance with the British standard specification (B.S. 1377, 1990).

2.1.1 Specific Gravity

Empty flask (density bottle) was weighed, about 5g of the soil plus different percentage of rice husk ash passing through 2 mm BS test sieve was transferred to the density bottle and weighed, Sufficient air distilled water was added to the soil in the bottle and shaken vigorously to expel air, the bottle was filled with more air free liquid and the stopper was replaced. The bottle was wiped dry and the whole content was weighed. The bottle was emptied of its content and completely filled with air free water; the stopper was replaced and the whole content was weighed. The procedure was repeated for different admixtures, the specific gravity was calculated with equation (1).

$$G_s = \frac{m_2 - m_1}{(m_4 - m_1) - (m_3 - m_2)} \quad (1)$$

Where,
G_s = specific gravity
m_1 = weight of empty flask, (g)
m_2 = weight of empty flask + weight of the soil mixed with RHA, (g)
m_3 = weight of empty flask + weight of the soil mixed with RHA + distilled water, (g)
m_4 = weight of empty flask + distilled water, (g)

2.1.2 Compaction Test

The compaction test was carried out at the percentages of 0%, 3%, 5%, 7%, 9%, 11%, 13% and 15% RHA to establish the moisture density relationship of each of the Clay-RHA mixture. About 3000g of dried soil sample was weighed and 3 % of water was added to the sample and mixed properly, the soil was compacted (light compaction) in three layers in a mould with volume of 1000cm^{3}and each layer received 27 blows, with a rammer falling freely from a height of 300mm, the blow was evenly distributed. The colar was removed and the soil was trimmed off so that the soil was flat to the top of the mould. The mould and its content were weighed. Some quantity of the compacted soil was taken for moisture content determination. The soil in the mould was broken up and about 3 % of the original water content was added and mixed thoroughly again. The procedure was repeated for increased 3 % of water until the weight of soil and mould began to fall. The dry unit weight was computed and the graph of gamma dry versus moisture content with gamma as the optimum moisture content (OMC) was plotted. Equation (2) was used to calculate the maximum dry density (MDD).

$$MDD = \frac{100 \times D_W}{100 + m} \quad (2)$$

Where,
MDD = maximum dry density (kN/m^3)
D_W = bulk density, (kN/m^3)
m = moisture content, (%)

2.1.3 Test Cube Production

Different percentages of Rice Husk Ash, that is, 3 %, 5 %, 7 %, 9 %, 11 %,, 13 % and 15 % of clay sample was thoroughly mixed with clay. Water was added according to the optimum moisture content determined during compaction. The mix was used to mold bricks each measuring 40 mm x 40 mm x 40 mm. using a cast iron mould cavity and compressed under 15 MN/m^2 pressure with a compaction machine. The moulded brick was extruded by loosening the mould and the brick was carefully removed after 24 hours. The brick was cured at room temperature for 12 days prior to burning.

Brick Burning

The firing of moulded Clay-RHA bricks was done at three different temperature levels 700 ^{0}C, 800 ^{0}C and 900 ^{0}C in an electric muffle furnace. When the temperatures were attained, the bricks were left in the furnace to ensure uniform cooling. They were collected the next day to avoid cracking of brick.

2.1.4 Compressive Strength Measurement

The compressive strength of each brick was determined in accordance with the specification of the standard organization of Nigeria (SON, 2000) as contained in test for compressive strength of solid bricks using the compressive machine (ELE Compact-1500).

A 40mm square platen was used on the compressive testing machine. Each test piece was preconditioned by immersion in cold water at room temperature (29 °C $\pm$ 2 °C) for 24 hours, after removing from water, all traces of water was wiped off and then stored under moist conditions for 24 hour prior to testing.

Each test piece was centrally positioned between the platens of the testing machine, the load was gradually increased and the value was read immediately as failure occurred. The compressive strength was calculated with the use of equation (3).

$$C_S = \frac{F}{A} \tag{3}$$

Where,

C_S = compressive strength, (N/mm^2)

F = force applied before crushing, (N)

A = area of brick, (mm^2)

2.1.5 Water Absorption Measurement

The water absorption test was performed by a "24 hour immersion in cold water" as specified by the standard organization of Nigeria. Three cubes were preconditioned by drying through in a ventilated oven at 10 °C until it attain constant mass and then cooled to room temperature and weighed to note its initial weight M_1. The precondition test piece was immersed in cold water at room temperature (29 °C $\pm$ 2 °C) for 24 hour and thereafter removed and traces of water was wiped off. The test piece was then weighed and water absorption, defined as the relative increase in weight, was calculated. The test was conducted on three test pieces for each mixture compositions. The water absorption was calculated with equation (4).

$$W_a = \frac{w_1 - w_2}{w_2} \times 100 \tag{4}$$

Where,

W_a = water absorption, (%)

w_1= weight of wet brick, (g)

w_2= weight of fired brick, (g)

2.1.6 Density Measurement

Density was measured for brick of each of the sample (3 % RHA, 9 % RHA, 13 % RHA). Each cube was preconditioned as in the water absorption test and was carefully weighed in air and in water. The density was calculated from the apparent loss in weight. Equation (5) was used to calculate the density of brick.

$$\rho = \frac{m}{v} \tag{5}$$

Where,

ρ = density of brick, (kg/m^3)

m = mass of brick (kg)

v = volume of brick (m^3)

2.2 Experimental Design and Statistical Analysis

The experimental design for the statistical analyses followed a two-treatment effect (RHA content and firing temperature) in a split-plot factorial design with Completely Randomized Design involving a two-way classification with three observations per experimental unit. The experimental unit comprised two factors; eight levels of RHA contents in each of the three levels of firing temperature giving a twenty four treatment combinations and seventy two observations for the experiment as RHA and firing temperature. The RHA forms the levels of factor 'A' while firing temperatures in the combination forms the levels of factor 'B'. All data recorded was subjected to Analysis of Variance to determine the extent to which RHA and firing temperature affected the soil index properties at 95% confidence level using the procedure recommended by Steel and Torries, (1980).

The F-test for treatment was significant and LSD was used to separate the means.

3 Results and Discussion

The summary of the index properties of the soil determined in accordance to BS1377 are presented Table 2.

3.1 Atterberg Limits

The behavioural pattern of the consistency limits of Clay-RHA mixtures at various RHA contents is graphically presented as shown in Fig.1.

3.1.1 Liquid Limits (LL)

The natural soil shows a low liquid limit (i.e 40.00 % < 50.00 %). The liquid limit was observed to decrease from 40 % at 0 % RHA to a minimum of 31.80 % at 9 % RHA.

3.1.2 Plastic Limit (PL)

The plastic limit was seen to increase from 19.23 % at 0 % RHA to a maximum value of 30.54 % at 9 % RHA.

3.1.3 Plasticity Index (PI)

The plasticity index experienced a reduction from 20.77 % at 0 % RHA to a minimum of 2.96 % at 9 % RHA. This can be classified as medium plasticity index. (i.e 20.77 % < 25 %). This indicates improvement in the solution of swelling and shrinkage potential of the soil.

3.1.4 Hydrometer analysis

From the hydrometer analysis it was found that the sample contained 13 % clay, 52 % sand and 35 % silt. The low liquid limit and plastic limit can be traced to the high content of silt 35 % and 52 % sand, therefore the soil sample is silty-sand-clay.

3.2 Specific Gravity

The specific gravity of the RHA was found to be 2.04 and that of clay was found to be 2.46. This could be as a result of the presence of plenty of organic matter in the soil. At the addition of RHA in different percentages, the specific gravity of the admixture was found to decrease from 2.46 at 0 % RHA to minimum of 2.16 at 15 % RHA. The very low specific gravity might have been caused as a result of the presence of much organic matter in the clay sample collected.

Figure 1 shows the variation of liquid limit, plastic limit and plasticity index with different percentages of RHA. The relationship between the liquid limit and RHA did not follow any discernible trend, but the plastic limit generally increased with increase in RHA content. This may be due to the addition of RHA which led to the reduction in the quantity of free silt and clay fraction by forming coarser material with large surface areas which require more water.

The plasticity index decreased from 20.77 % at 0 % RHA to a minimum value of 4.58 % at 9 % RHA. A decrease in plasticity index is a sign of an improvement on the soil.

The linear shrinkage did not follow a uniform trend it increased from 5.00 % for the natural soil sample to a maximum of 9.29 % at 7 % RHA, the minimum value was obtained to be 4.29 % at 9 % RHA. The specific gravity of the RHA was found to be 2.04 while that of clay was found to be 2.46. Therefore the addition of RHA to the soil led to a reduction in the specific gravity of the admixture. The compressive strength of the brick was seen to be maximum a 0 % RHA, that is it decreased with increase in RHA content. On the other hand, the compressive strength decrease with increase in temperature this can be attributed to increase in glass phase due to melting of the fluxes like mica, sodium and potassium and the iron oxide.

The excess RHA content in the mix may have caused weakening in the interparticle bonding that could have been formed by the soil particles. This was probably responsible for the increase water absorption in the water absorption result obtained. It might also be explained that during vitrification at different temperatures in the furnace, the malting temperature of Rice Husk Ash and that of the laterite differed thereby resulting to a heterogeneous compound whose strength diminished with increased RHA.

3.3 Effect of RHA and Firing Temperature on the Compressive strength of Bricks

The mean compressive strength obtained foe different RHA content fired at three temperature levels are presented in Table 3 and the characteristic curve in Fig. 2. This shows that the highest mean compressive strength of 4.79 MN/m^2 was obtained at 0 % RHA for the brick burnt at 700 ^{0}C. Generally, the values of compressive strength were observed to decrease from 0% RHA to 15% RHA. Though few of the values disobeyed the trend of the curve; the abnormality can be traced to machine errors. The result value obtained for soil amendment with 3% RHA was very close to that of only clay as they do not differ significantly ($P<0.05$).

The ANOVA result indicates that at 3% RHA content, the compressive strength of the bricks was significantly ($P<0.05$) higher. While no significant difference was observed among the compressive strength of the other treatments.

The ANOVA result also indicates that at temperature level of 700^0C, the compressive strength of the bricks was significantly ($P<0.05$) higher.

The ANOVA result also indicates that at temperature level of 700^0C and 13% RHA content, the compressive strength of the bricks was significantly ($P<0.05$) higher, while no significant difference was observed at 7% and 9% RHA at 700 ^{0}C, 5% and 9% RHA at 800^0C and 9% RHA at 900^0C.

The result of analysis of variance (ANOVA) presented in Table 4 shows RHA content and firing temperature well as their interactions had significant effect on compressive strength of bricks at 5% level of significance.

3.4 Effect of RHA and temperature on Water Absorption of Bricks

The water absorption characteristic of the brick was found to increase with the increase in the percentage of RHA. At three (3) different temperatures levels of 700^0 C, 800^0C and 900^0C, the maximum water absorption of 29.31 %, 32.90 % and 37.64 % was obtained for 15 % by weight of RHA compared to water absorption of 16.36 %, 16.51 % and 18.07 % at 0% RHA or plain brick respectively. The mean values are presented in Table 5 and the characteristic curve in Fig. 3.

The ANOVA result indicates that at 13% RHA content, the water absorption of the bricks was significantly ($P<0.05$) higher than all other RHA contents.

The ANOVA result also indicates that at temperature level of 800^0C, the water absorption of the bricks was significantly ($P<0.05$) higher than other temperature levels.

The ANOVA result also indicates that at temperature level of 900^0C and 13% RHA content, the water absorption of the bricks was significantly ($P<0.05$) higher. However, no significant difference was observed at 3% and 11% RHA at 700^0C and 9% RHA at 800^0C.

The result of analysis of variance (ANOVA) presented in Table 6 shows RHA content and firing temperature as well as their interactions had significant effect on the water absorption of bricks at 5% level of significance.

3.5 Effect of RHA and Temperature on Density of Bricks

The density of bricks was found to decrease with the addition of RHA at different percentages. The maximum density of 3088.59 kg/m^3, 3151.56 kg/ m^3 and 3026.09 kg/ m^3 was obtained at 0 % RHA compared to the minimum values of 2505.16 kg/m^3 , 2390.63 kg/m^3 and 2296.88 kg/ m^3 obtained at 15 % RHA for three different temperatures of 700^0C, 800^0C and 900^0C respectively. The mean values are presented in Table 7 and the characteristic curve in Fig. 4.

The ANOVA result indicates that at 13% RHA content, the density of the bricks was significantly ($P< 0.05$) higher than all other RHA contents.

The ANOVA result also indicates that at temperature level of 800^0C, the density of the bricks was significantly ($P< 0.05$) higher than the other temperature levels.

The ANOVA result also indicates that at temperature level of 800^0C and 13% RHA content, the density of the bricks was significantly ($P<0.05$) higher than all other interaction effects of temperature levels and RHA contents.

The result of analysis of variance (ANOVA) presented in Table 8 shows RHA content and firing temperature as well as their interactions had significant effect on the density of bricks at 5% level of significance.

4 Conclusion and Recommendation

4.1 Conclusion

The test result showed that more than 90 % of the particles of Ikpayongo laterite passed through BS sieve number 1.18. The values of liquid limit and plastic limit at zero percent RHA were found to be 40.00 % and 19.23 % respectively. The plasticity index was found to be 20.77 %. As the RHA increased, the liquid limit decreased to a minimum value of 32.00 % at 15 % RHA. The plastic limit also increased with the increase in RHA content, while the plasticity index reduced considerably. The reduction in plasticity index and shrinkage limit suggests a reduction in swell potential. The addition of RHA content was seen not to enhance the compressive strength of the clay in this study, but the most important properties of burnt bricks, namely compressive strength and water absorption were determined. Bricks are classified by both the average or minimum compressive strength and the percentage water absorption. According to this classification, minimum compressive strength of brick should be 3.5MN/m^2 and the water absorption should not exceed 20 % (Brick Development Association, 1974; IS 1077. 1992). At 0 % RHA, the compressive strength and water absorption of 4.79 MN/m^2 and 16.36 % were obtained respectively. From the results obtained, the addition of RHA and increase in temperature in the range of 700 – 900^0C was deleterious to the strength value of the burnt brick, therefore Ikpayongo laterite can be moulded into bricks, burnt at 700 ^{0}C or below and used as sub-base material in pavements construction without RHA as additive.

4.2 Recommendations

i. The research revealed that the average compressive strength of Ikpayongo Lateritic clay burnt brick at 700 ^{0}C was 4.79MN/m^2, the results further indicate that the compressive strength of the burnt bricks decreased with increase in firing temperature.
ii. The compressive strength of Ikpayongo laterite decreased with the increase in percentage RHA. Therefore, Ikpayongo Laterite should be used for brick production without additive as a sub-base material for pavement.

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Table 1: Chemical Analysis of RHA

S/No	Parameter	RHA (%)
1	Silica (SiO_2)	76.0
2	Aluminium oxide (Al_2O_3)	3.0
3	Ferrous oxide (Fe_2O_3)	Not detected
4	Calcium oxide (CaO)	6.0
5	Magnesium oxide (MgO)	1.3
6	Sodium oxide (Na_2O)	1:18
7	Potassium oxide (K_2O)	0.10
8	Barium oxide (BaO)	0.24
9	Lead oxide (PbO)	Not detected
10	Sulphite ($SO_3{}^{2-}$)	Not detected
11	Chloride	Not detected
12	Moisture	0.27
13	Ash	11.28

Source: Oyekan and Kamiyo (2011)

Table 2. Index Properties of Lateritic Clay without Additive

PHYSICAL PROPERTIES	RESULT VALUE
Liquid Limit	40.00 %
Plasticity Limit	19.23 %
Plasticity Index	20.78 %
Specific Gravity	2.46
Shrinkage Limit	5.00 %
Maximum Dry Density	16.7kN/m^3
Optimum Moisture Content	18.00 %
Percentage Passing BS Sieve 1.18 mm	90.2 %

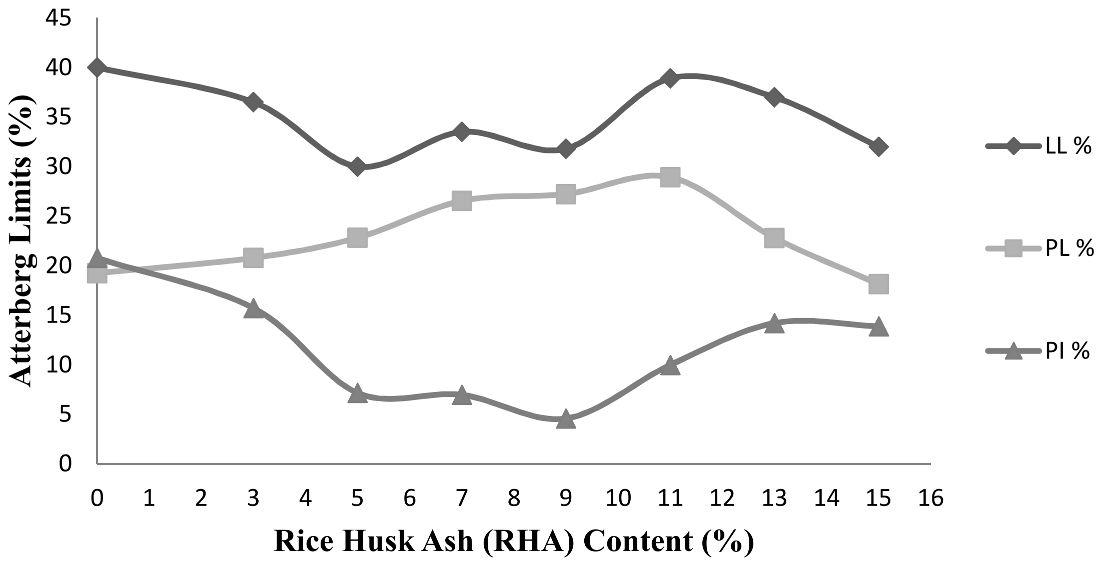


Figure. 1: The Relationship between Atterberg Limits and RHA content (%).

Table 3: Compressive Strength of Makurdi Lateritic Clay Bricks

% RHA	**Compressive Strength (MN/m^2)**		
	700 ^{0} C	**800 ^{0} C**	**900 ^{0} C**
0	4.79±0.23^a	2.29±0.05^a	1.25±0.03^a
3	4.16±0.02^a	1.67±0.06^a	1.04±0.02^a
5	3.33±0.03^a	0.83±0.02^{ab}	0.83±0.05^a
7	2.50±0.02^{ab}	0.83±0.05^{bc}	1.46±0.05^a
9	2.50±0.05^{bc}	0.42±0.03^{cd}	0.63±0.03^{ab}
11	2.50±0.06^{bc}	0.42±0.03^{de}	0.63±0.03^{bc}
13	3.12±0.03^a	0.21±0.03^e	0.21±0.03^c
15	0.83±0.05^c	0.00±0.00^e	0.00±0.00^c
LSD = 0.098			

- Means with the same superscript letter along the same column differ significantly (P<0.05)
- Means with different superscript letter along the same column do not differ significantly (P<0.05)

Table 4: Analysis of Variance (ANOVA) of Compressive Strength at different RHA contents and Firing Temperatures.

Source of variation	**D.F.**	**SS**	**MS**	**F.cal**	**F pr.**
RHA (%)	7	36.780187	5.254312	1464.62*	<.001
Temperature (^{0}C)	2	75.501300	37.750650	10522.83*	<.001
RHA (%).Temperature (^{0}C)	14	11.509500	0.822107	229.16*	<.001
Residual	48	0.172200	0.003588	-	-
Total	71	123.963188	-	-	-

D.F= Degree of Freedom, SS= Sum of Square, MS= Mean Square, F.cal= F calculated, * = Significant at (P<0.05)

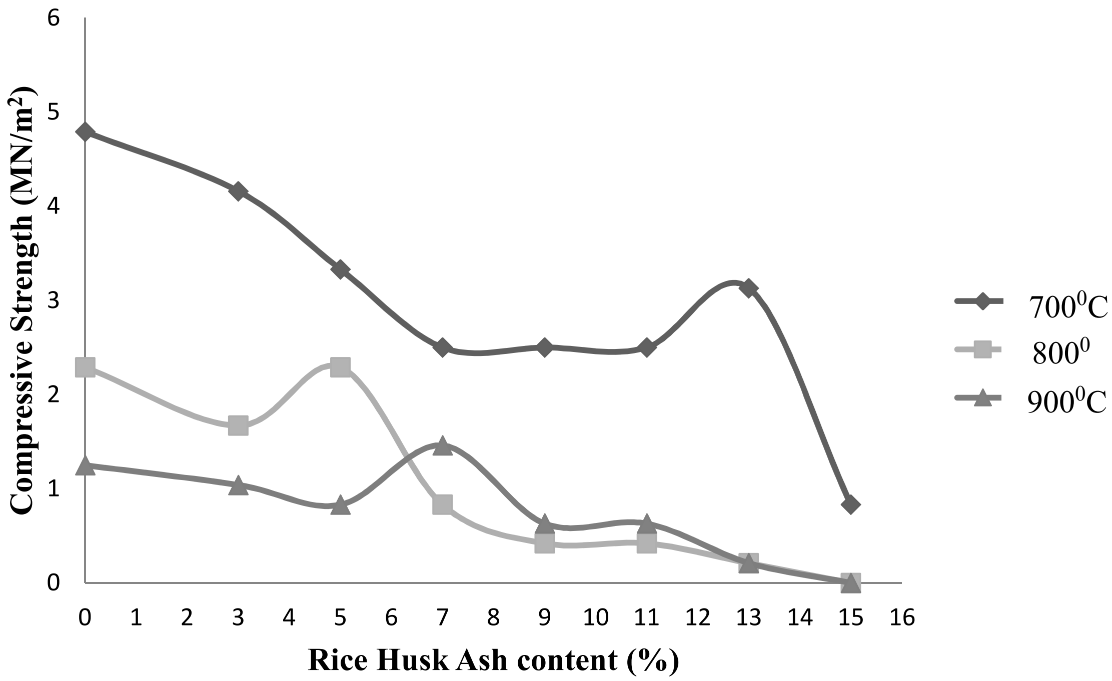


Figure 2: Graph of Compressive Strength of Makurdi Lateritic Clay at different percentages of RHA

Table 5: Water Absorption of Bricks at different RHA contents and firing Temperatures

% RHA	Water Absorption (%) 700 ^{0}C	800 ^{0}C	900 ^{0}C
0	16.36±0.05^{e}	16.51±0.05^{c}	18.07±0.05^{a}
3	17.91±0.05^{de}	17.35±0.02^{c}	19.84±0.05^{a}
5	18.47±0.02^{cd}	19.52±0.02^{c}	20.93±0.05^{a}
7	19.81±0.02^{c}	22.80±0.03^{c}	24.77±0.02^{a}
9	24.05±0.02^{c}	26.06±0.05^{bc}	28.28±2.14^{a}
11	26.09±0.02^{bc}	26.29±0.02^{ab}	26.59±0.05a^{a}
13	26.34±0.05^{ab}	28.65±0.03^{a}	30.75±0.03^{a}
15	29.31±0.05^{a}	32.90±0.02^{a}	37.34±0.50^{a}
LSD = 0.74			

- Means with the same superscript letter along the same column differ significantly (P<0.05)
- Means with different superscript letter along the same column do not differ significantly (P<0.05)

Table 6: Analysis of Variance (ANOVA) of Water Absorption at different RHA contents and Firing Temperatures.

Source of variation	D.F.	SS	MS	F.cal	F pr.
RHA (%)	7	1958.6400	279.8057	1372.10*	<.001
Temperature (^{0}C)	2	150.8351	75.4175	369.83*	<.001
RHA (%).Temperature (^{0}C)	14	64.8667	4.6333	22.72*	<.001
Residual	48	9.7884	0.2039	-	-
Total	71	2184.1302	-	-	-

D.F= Degree of Freedom, SS= Sum of Square, MS= Mean Square, F.cal= F calculated, * = Significant at (P<0.05).

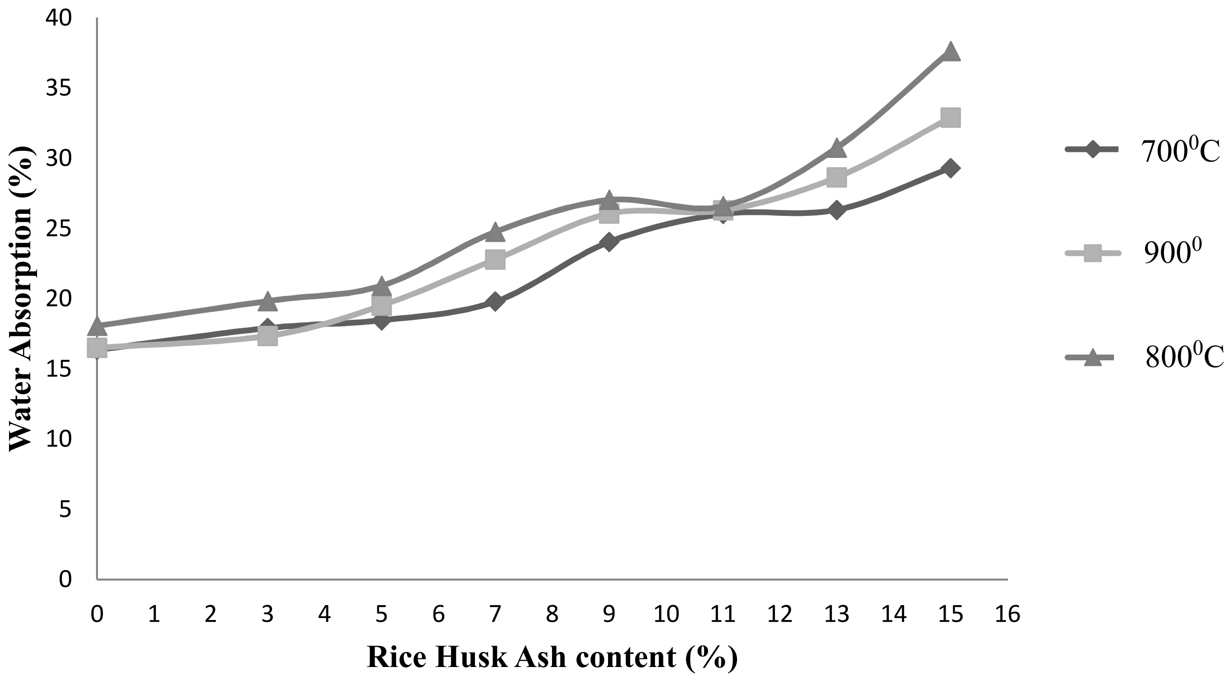


Figure 3: Water Absorption Characteristics of Makurdi Lateritic clay

Table 7. Density of Bricks at different RHA contents and firing Temperatures

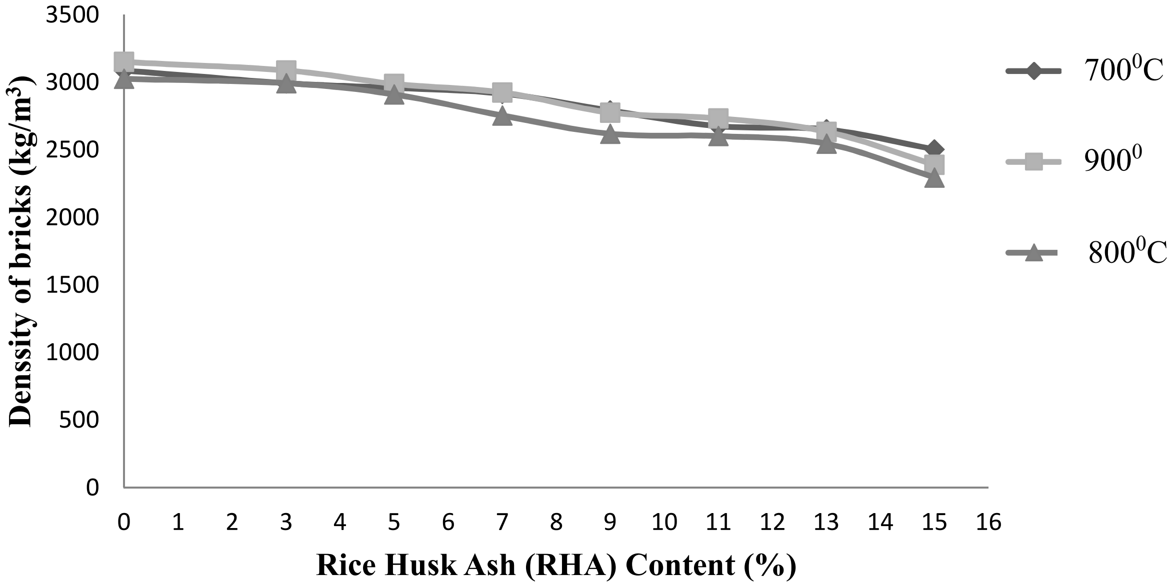
% RHA	**Density (kg/m^3)**		
	700 ^{0}C	**800 ^{0}C**	**900 ^{0}C**
0	3088.59±5.17^a	3151.56±15.23^a	3026.09±3.06^a
3	2994.84±39.66^a	3089.06±8.31^a	2994.84±6.09^a
5	2960.30±18.00^a	2989.06±19.02^a	2911.41±2.96^a
7	2917.19±21.35^a	2926.56±13.49^a	2755.16±4.12^a
9	2792.19±9.06^a	2776.56±13.43^a	2619.84±8.84^{ab}
11	2676.25±9.15^{ab}	2734.38±1.78^a	2603.13±8.37^{bc}
13	2652.19±27.03^{bc}	2635.47±23.28^a	2546.88±14.41^c
15	2505.16±12.06^c	2390.63±18.09^a	2296.88±14.21^c
LSD = 25.85			

- Means with the same superscript letter along the same column differ significantly (P<0.05)
- Means with different superscript letter along the same column do not differ significantly (P<0.05)

Table 8: Analysis of Variance (ANOVA) of Density of bricks at different RHA contents and firing temperatures.

Source of variation	**D.F.**	**SS**	**MS**	**F.cal**	**F.pr**
RHA (%)	7	3431175.3	490167.9	1976.71*	<.001
Temperature (^{0}C)	2	198132.0	99066.0	399.51*	<.001
RHA (%).Temperature (^{0}C)	14	73108.8	5222.1	21.06*	<.001
Residual	48	11902.6	248.0		
Total	71	3714318.7			

D.F= Degree of Freedom, SS= Sum of Square, MS= Mean Square, F.cal= F calculated, * = Significant at (P<0.05)



Fiure. 4: Density Characteristics of bricks at different temperatures