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Industrial Potential and the Suitability of Emu-Agbaja, Oworo Clay for the Production of Refractory Bricks

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***Abstract*— Five brick samples of different line blends were made and fired at a temperature of 13000C. All the Five samples survived firing with no single one crumbling. The brick samples gave the following limits of results. Total shrinkage: - 6.52%, - 8.69%, Effective moisture content: - 22.22%, - 29.27%, Modulus of rupture: – 1.25kgf/cm2 - 2.20kgf/cm2. Apparent Density: 3.413g/cm2 - %, 69.26g/cm2. Bulk density: 1.080g/cm3. - 1.414g/cm3, Drying Shrinkage: - 1.30%, - 3.47%, Fired shrinkage: - 3.15%, - 6.67%, Apparent Porosity: 58.57%, - 79.27%, Water Absorption Test: 41.41 %, - 85.10%, the results showed that almost the entire brick samples had good insulating characteristics.**

***Index Terms*— Potential, Suitability, Refractory, Kiln, Binder.**

I. INTRODUCTION

Refractories are materials having high melting points, with properties that make them suitable to act as heat-resisting barriers between high and low temperature zones. Refractories are useful in constructing application-specific high temperature areas/surfaces, particularly in furnaces of boilers, as they minimize heat losses through structure. A kiln may be described as an enclosure to contain heat. Potters use it to fire their pots and they have developed a countless number of different kiln types, each one reflecting the demands of local markets, tradition, skills and materials.

Emu – Agbaja, Oworo, Lokoja is a town located in the heart of Kogi State. It is an ancient town at the Western Senatorial District of the State. The town is naturally empowered with kaolin at a commercial quantity. Kaolin is a commercial term used to describe white clay composed essentially of kaolinite, Al4Si4O10 (OH) 8. The term is typically used to refer both the raw clay and the refined commercial product. (Bloodworth, 1993).

A. *Statement Of The Problem.*

Insulating bricks are generally become popular in the world today as a result of technology advancement. Insulating bricks can also be referred to as refractories. According to Hloben, (2000) refractory literally means “Stubborn to withstand not only heat but in many cases chemical attack, abrasion, thermal shock and rough handling”

Insulating bricks are not always readily available in the country, most of the users of refractory in Nigeria such as iron and steel industries, cement, glass, refineries, bakeries and ceramics industries depend on the importation of such. When imported the cost is always exorbitant due to the foreign exchange. There are only few manufacturers within the country and production depends mostly on demand by the users. With the endowment of kaolin in Kogi State, thus, necessitating this research. In the light of these points the researcher dim it fit that it is expedient to go into this type of research in other to facilitate the production, availability and the usage of insulating bricks. Thus, the statement of the problem of this study is the exploration of Emu - Oworo kaolin for the production of insulating refractory bricks

B. *Objectives Of This Study Are To*

1. produce standard refractory bricks with Emu - Agbaja kaolin in Kogi State, Nigeria.
2. use suitable pore formers that are available within our reach in the state to produce good quality bricks.
3. carry out performance and property tests on the bricks made.

II. LITERATURE REVIEW

A. *Insulation Bricks.*

The materials that has the ability to retain their physical shapes and chemical identity when subjected to high temperatures. Refractories are inorganic, non-metallic, porous and heterogeneous materials composed of thermally stable mineral aggregates, a binder phase and additives (Henrik, 1987). According to Henrik, 1987 insulation brick is also refractory brick but characterized by the presence of large amount of porosity in it. The pores are mostly closed pores. The presence of porosity decreases the thermal conductivity of the refractory drastically. Therefore because of the porosity refractories are popularly referred to as insulation brick. The bulk densities of these bricks are usually low due to the presence of the porosity in these bricks.

B. *Importance of Insulating Bricks to Kiln.*

The need to minimize the waste of fuel in any firing process in ceramics is very important, so using insulating bricks for construction of kiln go a long way in reducing the cost of

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fueling during firing processes. A large amount of heat is lost through the walls of kilns. Proper insulation of the structure can reduce this loss to negligible amount. Good insulation does not only reduce the quantity of fuel consumption but also helps in keeping the kiln at a more uniform temperature and makes working conditions in the environment of the kilns very much more pleasant (Ewule, 1987).

C. Physical Properties of Insulating Fire Bricks:

According to Traditional ovens, (2014) the following points are the physical properties and chemical composition of insulating fire bricks.

- Bulk Density: 604 kg/m³
- Modulus of Rupture: 1.52MPa
- Permanent Linear Change on reheating 24hrs. @ 1280°C: 1.95%
- Cold Compressive Strength: 2.01 MPa
- Thermal Conductivity 300°C: 0.2 W/m.°K
- Thermal Conductivity 750°C: 0.28 W/m.°K
- Thermal Conductivity 1000°C: 0.32 W/m.°K

D. Insulating Fire Bricks Chemical Composition:

- Alumina: 37 %
- Silica: 61%
- Ferric Oxide: 1.6 %

III. MATERIALS AND METHODS

Table 1: The Results of the chemical analysis on Emu - Agbaja, Oworo and Ganaja-Meme clay.

Element	Emu – Agbaja, Oworo Kaolin	Ganaja-Meme clay
SiO_2	54.80	46.80
$Al_2 O_3$	31.60	11.77
Na_2O	-	2.41
K_2O	0.88	1.40
CaO	0.409	6.47
MgO	0.002	1.05
TiO_2	3.13	-
Cr_2O_3	0.073	-
V_2O_5	0.09	-
MnO	0.15	0.02
Fe_2O_3	0.87	15.19
CuO	0.016	0.094
Ga_2O_3	-	0.0075
ZnO	-	0.023
Y_2O_3	-	0.025
I	-	0.30
PbO	-	0.006
NiO	-	0.019
SrO	-	0.15
L.O.I.	11.09	10.75
TiO_2	0.27	-
BaO	0.024	-

Source: *National Geosciences Research Laboratory, (NGRL) Kaduna (2019)*

A. Raw materials for Insulating Bricks

The materials used for the production of insulation bricks can be categorized into three namely aggregates, binders and combustibles/ pore formers

B. Kaolin, Binders and Combustibles

Kaolinite is a mineral belonging to the group of alumino silicates. It is commonly referred to as "China Clay" because it was first discovered at Kao-Lin, in China. The term kaolin is used to describe a group of relatively common clay minerals dominated by kaolinite and derived primarily from the alteration of alkali feldspar and micas. Kaolin is an industrial mineral used primarily as inert filler and common Kaolin is white, soft, plastic clay mainly composed of fine-grained plate-like particles (Murray, 1960)

Plastic clay can be used as binder is used in manufacturing of insulation brick. Other binders that can be used are ethyl cellulose, starch and molasses. Rice husk, sawdust, straw or low cost biomaterial are used as combustibles or pore former in manufacturing of insulation brick. However naphthalene, starch are also used for pore former in high duty insulation brick.

C. Insulating firebricks Production Procedures.

Dry-Press Process is to be used for the production of the insulating bricks because this process is particularly suited to clays of very low plasticity. Clay will be mixed with a minimal amount of water (up to 10 percent) left for five days to ferment for a better result, then pressed into steel moulds under pressures.

Sawdust will be screened through a mesh of at least mosquito net size. Mesh16 mesh 29 were used for the screening because if the particle are too big the resultant holes in the finished brick will allow the air inside to rotate, which means the air will transfer heat and this will defeat the purpose of production (Duggal, 2003)

D. Drying.

Wet brick from moulding or cutting machines will still contain some amount of moisture, depending on the method of production and so the bricks will be dried under the room temperature for the brick not to crack before firing.After the formation of bricks according to Sullayman, (2006) bricks need a totaldrying period of between 24 and 200 hours, depending on the size of the product and the atmospheric condition.

E. Firing

The bricks will be stacked in the kiln for firing. It is of the belief that after drying bricks in air the green brick still contains 9-15%of water (Ricks, 2011). During firing many changes use to take place such as evaporation of water vapour present in clays. This usually done in other to obtain stability, strength and brick colour.

Table 2:- Batch formulation for the Production of the Brick.

Materials	Kaolin % in volume	Ball Clay % in volume	Saw Dust % in volume	Dry weight (kg)	Wet Weight (kg)
Batch 1	Calcined Kaolin 50	20	30	8.5	10
Batch 2	40	20	40	7	10
Batch 3	40	10	50	6.5	9.8
Batch 4	30	20	50	6	8.7
Batch 5	50	Nil	50	5.75	9.4

Source: Laboratory and Studio Analysis (2019)

IV. REFRACTORIES TESTS

Thetests deals with the method and procedures that were used to achieve the set objectives of the study. In order to achieve the stated objectives the paper seeks to highlight the usefulness of information acquired from the review of the literature into the practical approach of the project. Some of the test samples of the bricks were done at Ahmadu Bello University (ABU); Zaria, Kaduna and Kogi State Polytechnic, Lokoja kiln building to avoid failure. A ceramist needs to be very sure about the strength and worthiness of bricks before used. Because of this the following physical and mechanical tests were performed to check the quality of the produced bricks.. Some of the important tests of refractories which were conducted are:

1) Soundness test
2) Hardness test
3) Structure test
4) Efflorescence test
5) Modulus of Rupture (M.O.R).
6) Absorption test
7) Shrinkage test
8) Porosity test
9) Bulk density and apparent test
10) Thermal shock resistance
11) Compression test

A. Visual Inspection.

The first test to be carried out was to check for any visual defects like crack and lamination by keen observation. It isexpected of a good quality brick to be regular in shape and size, refractories is an important feature in design since it affects the stability of any structure. Dimensional accuracy and size were also done because it is very important to enable proper fitting of the refractory shape and to minimize the thickness and joints in the process of construction. The corners were check with a "T" square ruler. This is to make sure that the sides are flat and the corners are all in 90odegrees. After this the good quality samples were selected for further characterization.

B. Sound Test

Another simple test that was conducted to see the suitability ofthe bricks was that two bricks were held within fingertips and lightly hit one against the other. They are to produce a ringing sound. The higher the pitch the harder the brick is. If instead of a ringing sound you hear a weak bad sound, one of the bricks is cracked. If they are hit little harder it is very likely the good brick will break the weaker one.

C. Hardness Test

Brick hardness was tested with finger nail by scratching the surface of the samples to see the level that the brick will scratch and if no impression is left on the surface, then the brick is said to be alright.

D. Structure Test

A sample from each batch after firing was broken and their structures examined. This is to determine the homogeneity of the bricks.

E. Efflorescence Test

The soluble salts if present in bricks can cause efflorescence on the surface of brick. This is the reason why the brick were tested to know if they contain soluble salts. A brick from each sample were immersed in water for 24hour. Then the samples were taken out and allowed to dry gradually under shade for some days. The absence of grey or other deposits on the surfaces indicates that there is absence of soluble salts. The observation was made with naked eyes.

F. Shrinkage Test

Test specimens from each also fired in gas kiln to temperature of 12000c. They were allowed to cool. The specimens were weighed and measured. And the fired weight and fired length was recorded. For each sample, 5 different specimens were tested and the averages of the above parameters were calculated and recorded. The drying shrinkage, firing shrinkage and the total shrinkage were calculated for each test specimen using the following formula:

$$\% \, Average\ Drying\ Shrinkage = (\text{OriginalLength} - \text{DryLength})/\text{OriginalLength} \times 100 \ \ldots\ldots\ldots (1)$$

$$\% \, Average\ Firing\ Shrinkage = (\text{DryLength} - \text{FiredLength})/\text{DryLength} \times 100 \ \ldots\ldots\ldots\ldots \quad (2)$$

$$\% \, Total\ Shrinkage = (\text{OriginalLength} - \text{FiredLength})/\text{OriginalLength} \times 100 \ \ldots\ldots\ldots\ldots .. (3)$$

$$\% \, Volume\ Change = (\text{OriginalVolume} - \text{FinalVolume})/\text{OriginalVolume} \times 100 \ \ldots\ldots\ldots \quad (4)$$

G.Modulus of Rupture (M.O.R).

Modules of rupture is the degree to which a material refractory or other materials cracks, tears,breaks, shatters, splits, burst, etc. This test was to assess the tolerance or beading strength of the refractory products against the force of breakage or crack due to application of certain amount of pressure or force. Monsanto Tensometer "N" an automated machine was used to obtain the breaking load. This was gotten at the strength of Material Laboratory, Department of Mechanical Engineering, Ahmadu Bello University, Zaria Nigeria. The rate, mode, and the amount of load or force that caused rupture were specified for each bar. The specimen bricks were placed between plates of the load breaking machine. Load is applied axially at uniform rate till failure.

Equation 1 was adopted for the Modulus of rupture calculation

$$\text{M.O.R} = \frac{3WL}{2bt^2} \left(\frac{\text{Kgf}}{cm^2}\right) \text{------------------------------------}(5)$$

Where L = the distance between bearing edges (M)
W = the load at which the specimen fails (N)
b = the width of the specimen (M)
t = the thickness of the specimen (M)

V. MODULUS OF RUPTURE (M.O.R).

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H.Apparent Porosity.

Samples of all the batches were used for the measurement as per random sampling, dry weights of the samples were recorded. The samples were then immersed in water and boiled for 2 hours. These samples were kept for twenty - four hours in the water bath in ordered to insure complete weighing the entire sample. Suspended weights of samples were taken by immersing the sample in water bath. Soaked weight of the samples were noted after removing the surface water by a wet cloth. The density and apparent porosity of the each sample 1-5 were calculated using the below formula. This type of measurement used is called Archimedes method.

$$Apparent\ Porosity = \frac{W-D}{W-S} \times 100\ \% \text{ --------------------------------- } (6)$$

Where *W = soaked weight*
S = suspended weight
D = dry weight.

I. Bulk Density:

The bulk density is generally considered in conjunction with apparent porosity. It is a measure of the weight of agiven volume of the refractory. For much refractoriness, the bulk density provides a general indication of the product quality. Dry weights (D) of sample of brick were measured in grammes to 2 decimal places, balance. Then the values were recorded respectively. A big container was sourced for to accommodate the bricks. The brick samples were placed on wire gauze and completely immersed in water and boiled for two hours. The wire will enable the brick samples to be boiled without having a contact or resting on the bottom of the container. The brick specimens were allowed to cool at room temperature while left in water. The weight of brick specimens to 2 decimal places wererecorded, while suspended in water at room temperature. Thisgave the values of the suspended weight (s). The samples wereremoved from water and damp towel was used in wiping off theexcess water on the surfaces.The saturated weight in air was taken by the use of balance.

Bulk Density (DB) was calculated:

$$\text{Bulk Density} = \frac{D}{W-S} \left(\frac{g}{cm^3}\right) \text{--------------------------}(7)$$

Where S = suspended weight in water (when cooled)
W = saturated weight in Air.

T = the thickness of the specimen (cm)

J. Thermal Shock Resistance:

Thermal shock resistance's test was conducted according to the ASTM method was adopted for the test. The five (5) samples were cut for the test and fired at uniform rate of 10000c in 3hours and soaked at that temperature for 30 Minutes the samples were removed with a pair of light tongs and placed on cold iron plate to cool for 10 Minutes. The test pieces were removed and replaced in the furnace in the same way in order to ensure the same period of heating and cooling. Toward the end of each cooling period the test samples were examined for cracks and a slight force applied on a rig. They were then replaced in the furnace while still maintained at the test temperature for another period of 10 Minutes. These cycles of heating, cooling and testing was repeated for 30 cycles. The number of complete cycles of heating and cooling required to fracture in each samples was notedTable 3 has to do with the physical properties of the brick samples suck as the states of each brick samples like colour, hardness, structure, efflorescence etc.

. V. RESULTS

Table 3:- The Physical Properties of Brick samples

Batch No	After Firing	Colour Change	Hardness	Structure	Efflorescence
Line Blend 1	No Crack	Creamy	Ringing Sound	Homogenous	No Soluble Salts
Line Blend 2	No Crack	Creamy	Ringing Sound	Homogenous	No Soluble Salts
Line Blend 3	No Crack	Creamy	Ringing Sound	Homogenous	No Soluble Salts
Line Blend 4	No Crack	Creamy	Ringing Sound	Homogenous	No Soluble Salts
Line Blend 5	No Crack	Creamy	Ringing Sound	Homogenous	No Soluble Salts

Source: Laboratory and Studio Analysis (2019)

A. Colour

Sample 5 the line blend that was not mixed with ball clay fired to white which shows that there is no or very minute presence of iron oxide. Colour bearing impurities, especially iron oxide absent in this sample this accounts for the whiteness of the brick after being subjected to firing. This suggests high refractoriness of the blend. Sample 1 – 4 has slight colour variations as per the presence of ball clay in percentage.

B. Sound Test

Samples 1 – 5 produced very good and strong sounds when held within finger tips and lightly hitone against the other and this shows that the bricks are good for refractories

C. Hardness test

Samples 2,3,4,5,, except sample 1 when the surface were scratched with finger nail there was no impression left on the surface, but sample 1which was made with Calcined clay is having crumple like structure though not so serious but still suitable as a refractory brick.

D. Structure Test

They were all homogeneous in structure, pores present, compact, and free from defects for example lumps. This means that both clays bond very well during mixing and firing.

E. Efflorescence Test

There was none of the sample bricks that have imperceptible efflorescence. The result shows that Emu – Agbaja Oworo clay contains two major oxides, SiO_2-54.80 wt %, Al_2O_3-31.60 wt % and other minor constituent elements as shown below; the result classifies this clay as kaolin, while Ganaja-meme clay contains only one major oxide 46.80 wt % and other minor constituent elements as shown in table 1. The result classifies this clay as ball clay.

F. Sinterability of the Brick Samples

Dry shrinkage and firing shrinkage of the sample bricks were also investigated by this study were documented in the Table 4 below. Also indicated are their averages linear shrinkage in dried and fired which were also considered in the table.

Table 4:- Shrinkage Values.

Sample code	Original Length(mm	Dry Length (mm)	Fired Length (mm)	Dry Shrinkage %	Fired Shrinkage %	Total Shrinkage %	Tempt.(°c)
1	230	227	215	1.30	4.86	6.52	1300
2	230	222	210	2.17	6.66	8.69	1300
3	230	222	215	3.47	3.15	6.52	1300
4	230	227	213	1.73	5.33	7.39	1300
5	230	223	215	3.04	3.56	6.97	1300

Source: Laboratory and Studio Analysis (2019)

G. Shrinkage

The relationship between total shrinkage % and sample blends. From the summary of shrinkage value results above table 4 the percentage shrinkage values of the samples obtained at 1300ºC varied. Especially samples 1and 3 have 6.52%, while sample 2 is 8.69 %. It does appear that kaolin inhibits shrinkage. This inference is clear from the values of samples 1-3, which have same weight percent of saw dust, but different kaolin content. The higher the kaolin content, the lower the shrinkage it appears.

H. Bulk Density and Apparent Porosity

The values obtained from the set – up for bulk density and apparent porosity were recorded. These values were later used for calculation, using the equation to obtain the actual bulk density and apparent porosity of the brick samples. The table below is the Bulk Density and Apparent porosity.

Table 5:- Percentage of Apparent Porosity, Water Absorption, Apparent Density and Bulk Density.

Sample code	Fired weight (g)	Suspended weight (g)	Soaked weight (g)	% Apparent porosity	% Water absorption	Apparent Density (g/cm3)	Bulk density (g/cm3)
1	1934	1602	3204	79.27	65.66	5.82	1.20
2	2463	1741.5	3483	58.57	41.41	3.41	1.41
3	1961	1500	3000	69.26	52.98	4.25	1.30
4	2182	1566	3132	60.60	43.47	3.53	1.37
5	1745	1615	3230	91.95	85.10	13.4	1.08

Source: Laboratory Source: Laboratory and Studio Analysis (2019)

I. Apparent Porosity

From Table 5 samples 5 shows the highest porosity, 91.95% while sample 2 showed the lowest 58.57% which is still the range of international slandered of 20 -80%. This is as a result of the saw dust burning out during firing and leaving of pores in a brick. These pores make a brick porous. The more porous the bricks the better heat insulator the brick would be because heat cannot pass through motionless air, which is trapped in the pores. This trapped air is what acts as insulator. Sample 5 is the most porous at 91.95% and should be the best for insulation just because the kaolin has no ball clay and it is ratio 50: 50 blend. Porous refractories have poor heat conductivity and therefore, act as good insulators. The degree of porosity can influence the thermal shock resistance of a refractory according to Berger, (2010) the more porosity of an insulating bricks the better thermal shock resistance. Higher porosity equals to higher electrical resistivity and low heat capacity. Berger, (2010) also buttress his point by saying that the toughness of a refractory by terminating propagating cracks. Finer closed porosity means more insulating.

J. Water Absorption

The relationship between water absorption % and the sample blends From Table 5 samples 2 shows the lowest water of the highest sawdust has the highest water absorption of 41.41% while sample 5 showed the highest of 85.10% followed by the sample 1 which is Calcined clay. This shows that blend without ball clay but with one. This may be that the sample permitted more pores than other samples thereby leaving plenty of pores, which leads to high absorption of water by that sample more pores than other samples thereby leaving plenty of pores, which leads to high absorption of water by that sample.

K. Apparent Density

Sample 2 shows the lowest apparent density, 3.41g/cm3 while sample 5 had the highest, 13.4g/cm3. For this trend, the explanation given above for bulk density holds good. The higher the density the higher the heat capacity of the insulating brick.

L. Bulk Density

Sample 5 shows the lowest bulk density of 1.08g/cm3 while sample 2 showed the highest of 1.41g/cm3. The higher the percentage of saw dust in a sample, the lower the bulk density of that sample, saw dust burns and leaves pores in a sample, which reduces its density. The lower the density of a sample, the lower its thermal conductivity becomes. As a result of this sample 5 was lower in thermal conductivity while sample 2 will be high in conductivity

Table 6:- Percentage of Moisture content, Wet Weight Dried Weight Shrinkage of Samples.

Batch Code	Wet Weight (g)	Dry Weight (g)	% Moisture Content
1.	360	280	22.22
2.	430	310	27.91
3.	410	290	29.27
4.	410	300	26.83
5.	380	290	23.68

Source: Laboratory and Studio Analysis (2019)

M. Effective Moisture Content

The relationship between moisture content % and the sample blends. Sample 3 shows the highest percentage moisture content of 29.27 percentage while sample 1 shows the lowest moisture of 21.95%. This is dependent on the cumulativeweight percent of kaolin and clay weight percent of kaolin and clay treated as a whole within the brick structure. When this combined weight percent is about $^{2}/_{3}$ of the total weight of the brick, the effective moisture content is least. This is an indication of the optimal combination ratio.

Table 7 Thermal Sock Test

Blend	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Temp.	1300^{0}C	1300^{0}C	1300^{0}C	1300^{0}C	1300^{0}C
No of Cycle	30	30	30	25	30

Source: Laboratory and Studio Analysis (2019).

N. Thermal Shock Resistance

Samples of the insulating bricks were tested for thermal sock resistance and all the samples were found to be good as insulating bricks they were able to pass through 30 cycles of 13000C furnace during the test except sample 5 which had a little crack at cycle 25 but with that it is still a good insulating brick.

O. Modulus of Rupture.

The main purpose of this investigation was to determine the bending strength of the brick samples. The values obtained showed a significant difference in the samples. All the six samples of the bricks showed these results and only break at the following points.

Table 8:- Values of Modulus of Rupture.

Test Specimen Code	Breaking Load (kN)	Length Distance Between Support (mm)	Width mm	Thickness mm	Modulus of rupture kgf/cm^2	Temp. °c
1.	5.0	210	100	85	2.18	1300°c
2.	19.4	210	105	85	1.32	1300°c
3.	22.7	213	103	75	1.25	1300°c
4.	24.0	212	105	75	1.32	1300°c
5.	9.5	215	100	80	2.20	1300°c

Source: Laboratory and Studio Analysis (2019)

P. Modulus of Rupture

Sample 3 shows the lowest strength of 1.25 kgf/cm^2 while sample 5 showed the highest at 2.20kgf/cm^3, it may be said that the higher the percentage of saw dust in a sample, the lower its strength, and vice versa. This is because, during firing in a furnace, the saw dust burns out leaving plenty of pores in the bricks. The presence of these pores in a brick induces poor transfer of load in the brick, and thus, lowers the modulus of rupture (strength) of the brick.

Q. Summary of the Tests.

Table 8 below has to do with the whole summary of the test results of the moisture content, modulus of rupture, apparent porosity, water absorption, and the density all these results were gotten byusing the correct formulae for calculating them.

Table 9:- Summary of the Tests, Moisture content, Modulus of Rupture, Apparent porosity, Water Absorption, and Density

Samples Line Blend	Total Shrinkage (%)	Moisture content %	Modulus of rupture (kgf/cm2)	% Apparent porosity	% Water absorption	Apparent Density (g/cm3)	Bulk Density (g/cm3)
1.	6.52	22.22	2.18	79.27	65.66	5.825	1.207
2.	8.69	27.91	1.32	58.57	41.41	3.413	1.414
3.	6.52	29.27	1.25	69.26	52.98	4.253	1.307
4.	7.37	26.83	1.32	60.60	43.47	3.538	1.373
5.	6.97	23.68	2.20	91.95	85.10	13.42	1.080

Source: Laboratory and Studio Analysis (2019).

VI. DISCUSSIONS

Compositions 1 – 4 showed a good level of refractoriness with the results obtained. Density and porosity measurements can indicate whether a refractory is likely to be strong in service higher density will results in to higher strength, modulus of rupture, abrasion resistance, knock resistance, high temperature creep is reduced. Composition 3 - 5 showed a high level of saw dust but composition 5 has the highest degree of porosity of 91.95 % among the three compositions, but with the lowest value of modulus of rupture of 2.20. Composition 5 has one of the highest saw dusts of 50% without ball clay but with the highest porosity of 91.95 percent because calcined kaolin was used for the composition.

VII. SUMMARY

The study also solved up to fifty percent of the problems facing kiln construction. With the clay able to produce insulating bricks that is of high standard. For anybody to be able to understand the use of the product; the procedures used are as follows: Sourcing for the material, measurement, formulation of different batches, mixing and making the line blend, making the bricks, then drying and firing. The bricks produced were subjected to firing at the temperature of about 13000C and after firing they were taken for tests, such as porosity, bulk density, modulus of rupture etc. The brick produced on the basis of the analysis of the data for this study, the following major findings were pertinent. The insulating bricks are suitable for constructing kiln. The insulating bricks are capable of being fired to temperature of 13500C (capable of heat storage).

VIII. CONCLUSION

The conclusion of this research was based on the specific objectives. The final outcome of theresearch was able to meet the main objective of the research which is to produce suitably and reliable insulating bricks from the kaolin evacuated from Emu – Agbaja, Oworo. Another objective is to carry out property tests on the clay. This objective was attained to a large extent: Several tests were carried out in other to evaluate the suitability of Emu – Oworo, Agbaja clay. Line blends were made to produce insulating bricks of different aggregates in other to ascertain the effectiveness of the clay. Strong and reliable refractory bricks for kiln building can be made with Agbaja clay.

The final objective was to carry out the mechanical properties test on the bricks made from the machine. Such tests include visual inspection (by keen observation), soundness, hardness, structure, efflorescence, absorption, compressive strength, shrinkage, porosity, bulk density and apparent test etc. The above mentioned tests were carried out and the results were found satisfactory.

Based on the properties of the brick samples tested and analyzed in this study, it can be finally concluded that: The local raw materials - kaolin, sawdust, and plastic clay are suitable for the production of insulating firebricks. Samples 1 - 3 are all insulating firebricks that can withstand temperature up to 1300°C. Samples 1 - 4 are of acceptable standard for hot-face insulating firebricks production. However, its composition can be varied to improve on its refractoriness. The mixing ratio of 50: 50 that is 50% of sawdust and 50% kaolin seems to be the best combination of strength and thermal conductivity and would perform best when used for hot-face insulating firebricks. From the study the minimal effective moisture content, the cumulative weight percent of kaolin and clay (treated as a whole) in the firebrick must be about 2/3 of the total weight of the fire brick.

IX. RECOMMENDATIONS.

Considering the place of refractory bricks in kiln building to ceramists as the majormeans of firing ceramic wares for bisque or glaze to bring out the beauty of wares and in the area of technological development in Nigeria, the researcher dims it fit to give the following:

Well-equipped material science workshops and laboratories with valuable materials and equipment can be established and be properly managed in some of the higher institutions to encourage researchers to embark on viable researches that can yield results necessary for Nigerian industrial development. Engineering Departments should be in collaborations with researchers who may be carrying out research work.

The government should encourage the intellectual property protection organization (the patent office) covering research that are done by researcher in the country especially, those that have direct bearing on the development of Nigeria. This will go a long way to encouraging other researchers to embark on more meaningful projects since they know that their sweat will not be in vain.

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Use

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