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CHARACTERIZATION AND PRODUCTION OF AJASE – IPO CLAY IN KWARA STATE AS REFRACTORY MATERIALS FOR FURNACE LINING

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ABSTRACT
Characterization and physical production of Ajase – Ipo clay in Kwara State as refractory material was carried out with a view to determine its possible applications. Twenty-four different clay mixes were prepared to test for each property. The clay mixes were formed with clay, 5%ww sodium silicate and 5%ww tempering water addition. Prepared samples were heated to temperature of 800, 900, 1000, 1100, 1200 and 1300^{0}C, soaked for 2 hours and allowed to cool to room temperature. Testing of properties such as gas permeability, apparent porosity, linear fired shrinkage, hot strength, baked strength, baked hardness and refractoriness were carried out on standard samples of these mixes. The experiment was carried out for both the local clay (Ajase-Ipo) and imported refractory materials (London and India). The result of the tests showed Ajase-Ipo clay mix has average values of 151ml/min gas permeability, 520KN/m^2 hot strength, 685KN/m^2 baked strength, 94.7BH baked hardness, 14.47% apparent porosity and 24% linear shrinkage at 1300^{O}C. These properties compared with clay materials used in local foundries for ferrous castings and could be a suitable replacement for those clay mixes in use at present.
Keywords: Characterization, production, clay, bond, furnace

INTRODUCTION
Monolithic refractories have been used for more than half a century in furnace lining (Subrata Banerjee, 1998, Agbalajobi and Omoijuanto, 2012). Major changes have occurred with every decade of use. Availability of better aggregates and bonding agents has assisted in improving such refractories through the years (Uche and Muhammad, 2011). Characterization of clay as refractory materials is an important research that leads to the awareness of its potential applications and utilization in Nigeria rather than importing from the developed countries. The characterization and production of refractories is one of Nigeria's objectives in its policy of transfer of research technology. This will resolve the problem of relying on much on imported costly

refractories hence improve the country scarce foreign reserve. Monolithic refractories made from clay should only be able to withstand the severe working conditions of temperature, erosion and thermal shock. Clay used in this work possesses high refractory properties, ease of moulding, reliability in service, vibration damping, surface harden ability and wide range strength. With a monolithic refractory, Ajase-Ipo clay can have average hot strength value of 520 KN/M^2 which possesses a comparative quality of 480 KN/M^2 of reference value of property of clay bonded core sand mix in use at Nigeria Machine Tool Limited, Oshogbo (Borode, 2004). Many investigations on the fired strength and porosity characteristics of the clay samples have shown that pottery clay samples have high percentage porosity (Hassan et al, 2019; Adidun et al, 2016; Gleason and Grenshaw, 2003). This work therefore serves to look into the adaptation of Ajase-Ipo clay in Kwara State as a substitute to imported refractories in furnace lining processes which is effective way of developing indigenous technology.

EXPERIMENTAL TECHNIQUES

The refractory materials for the experiments consist of local clay (acidic) from Ajase-Ipo in Kwara State Nigeria. The acidic lining refractory (England), the acidic lining refractory (India) and basic lining refractory (India) were obtained from Nigerian Foundries Limited, Lagos. Chemical analysis of samples were done on Atomic Absorption Spectrophotometer (AAS) and are presented in Table 1

Table 1: Chemical Analysis of materials

Chemical compound	London (A)	India (B)	India (C)	Nigeria (D)
SiO_2	84.652	60.131	-	69.182
Al_2O_3	6.121	32.271	10.181	18.372
MgO	-	-	81.191	-
TiO_2	1.626	1.823	2.112	1.511
CaO	0.475	0.113	2.147	0.631
K_2O	2.861	0.176	0.916	3.014
Na_2O	0.037	0.026	0.014	0.046
Fe_2O_3	0.127	1.076	0.452	2.157
Loss of ignition	3.011	2.373	1.912	3.025
Others	1.090	2.011	1.075	2.062
Total	100.000	100.000	100.000	100.000

An American Tyler screen was used. 250grams of various samples labeled A – D were poured into screen of mesh 2.8mm, 1.0mm, 0.6mm and vibrating sieve made the grain to pass through the mesh and weight of various individual meshes was taken and recorded. Four different refractory materials mixes were prepared. 5% by weight of sodium silicate was added to each of these compositions and it was mixed dry thoroughly for 10minutes before a gradual addition of 5%ww tempering water was added. Mixing of the material continued for another 10 minutes, before finally compacting the samples into cylindrical shapes. The choice of 5% by weight of sodium silicate and 5%ww tempering water was based on preliminary works carried out on the clay mix (Olusanya et al, 2014).

Samples dimensioning 50mm diameter x 50mm height were compacted by American Foundrymen Society (AFS) standard procedures. These procedures were repeated for samples with acidic refractory from England (A), acidic refractory from India (B), basic refractory from India (C) and acidic refractory from Nigeria (D). The prepared samples were dried in an oven for 2hours at 110°C and allowed to cool to room temperature. The following tests were performed on the prepared samples.

(i) Gas Permeability: Dried samples were baked at 800, 900, 1000, 1100, 1200 and 1300°C and left for 2hours to soak. They were brought out and allowed to cool to room temperature and there after tested using the permeability testing machine.
(ii) Apparent Porosity: Each of the samples tested was dried for 2hours at 800, 900, 1000, 1100, 1200, and 1300°C cooled in air to room temperature and then transferred into a desiccator and weighed to the nearest 0.01g (dried weight). Each of the specimens was transferred into a 250ml beaker in empty vacuum desiccators. Water was then introduced into the beaker until the test pieces were completely immersed. Each specimen was allowed to soak in from time to time to assist in releasing trapped air bubbles. Each specimen was transferred into empty vacuum desiccators to cool. The soaked weight (W) was recorded. The specimens weighted was suspended in water with beaker placed on balance, this gave suspended weight (S). The apparent porosity was calculated using (ASTM, 2001)

$$\text{Apparent porosity} = \frac{W - D}{W - S} \times 100\% \qquad (1)$$

Where, W is the soaked weight, D is the dried weight and S is the suspended weight

(iii) Linear Fire Shrinkage: cylindrical samples dimensioning 50mm diameter x 50mm height were prepared and dried in an oven at 110°C for 2hours. They were brought out and allowed to cool to room temperature and thereafter, a line of 30mm was drawn on it and the dried length, L_1 taken. Each sample for this investigation was gradually heated to 800, 900, 1000, 1100, 1200 and 1300°C in the furnace and left for 2hours to soak. They were brought out and allowed to cool to room temperature and the fired length L_2 is measured.

$$\text{Fired Shrinkage} = \frac{L_1 - L_2}{L_1} \times 100\% \qquad (2)$$

Where L_1 and L_2 are respectively the dried length and fired length

(iv) Hot Strength: Each sample for this investigation was gradually heated to 800, 900, 1000, 1100, 1200 and 1300°C. When these temperatures were attained, the samples were compression tested and the strength recorded.

(v) Baked Strength: prepared samples heated to temperature of 800, 900, 1000, 1100, 1200 and 1300°C and left for 2hours to soak. They were brought out and allowed to cool to room temperature and thereafter tested for baked strength.

(vi) Baked Hardness: Samples heated to temperatures of 800, 900, 1000, 1100, 1200 and 1300°C soaked for 2hours and allowed to cool to room temperature. The surface of each sample was tested at four different points for hardness using the Dieter Hardness tester. Average values were taken and recorded.

(vii) Refractoriness: The refractoriness test was carried out by heating the samples on a pyrometric dish to a temperature of 1510°C and thereafter increasing it in steps of 100°C. The samples were checked for fusion at every temperature to note any change of glassy form. Slight sintering was observed at above 1600°C. The temperature increase was now done at 10°C intervals and samples observed.

RESULTS

Table 1 gives the results of the chemical analyses of samples done on AAS while Table 2 presents the results of refractoriness test.

The reference values of properties of clay bonded core sand mix in use at Nigerian Machine Tools Limited, Oshogbo is presented in Table 3. The results of the other tests are presented in figures 1 to 6.

Table 2: Refractoriness Test

Refractory Materials	Sintering Temperature (°C)
Acidic refractory, London (A)	1650
Acidic refractory, India (B)	1750
Basic refractory, India (C)	1600
Acidic refractory, Nigeria (D)	1650

Table 3: Reference Data on the properties of clay bonded core sand

Properties	Values
Dry Compression Strength	$610KN/M^2$
Dry Shear Strength	$140KN/M^2$
Hot Strength	$480\ KN/M^2$
Baked strength	$648\ KN/M^2$
Gas Permeability	150ml/min
Baked Hardness	92.5BH

*Nigeria Machine Tools Ltd Oshogbo (Borode, 2004)

DISCUSSION

The effect of temperature on the gas permeability of the clay mix is presented in fig 1. The curves show that the clay mix causes a continuous decease in gas permeability after firing at various temperatures using silica binders. These results suggest that addition of sodium silicate content is an example of inorganic binder used in ramming materials which burns up at higher temperature thereby creating pores within the solid mass (Subrata Banerjee, 1998). This characteristic is good for clay material in lining furnace. However, as temperature increases the gas permeability reduces. The gas permeability of acidic lining from Nigeria falls within the range of imported acidic and basic lining. Fig. 2 presents the variation of apparent porosity with temperature. There is a progressive decrease in apparent porosity with increase in temperature. These results suggest that mixing refractory materials quantity to achieve higher strength required a gradual addition of water which creating more porosity. Although low-temperature properties improved, intermediate - and high-temperature properties did not. The values of Ajase-Ipo clay refractory falls within the range of 10 – 25% as compared with imported refractory lining which is good for induction furnace.

The result of the effect of temperature on linear fired shrinkage of the clay mix is presented in fig. 3. The curve shows a progressive decrease in clay sample of Ajase –Ipo from imported refractory samples for linear fired shrinkage with their constituents of chemical compound SiO_2, Al_2O_3, MgO, TiO_2, CaO, K_2O, Na_2O, Fe_2O_3. This is attributed to the fact that the sodium silicate being a binder forms a gelatinous bond with clay in the presence of water, binding them more firmly together (Borode, 2004). Figs. 4 and 5 present the variation of temperature with hot strength and baked strength respectively. There is progressive increase in both hot strength and baked strength with temperature. As shown in fig 5, the baked strength increases initially, attain a maximum and then decreases. This trend can be explained in that the dried sodium silicate film at 1200°C around the binding power is still effective due to the short inter-particle distance in the clay system. Fig. 6 shows the effect of temperature on baked hardness of the samples. It was observed that there is a general increase in the baked hardness with increasing in temperature. It was reported by Heine et al (1967), that 30HB and 95 HB are for soft and hard cores respectively. However, the observed values for Ajase-Ipo clay refractory ranged between 86 HB and 95.5 BH which imply that the clay is suitable for preparation of refractory materials and therefore useful for furnace lining. All the compositions tested for refractoriness sintered in the range of 1600 – 1750°C. This makes them suitable for furnace lining.

CONCLUSIONS

Correlation of the results of the tests on the various refractories of clay materials with the one in use at the Nigeria Machine Tools Limited, Oshogbo shows that Ajase – Ipo clay material which has average values of 151ml/min gas permeability, 520KN/M^2 hot strength, 685 KN/M^2baked strength and 94.7 BH baked hardness at 1300ºC posses a comparable quality. It is therefore concluded that this clay can serve as a replacement for the imported refractory material in use in furnace lining in Nigeria.

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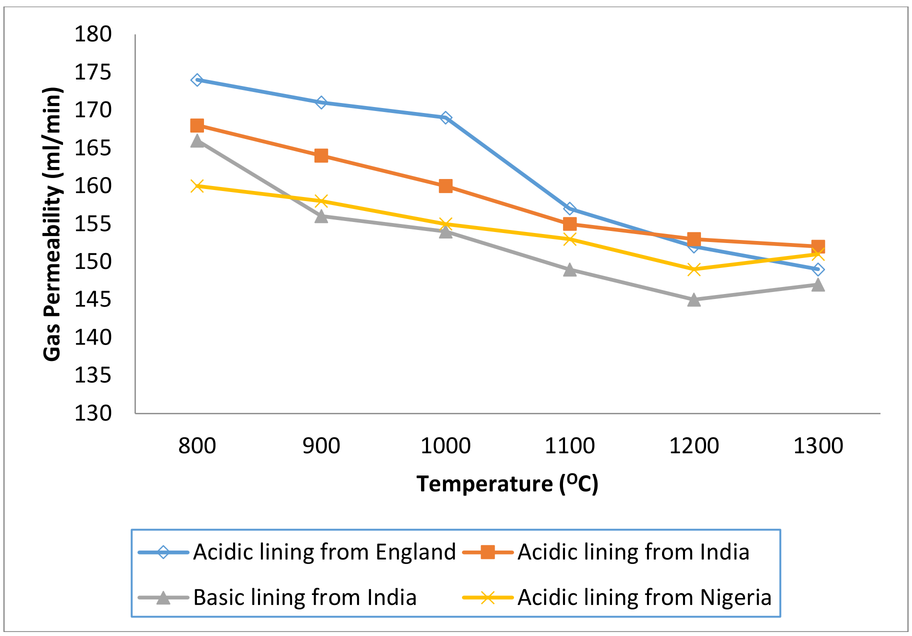
Figure 1 Effect of Temperature on Gas Permeability



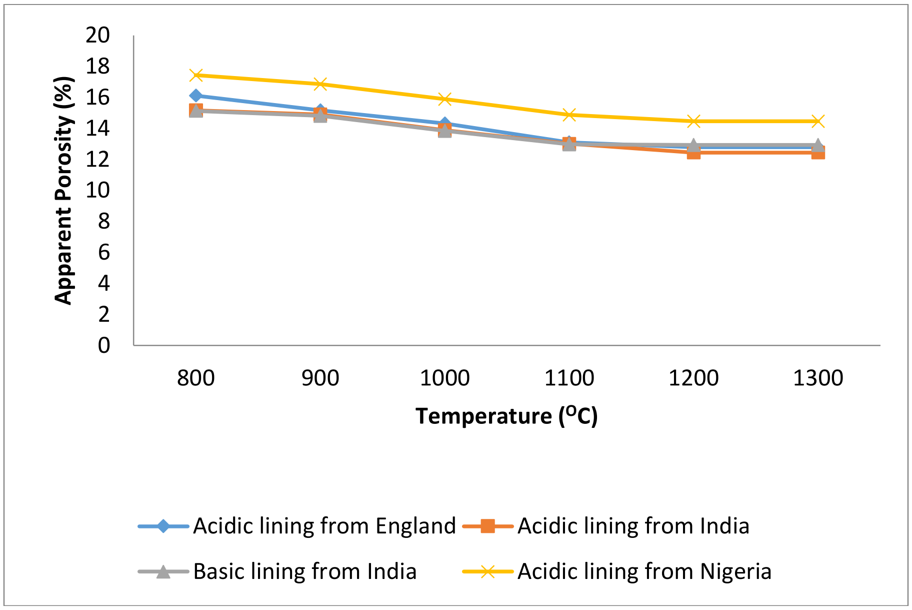


Figure 2 Effect of Temperature on Apparent Porosity

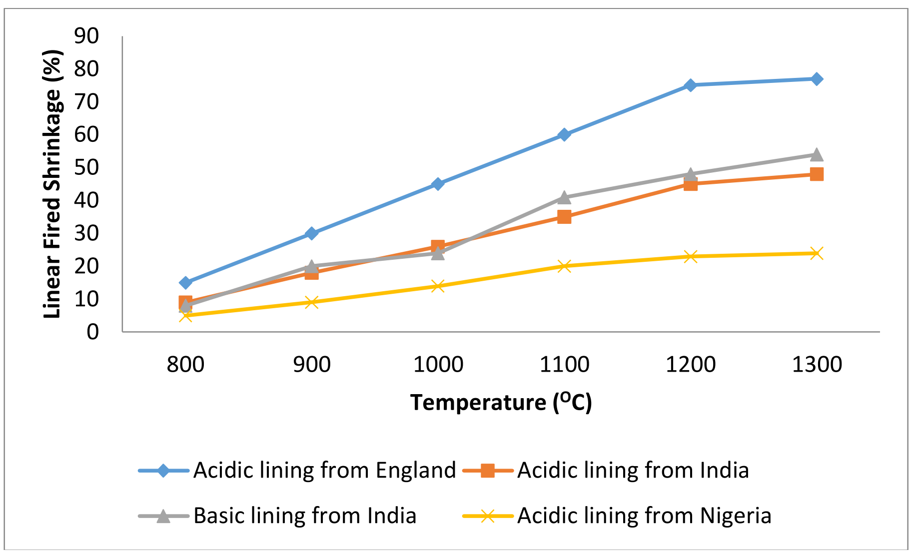


Figure 3 Effect of Temperature on Linear Fired Shrinkage

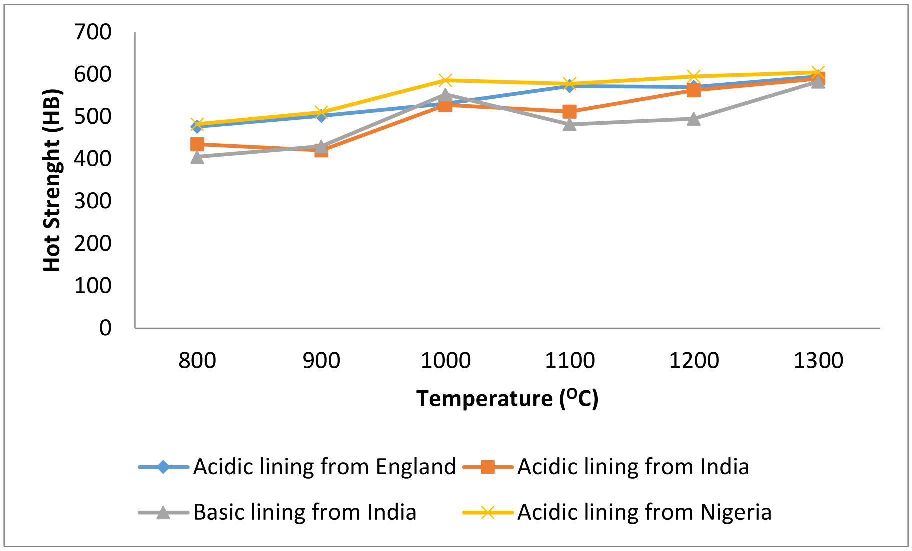


Figure 4 Effect of Temperature on Hot Strength

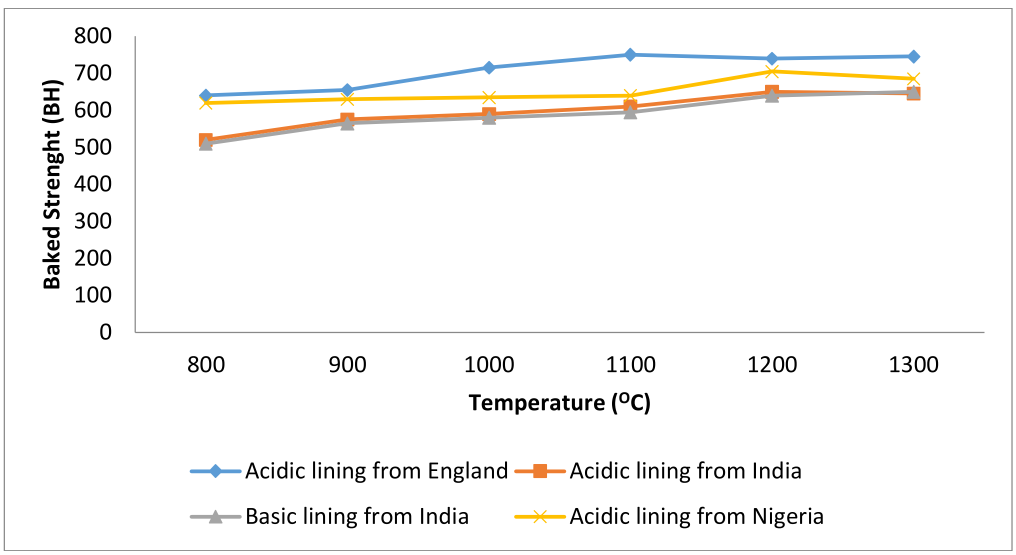


Figure 5 Effect of Temperature on Baked Strength

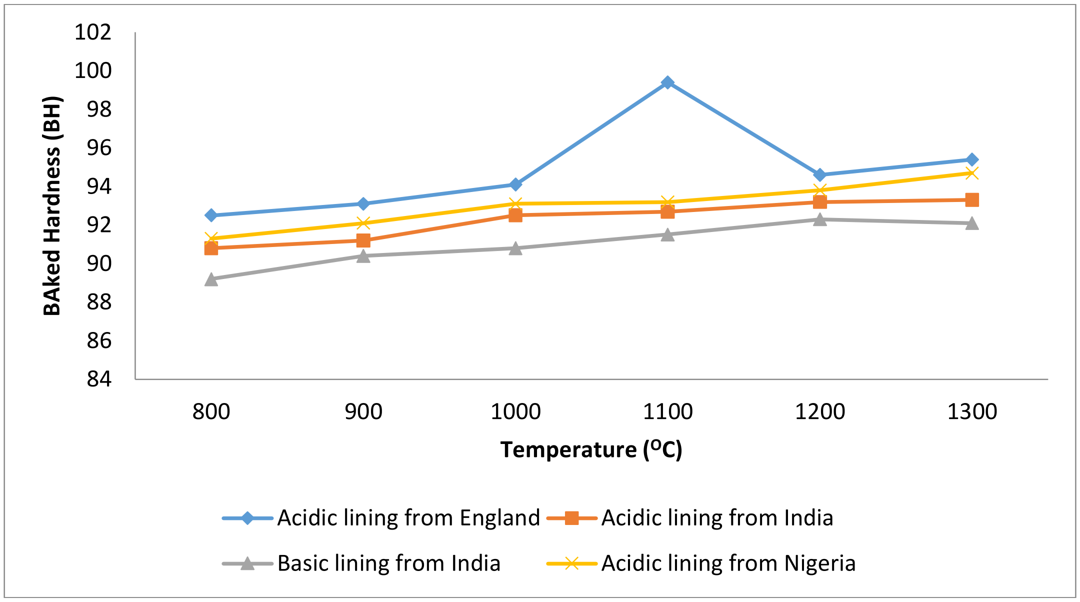


Figure 6 Effect of Temperature on Baked Hardness