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PONTENTIAL OF RICE HUSK AND LUFFA SPOUNGE ON NKPOLOGU CLAY DEPOSITE FOR INDUSTRIAL APPLICATIONS

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Abstract
The effect of the addition of luffa sponge and Adani rice husk to Nkpologu clay has been investigated. The three samples were first sourced and characterized using XRD and XRF which showed that Nkpologu clay has about 20% Al_2O_3, 79% of SiO_2 and little of FeO and CaO making it very good refractory clay. The rice husk and luffa sponge contains almost the same mineral contents. The samples were prepared and mixed in different ratios with clay being constant and the additives varied which led to the production of five different insulating bricks with which its micrographs were obtained after being fired in a heat treatment furnace. There was no colour change in the clay before and after the experiment.
Keywords: Pontential, Rice Husk, Luffa Spounge, Nkpologu Clay Deposite

Introduction

Most metallurgical processes are heat generating systems. Such systems require materials that can withstand not only the high temperature generated but equally must be able to withstand both physical and chemical action of molten metals, slag and gases without crumbling. Engineering materials that possess these attributes are referred to as refractory materials. Refractories are those materials that can withstand high temperatures and still retain their strength. They are usually made from inorganic, non-metallic and heterogeneous materials composed of thermally stable mineral aggregates. They have physical and chemical properties that enhance resistance to their physical wear, high temperatures and corrosion. [1, 2, 3]. Refractory materials include ceramic materials like clay, oxides of silicon, aluminum and zirconium. The base material for refractory production is clay. Clays are naturally occurring sediments produced by chemical actions resulting from weathering of rocks [4]. An earthly fine-grained material, which develops plasticity when mixed with water, Clay has silica (SiO_2), alumina (Al_2O_3) and water as primary constituents. Other constituents are iron, alkaline, and alkaline earth metals [4].

Clay as an important material in modern technology finds applications in ceramics, refractories, paper, foundry, rubber, paints, plastics, insecticides, pharmaceutical,
textile and adhesives industries [5]. In response to the challenges that may be posed by the demand for clay materials in Nigeria, indigenous clays with industrial potentials need to be investigated. It has been discovered that clay from different areas differs in their mineral contents and thus possess different properties. It was reported that the alumina content of some Nigerian clays are low, for their use alone without blending and that clay alone cannot produce enough pores needed for thermal insulating properties [6]. Therefore, there becomes a need for inclusion of materials that will create pores in the clay. Materials usually used include rice husk, saw dust and diatomite. Clays are complex alumino-silicate compounds containing attached water molecules. Clays and soils have their origin in the mechanical and chemical disintegration of rocks.

AIM

The aim of this work is to study and develop an insulating brick from locally sourced materials (Nkpologu clay, Adani rice husk and luffa sponge sourced from any part of Nigeria).

Problem Statement

Nigeria has appreciable distribution of metal and process industries where high temperatures are generated and as such have considerable needs for Refractories. Present economic realities dictate the need for internal sourcing of raw materials to be used in the production of engineering materials. Refractories, being a class of materials largely used in metallurgical plants and cement industries, are presently largely sourced by importation (about 38,000 to 120,000 tons annually) with enormous financial implications to the country.

Objective

- To produce refractory bricks using Nkpologu clay and a blend of Adani rice husk and luffa sponge.
- To evaluate the effect of Adani rice husk and luffa sponge on the thermal insulating properties of Nkpologu clay.
- To determine the best blending ratio.

- To ascertain the efficiency of using rice husk and luffa sponge as additives in clay to produce insulating bricks.

Potential Benefits

- To bridge the importation of refractories into Nigeria.
- To convert luffa sponge and rice husk (agro waste) into useful materials.

Materials and Methods

The materials used are Nkanu area luffa sponge, Adani rice husk and Nkpologue clay.

The machines and equipment used are the following:

Hydraulic pressing machine, Heat treatment furnace, Electric oven, Metal mould, weighing balance, Meter rule, Water bath, Sieves, Crushing tool, Rammer and other minor tools like meter rule, scissors, bowl, measuring cylinder, polythene, etc

Materials Preparation

The clay was sun dried, crushed and sieved using 0.2mm aperture sieve. The rice husk was also sieved using 0.8mm aperture sieve. The luffa sponge was cut into very tiny pieces using scissors. A metal mold of dimensions 180mm x 80mm x 40mm was also produced.

Bricks Preparation

The comminuted and sieved materials were weighed and mixed in different ration as indicated in table.1. The blend was thoroughly mixed to enhance homogeneity. Then the sample was then poured into the mould and pressed at a pressure of 500kPa using a hydraulic pressing machine. The green weight and dimension was measured and recorded

TABLE 1 Percentage Compositions of Sample Bricks

	Clay (gram)	Rice Husk (gram)	Luffa sponge (gram)
Sample A	1000	90	10
Sample B	1000	130	20
Sample C	1000	170	30
Sample D	1000	_	50
Sample E	1000	150	_

Molding of sample

The produced samples were dried at room temperature for one week before they were then oven dried at 110^{o}C for one hour and the oven dried weights and dimensions recorded.

The oven dried samples were fired in the heat treatment furnace (model: KOHAZATI GYRAEPITO VALLALAT BUDAPEST) at intervals of 200°C and 10 minutes from 600°C to 1000°C and then held at 1000°C for four hours. They were left in the furnace to cool to room temperature to avoid thermal shock. The fired weights and dimensions were also recorded.

Testing of Samples

After cooling of the fired bricks, the physical, thermo-physical, mechanical and chemical test were run on them. The tests carried out included linear shrinkage, apparent porosity, bulk density, thermal conductivity and cold crushing strength.

Shrinkage Test**:** The test pieces of the refractory materials were made into rectangular shapes in a mould and compacted. A slanted line was inserted diagonally on each piece and recorded as (L_1). The test pieces were then placed inside the furnace and fired up to 1000°C and the line drawn across the diagonal axis of the pieces were measured to determine their final length (L_2) after firing. The drying shrinkage indicates to some degree the plasticity of the mixture. A large drying shrinkage means that mixture could absorb much water, which in turn indicates fine mixture particles. The firing shrinkage indicates how fusible the mixture is. A high shrinkage normally means a lower melting point. The total shrinkage of refractory bodies tells how much bigger we should make our molds. The linear shrinkage, Fired Length Shrinkage and Total shrinkage percentage of the materials were determined with equation (1, 2 and 3) respectively. [36,]

Drying Shrinkage (%) = $\frac{L_2 - L_1}{L_1}$ --- (1)

Fired Shrinkage length = $\frac{DL - FL}{DL} \times \frac{100}{1}$- --- (2)

Total shrinkage percentage = $\frac{WL - DL - FL}{WL} \times \frac{100}{1}$ -- (3)

Where: L_1 = Initial length of sample before firing, L_2 = Final length of sample after firing

Apparent porosity, water absorption and Bulk density: The dried specimens were suspended in a beaker containing water and kept for two hours. After two hours the suspended weights were determined (W_S). The specimen were removed from water and weighed in air to obtain (W_W).

Apparent Porosity (P), water absorbed (WA) and bulk density were determined using equation (4), (5) and (6) respectively:

Porosity = $\frac{W_W - W_D}{Ww - Ws}$ X 100 -- (4)

% Water Absorbed (WA) = $\frac{W_W - W_D}{W_D}$ -- (5)

Bulk density = $\frac{W_D}{W_D - W_S}$ --- (6)

Where W_D = Weight of fired specimen, W_S = Weight of fired specimen in water,
W_W = Weight of soaked specimen suspended in air.

The loss on ignition: The loss on ignition (LOI) is the weight reduction on the total weight of the prepared samples, in percentage. Hence, the loss in weight by each sample were determined to be the difference in their weights before and after firing and consequently, the loss on ignition at that temperature was determined as shown in equation (7). [43]

Loss on ignition = $\frac{W_1 - W_2}{W_1}$ X 100 --- (7)

W_1 is the weight before firing
W_2 is the weight after firing

Cold crushing strength (CCS): Cold crushing strength is the amount of load that the refractory material could withstand after they have been fired. In determining the cold crushing strength of the refractory samples, specimens were made from the refractory samples. The dimensions of the test pieces were taken after they are fired to 1000°C temperature. Load was applied on the test piece with the aid of Hounsfield Tensometer until the test piece failed to support the load. The maximum recorded load was taken as the crushing load. The CCS was calculated using equation (8).

CCS = $\frac{Load}{Area}$ --- (8)

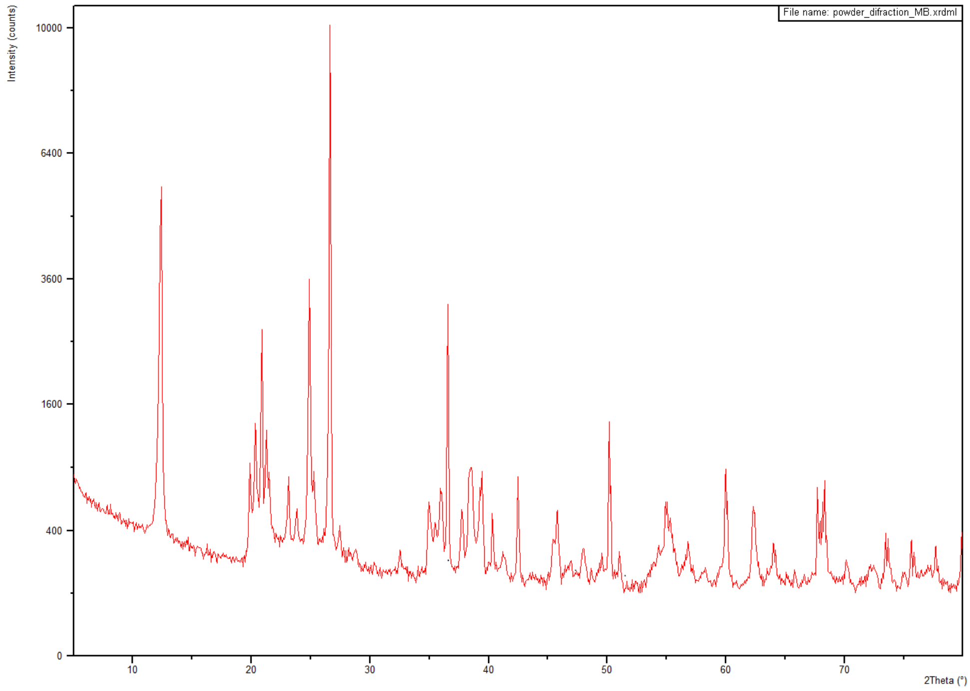
Thermal conductivity test: Thermal conductivity test was carried out on the fired bricks using thermal conductivity meter (fox 600 GHP). Thermal conductivity indicates the rate of heat flow through a material. Poor conduction of heat is desired in insulating refractory bricks.

Slag Attack Resistance Test: The fired bricks produced were used for this test with a hole of about 20mm drilled into them. The hole were packed with the sample of slag that it will likely encounter when put to service. The refractory brick were heated to a temperature of about 1200°C and maintained at this temperature for a period of one hour. The brick were then cooled in the furnace, sectioned and examined to observe the degree of attack and penetration of the slag.

Visual Test: The brick samples were observed to determine the colour changes after firing if any.

Materials and sample characterization: The clay sample was characterized via X-Ray diffraction while the rice husk and luffa sponge samples were characterized via X-Ray fluorescence. The produced samples were characterized using Scanning electron microscope machine (using back scattered secondary imaging)

Results and Discussion



XRD Spectrum of Clay

Table 2: XRD Analysis Data of Clay

Name & Formula				Crystallographic Parameters									
Mineral Name	**PDF Index Name**	**Empirical Formula**	**Chemical Formula**	**Crystal System**	**Space Group**	**Space Group No**	**a (Å)**	**b (Å)**	**c (Å)**	**Alpha (°)**	**Beta (°)**	**Gamma (°)**	**% Composition**
Quartz low	Silicon Oxide	O_2Si	SiO_2	Hexagonal	P3221	154	4.9124	4.9124	5.4039	90.0000	90.0000	120.0000	0.192
Kaolinite-1A	Aluminium Silicate Hydroxide	$Al_2H_4O_9Si_2$	$Al_2Si_2O_5(OH)_4$	Anorthic	C1	1	5.1556	8.9397	7.4073	91.7133	104.8265	89.8343	20.346
Halloysite	Aluminium Silicate Hydroxide	$Al_2H_4O_9Si_2$	$Al_2Si_2O_5(OH)_4$	Orthorhombic	P237	2	5.1600	8.9400	7.4000	90.0000	90.0000	90.0000	79.462
Calcite	Calcium carbonate	$CaCO_3$	$CaCO_3$	Trigonal	R3 2/C	180	4.9020	8.7421	5.5810	90.6190	90.0000	120.4838	0.038
Magnetite	Iron (III) Oxide	Fe_3O_4	Fe_3O_4	Hexagonal	R3C	3	5.2230	8.9275	7.0940	90.9439	90.0000	90.5647	1.126

The wet chemical analysis of clay shows that Nkpology clay contains about 20% Al_2O_3, 79% SiO_2, and little of Fe_3O_4 and CaO

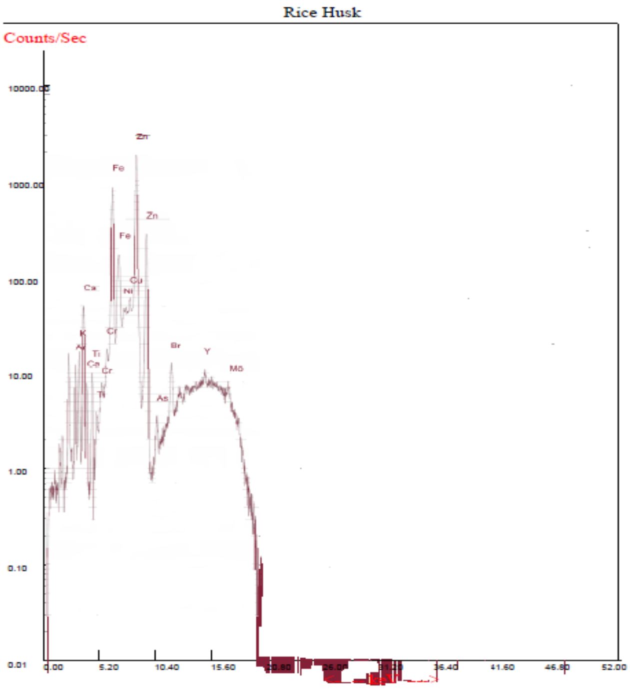


Fig.2: XRF Spectrum of rice husk

From XRF, Adani rice husk contains iron, zinc, calcium, nickel, copper, bromine, chromium, titanium. Arsenium, Argon, potassium, molybdenium and yttrium

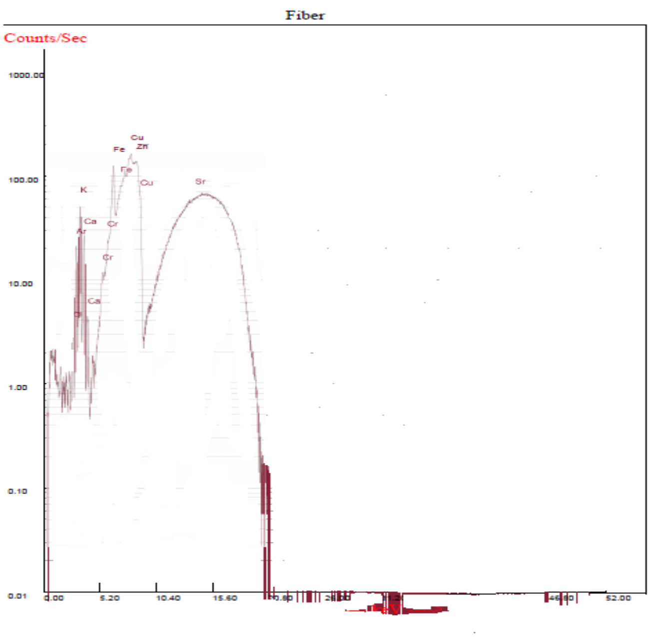
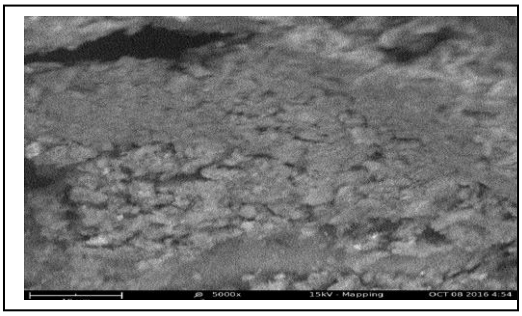


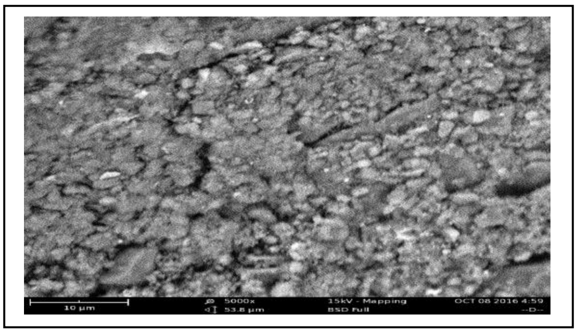
Fig.3 XRF Spectrum of luffa sponge

From XRF conducted on luffa sponge, it shows that it contains copper, zinc, iron, potassium, argon, calcium, chromium, chlorine and strontium.

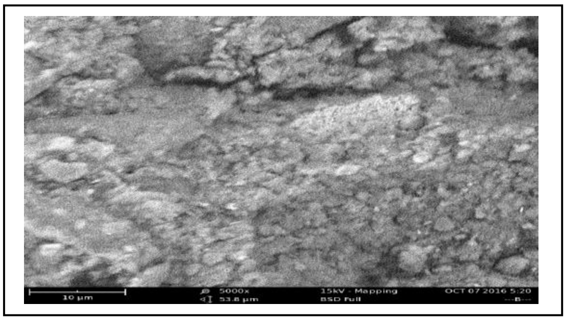
Micrographs of brick samples



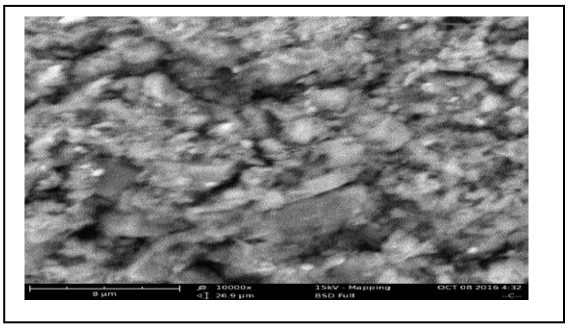
Sample A



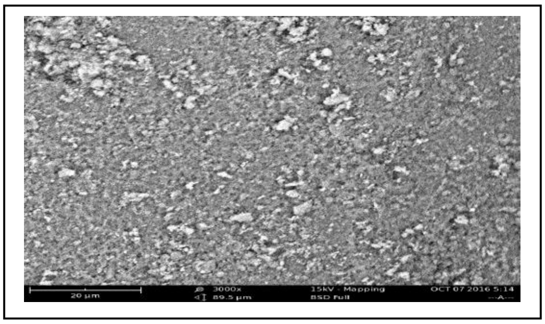
Sample B



Sample C



Sample D



Sample E

FIG 4.SEM Micrographs of brick samples

The micrographs of the brick samples showed that the burning of the rice husk and luffa sponge in the clay creates some pore spaces in the clay. It was observed that the pores increased with increase in rice husk and luffa sponge percentage.

Visual Inspection

The brick samples maintained a milky colour even after firing. As observed, there was no colour change in the samples before and after diring.

PHYSICAL TESTS

Shrinkage Analysis

Table 3: Shrinkage analysis

	Original length(mm)	Dry length(mm)	Fired length(mm)	Drying Shrinkage (%)	Firing Shrinkage (%)	Total Shrinkage (%)
Sample A	196	178	175	9.184	1.714	10.714
Sample B	196	176	174	10.204	1.149	11.224
Sample C	196	177	170	9.694	4.117	13.265
Sample D	196	177	176	9.649	0.568	10.204
Sample E	196	179	178	8.673	0.562	9.184

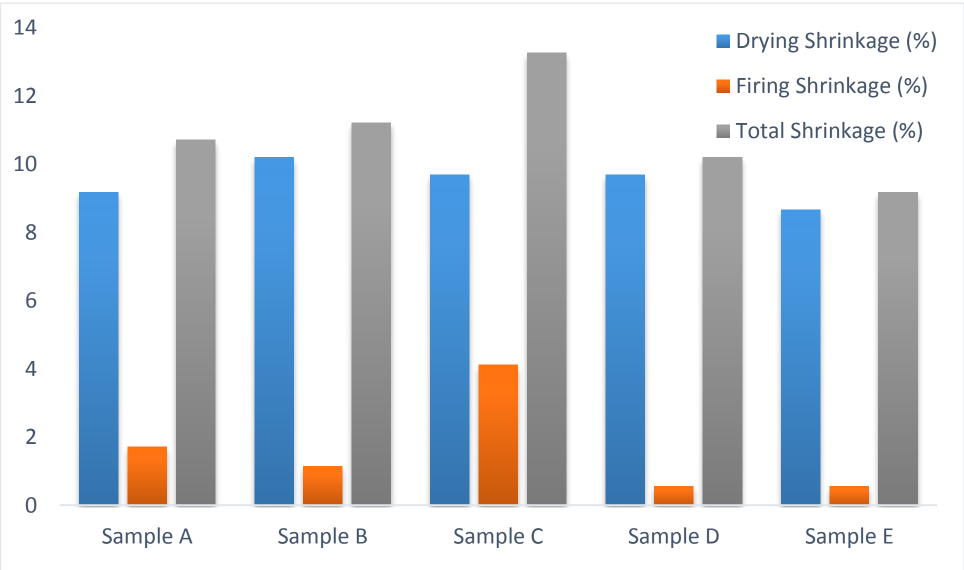


Fig 5: Percentage shrinkages of brick samples

From above table 3 and fig 5, sample C has the highest total shrinkage percentage while sample E has the lowest shrinkage percentage. This indicated that the shrinkage increased with increased in percentage addition of the additives.

Table 4: Bulk density, apparent density, Apparent porosity and Water absorption

Sample Parameter / Sample codes	Fired weight(g)	Upthrust weight(g)	Soaked weight in air(g)	Bulk density (g/cm^3)	Apparent density (g/cm^3)	Apparent porosity (%)	Water absorption (%)
Sample A	800	650	1000	2.286	5.333	57.143	25
Sample B	780	633	1120	1.602	5.306	67.820	43.59
Sample c	950	770	1430	1.439	5.277	72.732	50.05
Sample D	800	700	1015	2.540	8.000	68.225	26.87
Sample E	860	650	1110	1.869	4.095	54.348	29.07

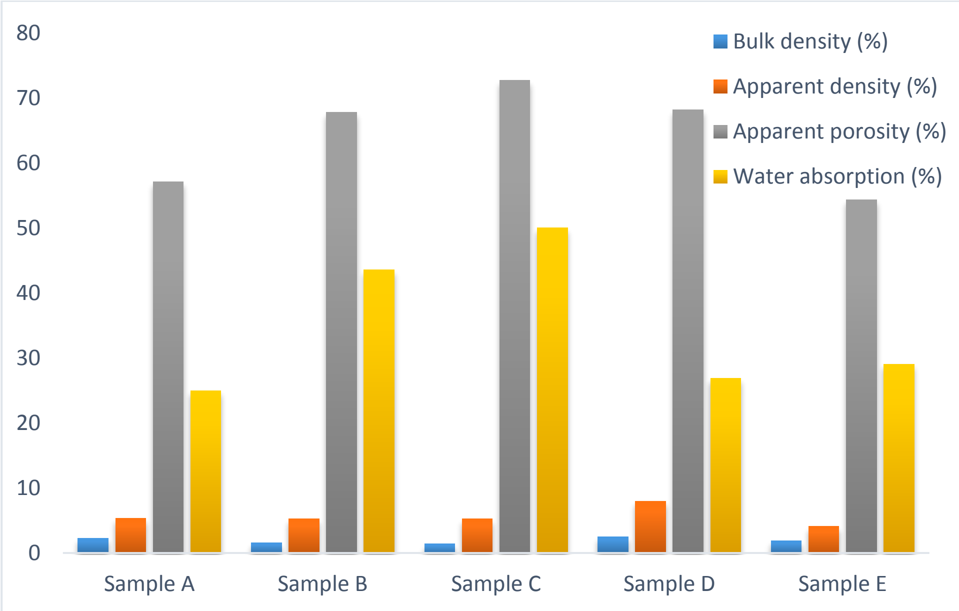


Fig 6: Gragh of Bulk density, apparent density, Apparent porosity and Water absorption for brick samples

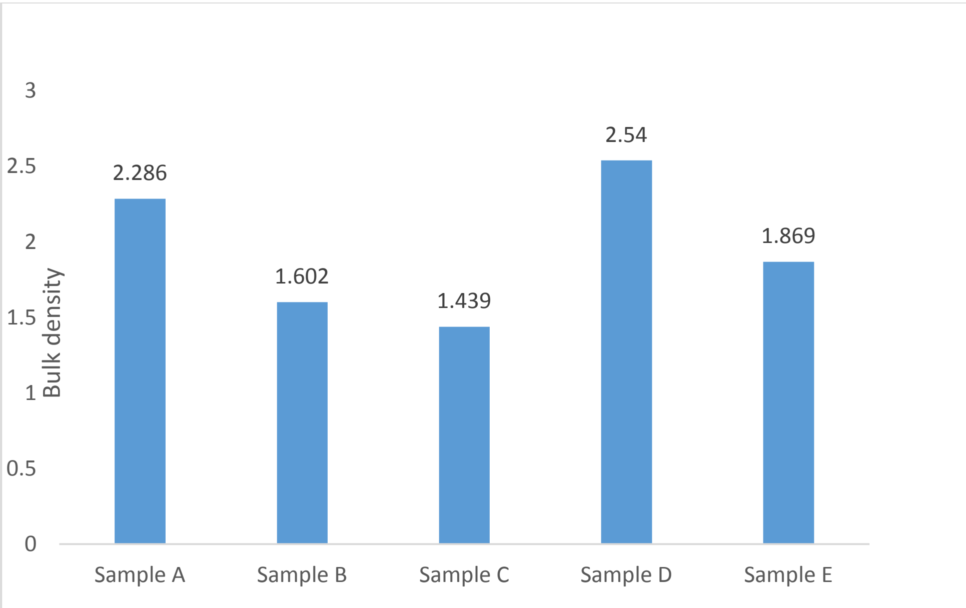


Fig7: Bulk densities for the brick samples

From the bulk density result obtained, it was observed that sample D had the highest value followed by sample A, sample E, sample B and then sample C which has the lowest value. It can then be said that increase in additives content lowers the bulk densities of the bricks. Bricks with higher bulk densities exhibit higher volume stabilities and strength.

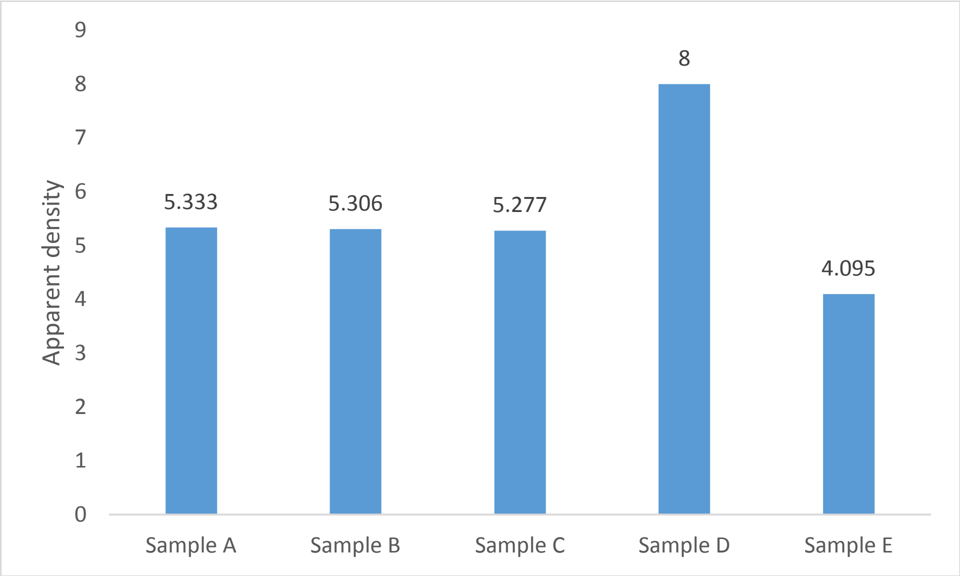


Fig 8: Graph of Apparent density of brick samples

It is observed from the apparent density table that sample D has the highest value followed by sample A, sample B, and sample C and then sample E which has the lowest value. This implies that the higher the percentage additives, the lower the apparent densities of the bricks. Sample D which contains five percent of luffa sponge only has the highest apparent density. It can then be said that luffa sponge has a higher tendency of increasing the apparent density of the bricks more than rice husk.

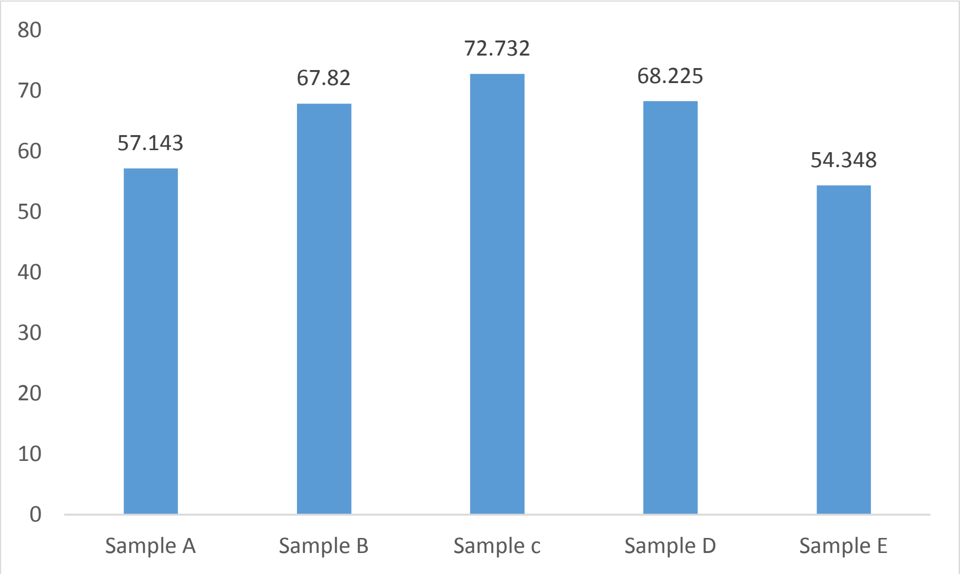


Fig 9: Graph of Apparent porosity of brick samples

From the table of apparent porosity, it is observed that the sample with the highest value is sample C followed by sample D, sample B, sample A and then sample E. This indicates that the higher the percentage of additives in a sample the higher porosity of that sample. This is as a result of the rice husk and luffa sponge burning out during firing and leaving plenty of pores in the brick. These pores make the brick porous.

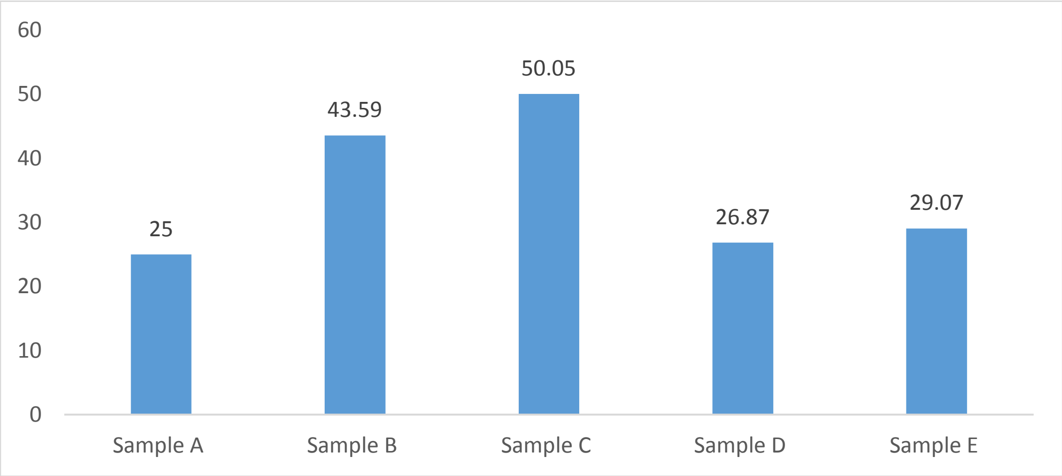


Fig .10: Percentage water absorption of brick samples

The water absorption table reveals that sample C is with the highest value followed by sample B, sample E, sample D and finally sample A. This indicates that the higher the additives the higher the percentage water absorption. This is because the burnt rice husk and luffa sponge leaved pore spaces

Table 5: Loss on Ignition

Sample A	Sample B	Sample C	Sample D	Sample E
0.091	0.637	9.564	2.439	11.795

From the table of loss on ignition, it is observed that the values decreased from sample E which has the highest value followed by sample C, sample D, sample B and finally sample A.

Table 6: Cold crushing strength

Sample Codes	Sample parameters	Load (N)	Area (cm^2)	C C S (N/cm^2)
Sample A		1600	16	100.000
Sample B		1500	16	93.750
Sample C		1100	16	68.75
Sample D		1350	16	84.375
Sample E		1750	16	109.375

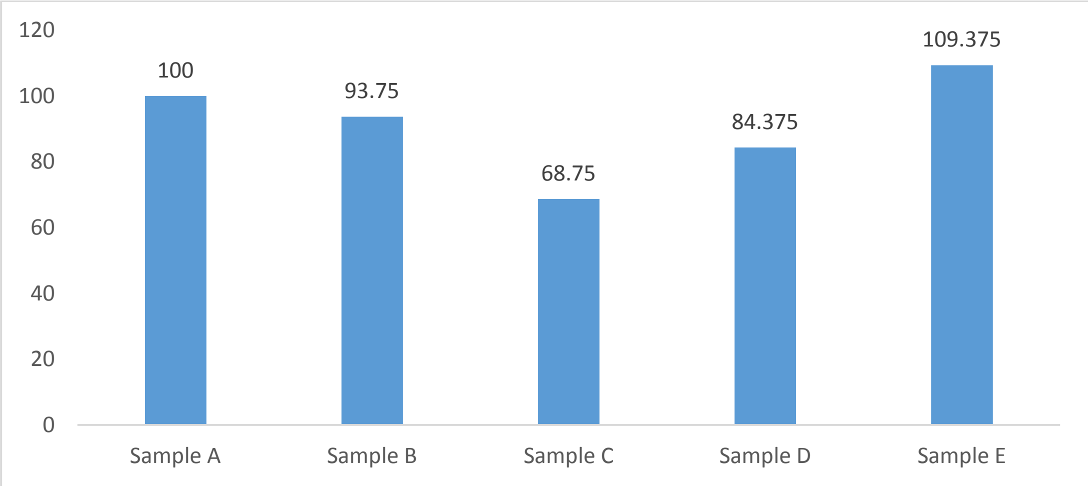


Fig .11: Graph of C C S of brick samples

From table 6 above, it can be observed that the cold crushing strength decreased in the following order, sample E with the highest value, followed by sample A, sample B, sample D and sample C. sample E which has the highest value of cold crushing stenght contains rice husk only and is higher in percentage than luffa sponge added to sample D. This can imply that burning of luffa songe within the clay has a tendency of reducing the cold crushing strength of the clay.

Table 7: Thermal conductivities of the brick samples

Sample A (W/mk)	Sample B (W/mk)	Sample C (W/mk)	Sample D (W/mk)	Sample E (W/mk)
0.0131	0.0129	0.0098	0.0125	0.01359

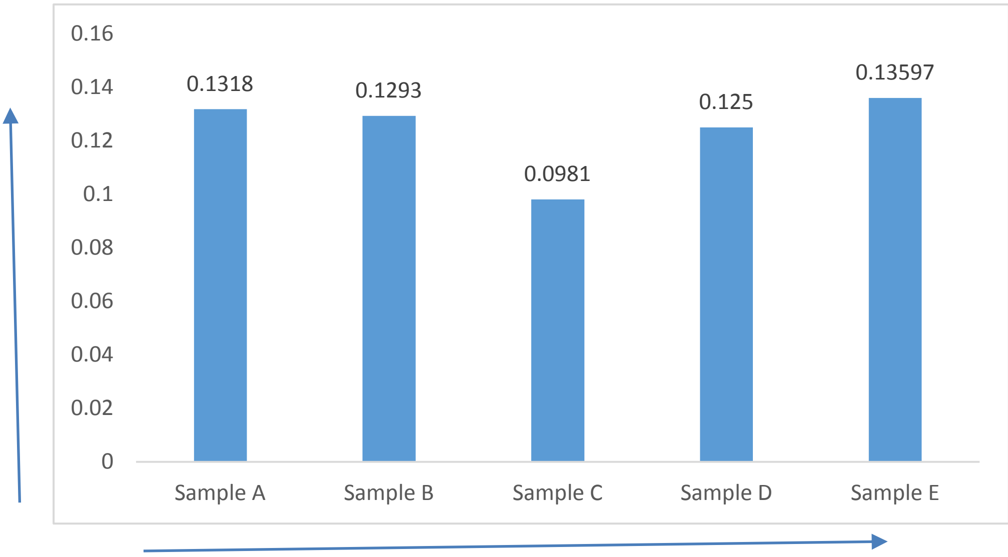


Fig 12: Graph of Thermal conductivity of brick samples

Table 7: shows that the thermal conductivities of the samples decreased in the following order: sample E > Sample A> Sample sample B> Sample D> Sample C. It is observed that

the thermal conductivities decreased with increased in the porosities of the samples. This is because the pores contain some quantities of air which are very poor conductor of heat.

Slag Attack Resistance

The brick samples were packed with slag gotten from gray cast iron melted in a cupola furnace. They were heated until the slag melted and then soaked for one hour. They were furnace cooled and sectioned. The observation showed that the five brick samples have good slag resistance because the melted slag did not penetrate inside any of them.

Conclusion

It was observed that:

1. There was no colour change in the bricks before and after firing up to 1000^oC
2. All the bricks can withstand a temperature of 1000^oC since none of them crumbled during firing
3. Increase in rice husk and luffa sponge increases porosity of the bricks and increase in porosity decreases thermal conductivity.
4. Luffa sponge has a higher tendency to increase the density of the bricks as observed from the density analysis.
5. All the bricks have good slag attack resistance

The results showed that the five bricks have good refractory properties. Therefore, the bricks are suitable for insulating refractories. They can be used in making linings of ovens, kilns, heating furnaces and ladles. More research should be done to improve the properties of the bricks and to find the best mixing ratio.

Since Nigeria is blessed with a lot of clay deposits and refractory materials, efforts should be made to exploit them. This will discourage the importation of refractories and enhance a rapid industrial and economic development in the country.

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