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Development and Characterization of Rice Husk Insulating Bricks from Two Selected Deposits in Ekiti State, Nigeria

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Abstract: ***In this work, the suitability of using Kaolin from two selected deposit sites in Ekiti state (Ijero and Ikere), Rice husk, and plastic clay to produce insulating firebrick was experimentally investigated and the optimal ratio of these constituents was determined. Brick samples of different compositions were produced from the two kaolin samples and fired to a temperature of 1200ºC. . The surviving samples gave the following limits of results: - shrinkage: 0.51% - 1.3%; apparent porosity: 13.28% - 92.00%; bulk density: 1.6g/cm^3 – 9.5g/cm^3; apparent density: 0.1g/cm^3 – 14.3g/cm^3; and thermal conductivity: 0.005W/mK - 0.117W/mK. The crushing strength of Ijero firebricks ranges from 0.0.KN to 121KN and Ikere from 0.00KN to 15KN, the average compressive strength of the produced brick is 23.5 KN/mm^2. The results showed that they all had good insulating characteristics, and showed good level of refractoriness.***

Keywords: Refractories, Firing, Shrinkage, Firebricks, compressive strength

1. Introduction

Insulating refractory firebrick is a class of brick, which consists of highly porous kaolin or fireclay. They have low thermal conductivity, and are lightweight. The growing needs of insulating firebricks in industries have promoted investigation into various alternative uses of more economical materials. The demand for high insulation ability bricks is increasing (Sabrah and Burham, 1981). Thermal conductivity is a decisive factor for the heat-engineering concept of thermal insulating material (Dondi *et al*., 2004). Over the years, insulating firebricks have been made in a variety of ways, such as mixing organic matter with clay and later burning it out to form pores; the presence of entrapped air in this pores have thermal insulating characteristics and thus make the porous fire brick structure suitable for back up insulation.

Thermal conductivity increases with the decrease of porosity. Porous refractories have air entrapped in their pores and this acts as a non-heat conducting material. According to the literature of(Chesti, 1986) that rice husk being a good combustible material that can be used to produce insulating firebrick since their complete combustion could create pores within the bulk of a clay composite material. The amount of the entrapped air increases with porosity of the refractory and hence its thermal conductivity decreases. Refractories used in melting furnaces, etc, should have low thermal conductivity to ensure least heat losses and maximum heat efficiencies, whereas in recuperators where maximum heat transfer is desired to take place, refractories with high thermal conductivities are used. Insulating refractories have low thermal conductivities.

The term refractory means hard to fuse according to (Chesti, 1986) however; refractories are mostly made of non – metallic minerals used to withstand high temperature as defined by (American society for testing and materials, 1975). Characteristically, Refractories are usually used to withstand strains, abrasion, impact, thermal shock, and corrosion. The characterization is technically used both in the design and construction of glass melting furnaces and some other heat manufacturing industries (Hassan, 2001 and Guo, 2004).

Heat insulating and building materials have thermal conductivity range of 0.023 to 2.9W/mºC (Rajput, 2003; Chesti , 1986)‟s Literature shows that high alumina wool, which is used as insulating material, has a thermal conductivity of not more than 0.29 W/mk. Kaolin has several industrial applications as new uses continue to be discovered, due to its several properties, to which includes chemical inertness over a wide range of acid and alkaline conditions. Some applications of kaolin require very rigid specification including particle size distribution, viscosity, and colour.

The thrust of this study is to examine the effect of rice husk on the engineering properties of Ijero and Ikere Kaolin in the production of insulating fire bricks for industrial applications such as glass furnace lining, and incinerator lining.

2. Materials, Equipment and Methods

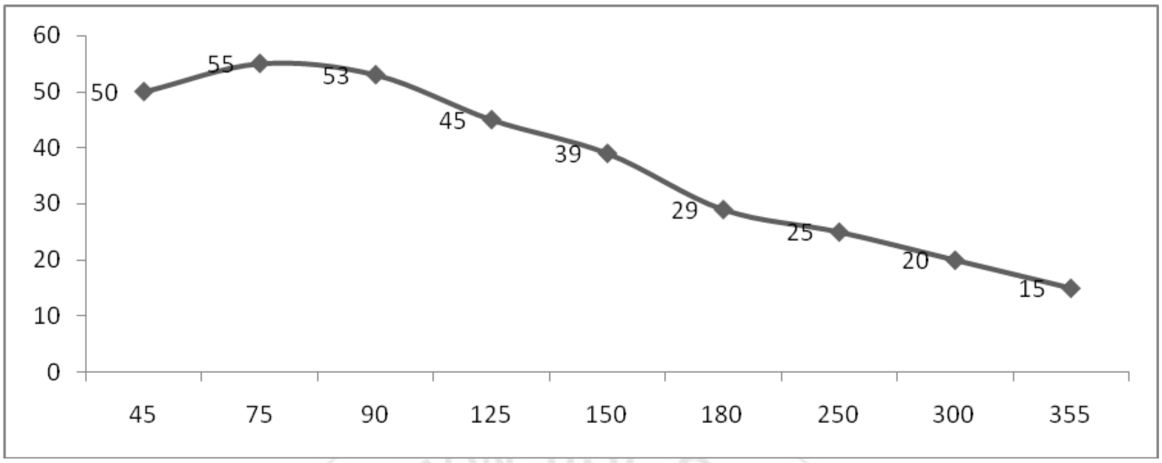
The materials used in this work include Kaolin, plastic clay, rice-husk, sodium silicate and water. The equipment employed include sieve, jaw crusher, pulverizer, electric weigh balance, hydraulic press machine, kiln, container, measuring tape, measuring cylinder, thermocouple, thermal conductivity apparatus.

2.1 Material and Methods

The refractory materials used for the various mixes are clay from two deposits in Ijero Township and Fagbohun area of Ikere, Ekiti State, South West Nigeria and Rice Husk obtained from Igbemo Ekiti rice processing mill. The clay samples were chemically analysed at the Centre for Energy Research and Development, Ahmadu Bello University Zaria. 50Kg of clay samples were collected from Ijero and 50kg from Ikere deposits respectively.

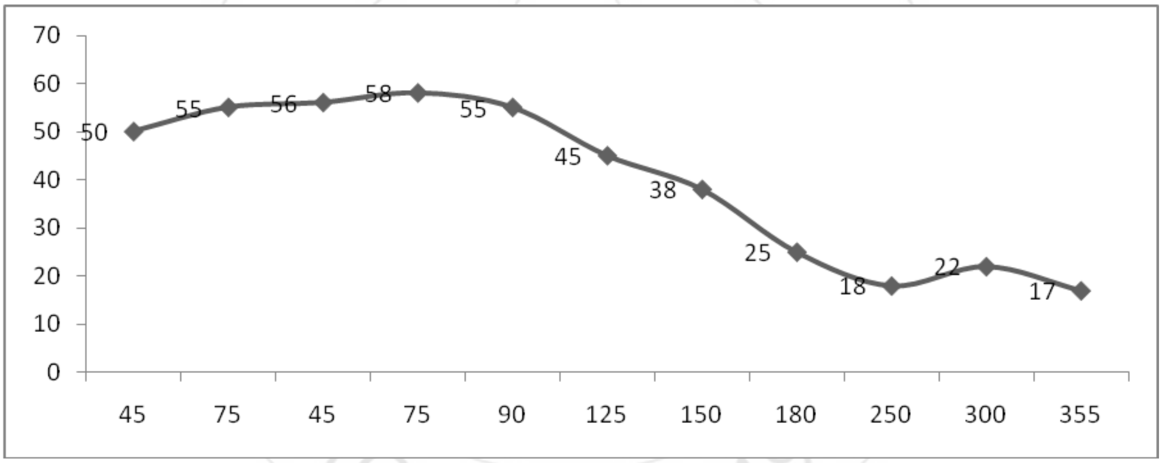
2.2 Materials Processing

There are numerous methods of beneficiating Kaolin, The complicated nature of the treatment sequence primarily depends on the nature of the deposit and the desired product (Prasad,et al., 1991). The clay samples were processed crushed using jaw crusher and pulverized. The two clay samples were sieved to the desire particle sizes (125μm). The collected Rice husk sample was sieved to desire particle size (30μm).



Sieve sizes (μm)

Figure 1: Grain size distribution percentage of clay deposits at Ijero, Ijero Local Government Area of Ekiti State, Nigeria (sample A) at 15meters depth



Sieve sizes (μm)

Figure 2: Grain size distribution percentage of clay deposits at Fagbohun, Ikere Local Government Area of Ekiti State, Nigeria (sample B) at 15 metres depth

Table 1: Composition of kaolin/rice husk mixture (% and gram) Total weight = 100g)

Sample	*Kaolin (%)*	*Rice husk (%)*	*Kaolin (g)*	*Rice husk (g)*	*Total kaolin/rice Husk % mixture*
1	100	0	100	0	100
2	90	10	90	10	100
3	80	20	90	20	100
4	70	30	70	30	100
5	60	40	60	40	100

Production of insulating brick samples

The processed fireclay and rice husk were stored in their respective labelled dry containers. Equivalent percentage rice husk compositions were measured with different weight value of kaolin samples. These materials were wet-mixed until a satisfactory and even distribution of aggregate was achieved in a container and each aggregate were used to mould firebrick samples in a mould of dimension (7 X 10 X 21) cm. The mixture was placed inside the hydraulic press machine, and then compressed; the pressure of 1000k_g/cm^3 was applied before it was demoulded from the pressing machine. The brick samples were left to dry atmospherically and then sun dried for 4 weeks. This increased their green strength and made them safe for subsequent handling.

The dried firebrick samples were finally fired to a temperature of 1200°C in a muffle Kiln. This resulted in the burning out of the rice husk and leaving plenty of pores in the finished bricks. The initial and original length, dried length, fired length, wet weight, and dry weights were determined.

3. Results

Linear shrinkage

The test specimens were dried in for 24 hours at 110°C their dimensions (length, breath and height) were measured, Lengths measured were recorded as dry length (D_L) and then fired in a muffle kiln to temperature of 1200°C, cooled to room temperature and their measurement were taken as fired length was recorded as (F_L). For each sample, one different specimen were tested and used to calculate the linear shrinkage using formula (3):

$$\% L_S = \frac{D_L - F_L}{F_L} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$\% L_S$ is the percentage linear shrinkage of the specimens.
D_L – Dry Length
F_L – Fired length

Bulk density, apparent density, apparent porosity, and percentage water absorption tests

The test specimens were dried at 110ºC for 24 hours to ensure total water loss, and later fired up to 1200ºC in an electric furnace. Their fired weights were measured and recorded. They were allowed to cool and then immersed in a beaker of water. Bubbles were observed as the pores in the specimens were filled with water. Their soaked weights were measured and recorded. They were then suspended in a beaker one after the other using a sling and their respective suspended weights were measured and recorded. Their respective bulk density, apparent density, apparent porosity, and percentage water absorption were calculated using the formulae:

Bulk Density = D/ (W-S) (g/cm^3) ....(4)
Apparent Density = D/ (D-S) (g/cm^3) ....(5)
Apparent Porosity = (W-D)/ (W-S) ×100 ....(6)
% Water Absorption

Where: D = Weight of fired specimen, S =Weight of fired specimen suspended in water, and
W = Weight of soaked specimen suspended in air

Thermal Conductivity Test (using Ibrahim's thermal conductivity apparatus; the steam method)

Test specimens of area 0.002m^2 and thickness of 0.01m were cut from their respective mother bricks. The test specimens were tested one after the other. Each specimen was fixed in the provided space within the equipment. A conical flask containing 50ml of water was placed directly above and in contact with the specimen. A cork having a thermometer passing through it was used to cork the mouth of the conical flask. The thermometer reads the temperature changes of the water in the flask. The test section was then closed and the initial water temperature was noted. A second thermometer with the aid of a cork was inserted into the steam outlet pipe offset to monitor the steam temperature so as to ensure a constant base temperature of 100ºC. The boiler water outlet valve was closed while 5 litres of water was measured and poured into the boiler. The steam inlet valve, outlet valve, and condensate outlet valve were all closed. With the boiler cover remaining opened, the boiler was switched on. Immediately the water started boiling, the boiler cover was closed, while the steam inlet valve was fully opened with all the remaining valves closed. Timing commenced with the aid of a stopwatch immediately the steam inlet valve was opened. The testing was timed in each case for 10 minutes and final temperature of the water in the beaker was noted at the end of time. Each specimen was tested (experimented) twice and a mean temperature value was obtained. At the end of each experiment, the steam outlet valve was opened to release steam. The water in the boiler was refilled to maintain 5 litres and the experiment was repeated as stated above for other specimens.

The value of the thermal conductivity, K for each of the specimen was determined using the formula:

$$K = 2.303MCL/A\,[\log(\theta 1/\theta 2)]/\tau \quad (7)$$

Where
- K = thermal conductivity of the specimen,
- T1 = temperature of steam k,
- Ti = Initial temperature of water in conical flask,
- T4 = Final temperature of water in conical flask,
- τ = Time (s), A = Specimen area, (m^2),
- M = mass of water in conical flask k (kg),
- C = specific heat capacity of water in conical flask (J/kgk),
- L = thickness of specimen (m),
- θ1 = T1 - Ti,
- θ2 = T1 - T4.

Table 2: Major Chemical Composition Evaluation of the samples

Samples (%)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	LOI
A	50.3	35	1	2	0.5	1	2.5	1.2	10
B	54.3	34	0.5	0.6	0.6	1	0.6	0.4	8

A – Ijero clay sample
B – Ikere clay sample

Table 3: Specific Gravity

Clay Sample	Specific Gravity
A	2.68
B	2.58

Table 4: Bulk density

Clay Sample	*Bulk Density*
A	2.5
B	2.7

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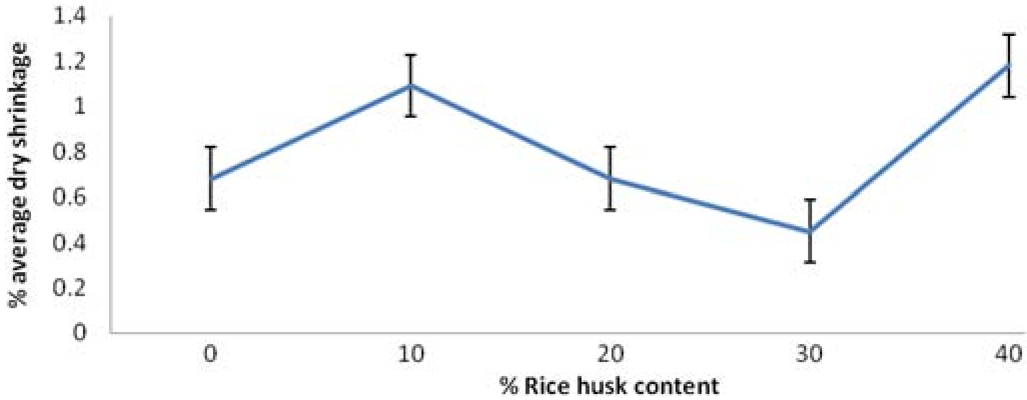

Figure 3: % average dry shrinkage of sample A firedbrick

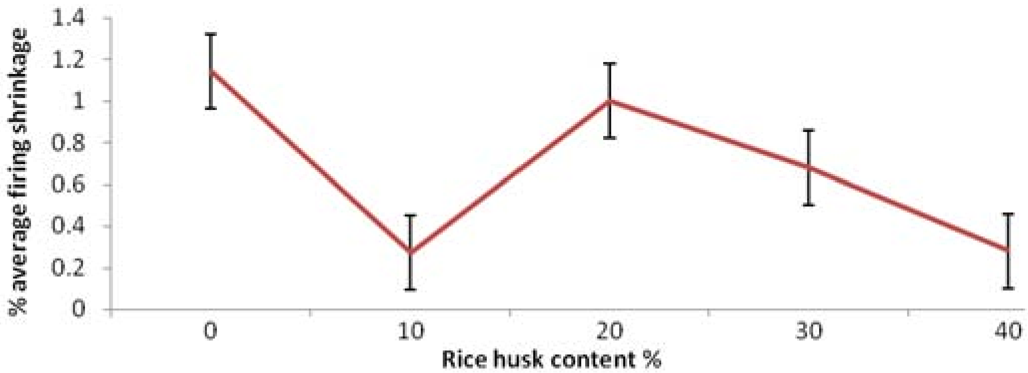

Figure 4: % average firing shrinkage of sample A firebrick

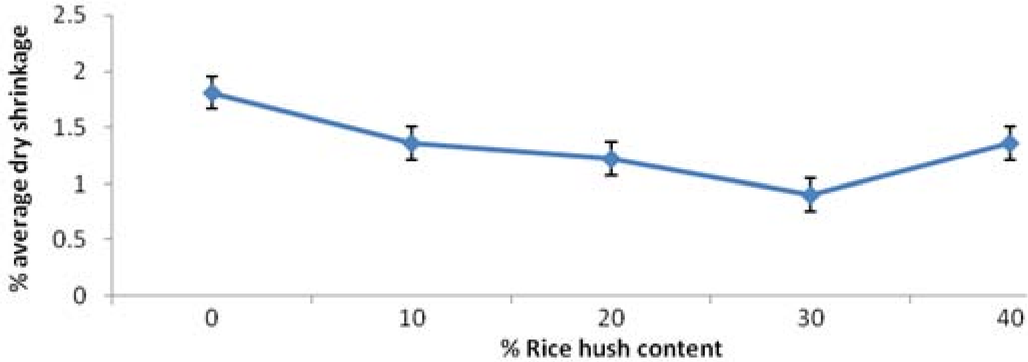

Figure 5: % average dry shrinkage of sample B firebrick

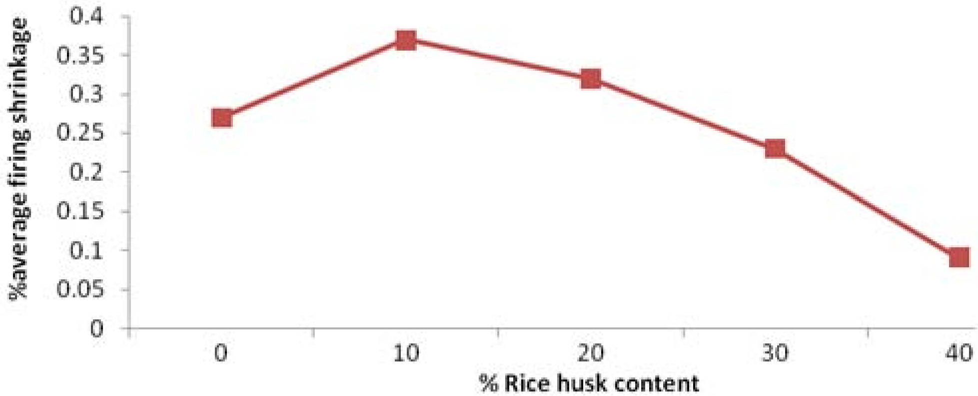

Figure 6: % average firing shrinkage of sample B firebrick

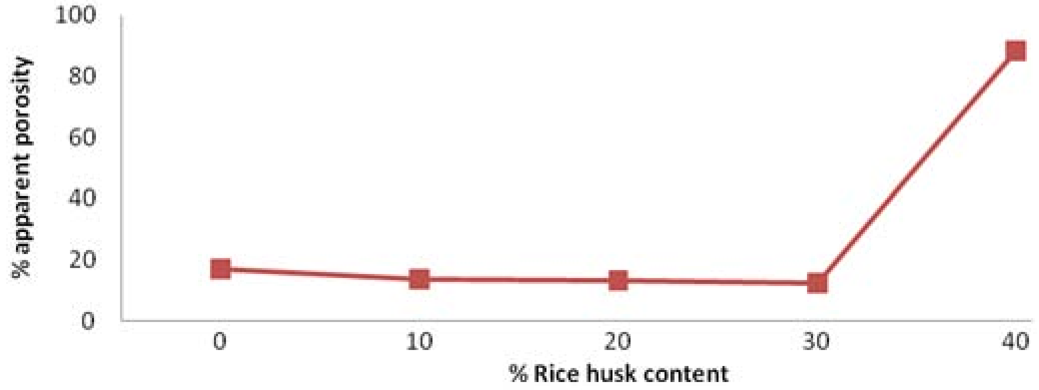

Figure 7: % apparent porosity at 110 °C for sample A

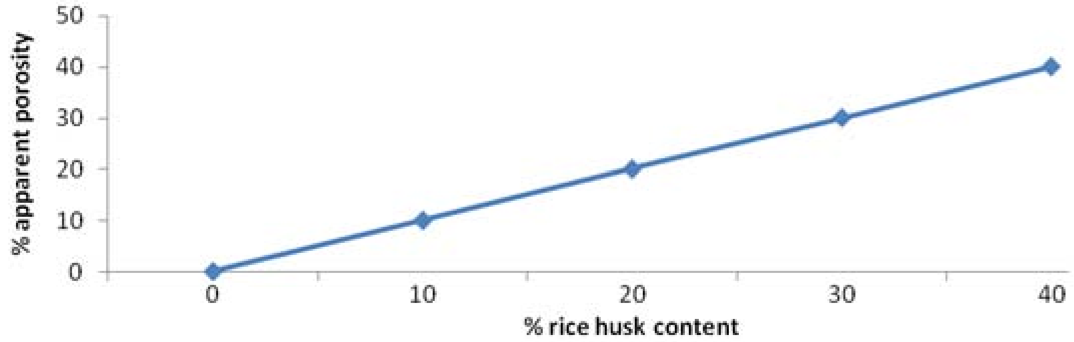

Figure 8: % apparent porosity at 110 °C for sample B

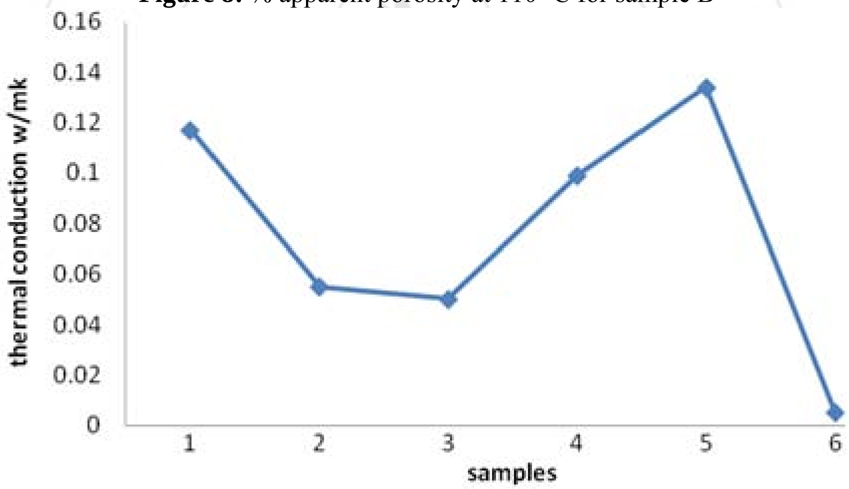

Figure 9: Thermal Conductivity of firebricks at 100°C steam temperature

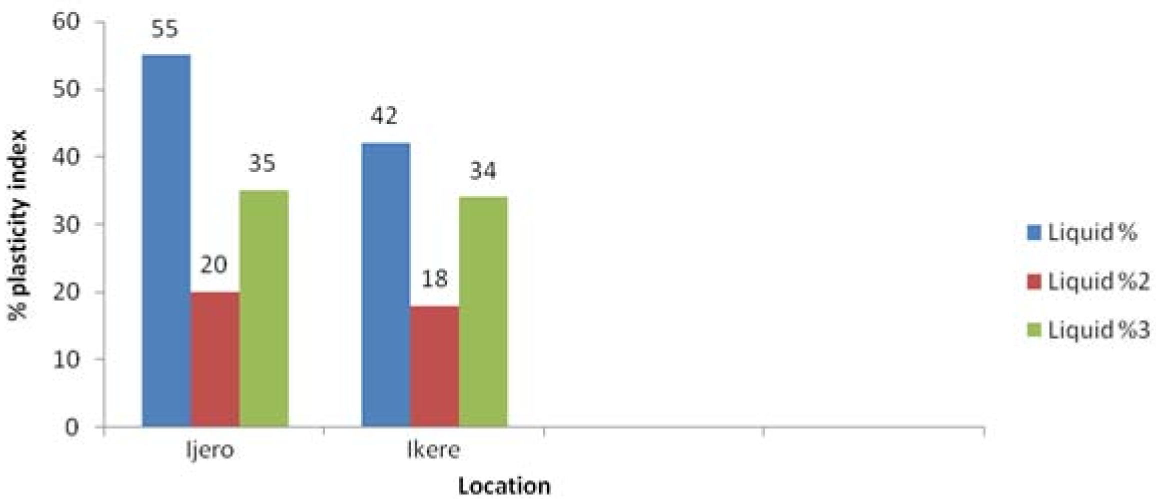

Figure 10: Percentage plasticity indices of cardinal deposits of both Ijero and Ikere fireclays

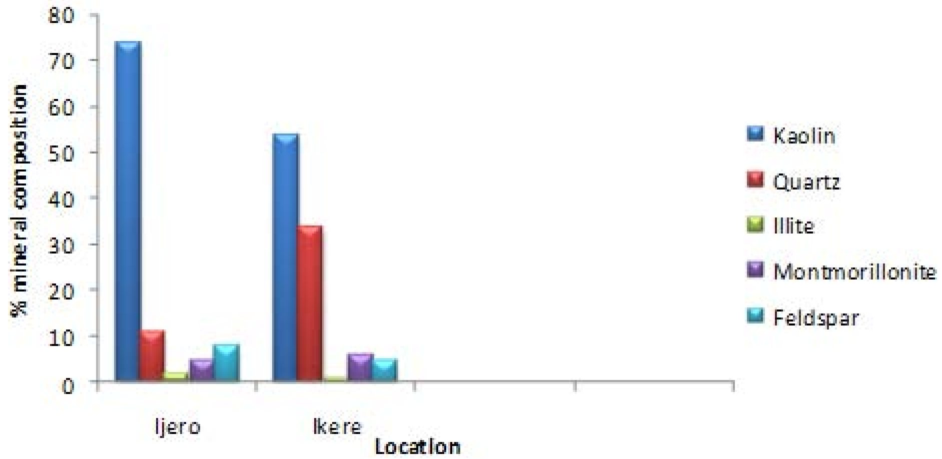

Figure 11: Percentage composition of major mineral deposits of both Ijero and Ikere

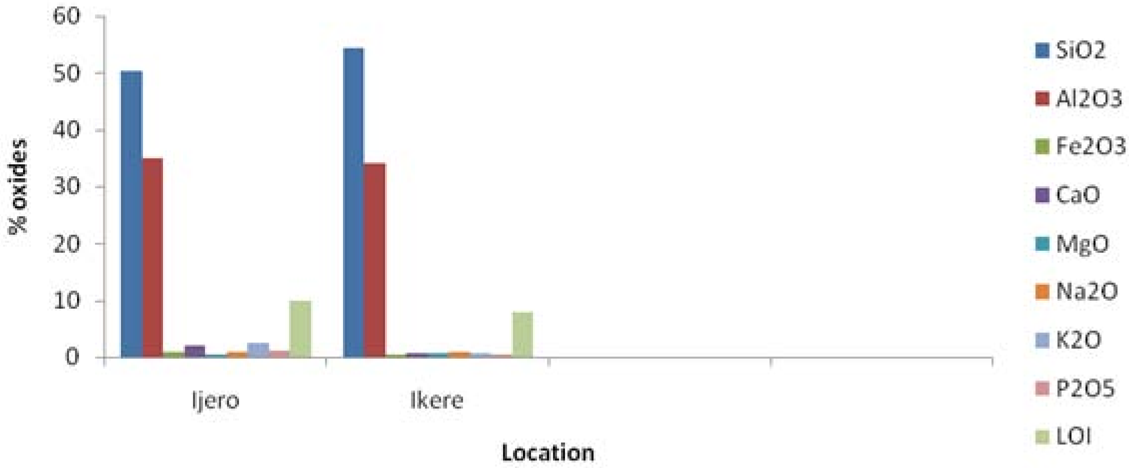

Figure 12: Major oxides present in the fireclays of Ijero and Ikere

4. Discussions

The value of alumina and silica contents for Ijero Ekiti fireclay are 35% wt and 52.3% wt respectively and alumina is 34% wt and silica is 54.3% wt for Ikere Ekiti compared with refractory standards (25-45wt% for alumina and 55 - 75%wt for silica), coupled with low levels of iron and organic matter makes the clay sample very suitable for refractory material.

The results from (fig 3 - 8) showed the total percentage shrinkage value of the sample at 1200^{o}C ranges from 0.51% for Ijero clay to 1.2% and 1.3% respectively. It is clear that for the varying weight percent of rice husk in different fireclay samples, the higher the fireclay content, the lower the linear shrinkage.

The highest bulk density is 2.16g/Cm^3 while the lowest is 1.97 g/Cm^3 for Ijero fireclay. Ikere fireclay showed the highest bulk density of 2.35 g/cm^3 while bulk density is 2.13 g/cm^3. The higher the percentage of rice husks in a sample, the lower the bulk density (Gerhard, 1987).

Figure 9 showed the lowest thermal conductivity 0.005W/mk with the highest as 0.117W/mk, these shows that high percentage of rice husk, which burns out during firing and leaves plenty of pores in a brick induces low thermal conductivity of that brick. Thermal conductivity has a relation with density and porosity of a brick. It decreases with decrease in density and increase in porosity of a brick. Porous refractories have poor heat conductivity and therefore, act as good insulators.

The crushing strength of Ijero firebricks ranges from 0.0.KN to 121KN and Ikere from 0.00KN to 15KN, the average compressive strength of the produced brick is 23.5 KN/mm^2

The compressive strength of the samples was increased steadily with percentage volume of sodium silicate as against ball clay used as binder.

Porosity test show that samples with high rice husk content show the highest porosity of 75.93% while the lowest porosity is 37.48% which is the result of rice husk burning out during firing and leaving small pores in a brick. These pores make a brick porous.

5. Conlusion

Based on the properties of the bricks samples tested and analyzed in this experimental work it can be concluded that:

1) The local raw materials –kaolin plastic clay and –rice husk are suitable for the production of insulating firebricks. And also ijero kaolin is the best that is suitable for insulating firebricks than ikere kaolin clay.
2) The mixing ratio used for samples B gave the best composition of strength and thermal conductivity and would perform best when used for hot-face insulating

firebricks. It can indeed serve well as firebricks both for backup and hot-face insulation.

3) If the production of insulating firebricks is commercialized, it will save Nigeria some foreign exchange. Further work is therefore recommended in this regard.

Rice husk insulating fired bricks

References

[1] Ahmed S.A.(1998). Development of phosphate bonded fireclay refractory castables ,M.Sc.Thesis
[2] Bodede, O. R. (2012). Effect of Sodium Silicate as a Binder on Kaolinite Clay for Lining Heat Treatment Furnaces, Unpublished M.Eng. Thesis, Department of Metallurgical and Materials Engineering, The Federal University of Technology, Akure. Pp. 43, 68 – 70.
[3] Borode JO, Olasupo OA (2009). “Development of Insulating Refractory Ramming mass from some Nigerian Refractory Raw Materials”, Journal of Materials & Materials characterization & Engineering, 8(9): 667-678.
[4] Chester‟s A.R.(2005). “Aluminum silicate‟‟‟ Refractory manufacture iron and steel instate, London; Page 262-175.
[5] Chesti A. R. (1986), Refractories: manufacture, properties, and applications, Delhi, Prentice-Hall of India Private Limited,
[6] Chester‟s J.H.(1973). „‟Ngerian indigenous technology.
[7] Doyle J.P.(2000). „‛Refractories material; „Glass making today; Red hill Portcullis press N.Y.; Pages 47-52.
[8] Dondi, M., Mazzanti, F., Principi, P., Raimondo, M. and Zanarini, G. (2004). Thermal Conductivity of Clay Bricks, Journal Material of Civil Engineering, 16(1): 8-14.
[9] Gerhard M (1989). “Basic Know-how for the making of burnt brick and tiles”. Misereor, Aachen, Fedral Republic of Germany
[10] Griffin, G.W (2001). Inorganic quantitative analysis. The Blackiton Inc. Toronto and stonghton,kent.U.K.Soc.1950.
[11] Guo (2004). refractory‟s material VI.5. Marshal Cavendish Ltd London; page 557-563.
[12] Hassan SB, Adewara JOT (1993). “Refractory properties of some Nigerian Clays”. Nigerian Society of Engineering, Trans. 28(3): 21 – 5
[13] Hassan S.B.(2001). Composite materials; Elsevier press Amsterdam, U.K.
[14] Ibrahim I.(2005). Design, construction and testing of thermal conductivity equipment, B.Eng. Thesis, Yola, Federal University of Technology, Yola, Nigeria.
[15] Prasad M.S, Reid K.J, Murray H.H. (1991). “Kaolin: Processing, Properties and Applications”. Elsevier Applied Clay Science,. Vol. 6. Pp.87-119
[16] Sabrah, B.A. and Burham, N. (1981). Thermal Studies of Basalt and Clay for the Manufacture of Building Bricks, Thermochimica Acta, 51(2-3): 315-323.
[17] Vashenko, E et al (2004). Mettlurgical furnace part II Mosco, Russia Publishers