An Evaluation of Strength Characteristics of Osiele Clay.

P.O. Aiyedun[1*], O.S. Olokode[1], S.O. Fakolujo[2], and B.U. Anyanwu[1]

[1]College of Engineering, Department of Mechanical Engineering,
University of Agriculture, Abeokuta, Nigeria.
[2]Department of Metallurgy, Yaba College of Technology, Lagos, Nigeria.

E-mail: laiyedun_494@yahoo.com*

ABSTRACT

This paper investigates the strength of clay from the Osiele Area of Abeokuta in Ogun State, based on physical and chemical composition. Refractory properties measured include, cold crushing strength, porosity, water absorption, density and shrinkage. A thorough review of literature was made and comparison made between the existing values and values obtained experimentally. The bricks were fired to temperatures of 1100, 1200, 1300, 1400, and 1.500^{o}C. The results indicated that Osiele clay is very good for the production of refractory bricks for furnace lining with little or no additives.

(Keywords: refractory, furnaces, lining, crucible, clay, bulk density, temperature)

INTRODUCTION

The present economic situation of Nigeria calls for the local sourcing of raw materials used in the production of engineering materials. Refractories are materials which can withstand high temperatures above 1580^{o}C and the physical and chemical action of molten metal slag, and gases in the furnace without deformation, failure or change in composition under their own weight. They are essentially used for the lining or construction of any thermal unit such as kiln and furnaces, tubes of electric furnaces, crucibles, thermocouple sheaths and refractory cements.

Refractories, being one of the materials largely used in metallurgical plants, cement industries, and power generating plants are, at present, sourced by importation. The metallurgical industry alone accounts for 80% of refractory consumption. If these valuable inputs in the foreign industry are sourced locally, there will be great conservation in the foreign exchange earnings of the country.

Typical refractory materials includes oxides like alumina (Al_2O_3), magnesia (MgO), Zirconia (ZrO_2), non-oxides like carbides: Silicon carbide (SiC), boron carbides (B_4C); nitrides (Si_3N_4), aluminium nitrides (AlN_4), etc., and carbon (graphite and coke). With the development of iron and steel industry in Nigeria, there has been a great increase in the use of refractory materials. For instance, the Ajaokuta Steel Complex on completion will require about 36,000 tones of refractory bricks worth over six million Naira just for furnace lining purposes only (Borode *et al*., 2000).

The development of our local materials for the production of refractories is justified by the need to meet the technological requirements of the country, and to conserve the much needed foreign exchange. Furthermore, certain properties of refractory materials, such thermal expansion, harness, specific heat, vapor pressure and decomposition pressure are inherent. The thermal conductivity and modulus of elasticity depend also on porosity. The strength properties of given materials are largely dependent on the microstructure. The micro-structural parameters of the principal importance to the strength of inorganic materials are porosity, grain size, and grain orientation in single-phase system (Callister, 1996).

EXPERIMENTAL METHODS

Sourcing of Materials

The basic raw materials used in this work are clays procured from Osiele (Abeokuta) Ogun State, Nigeria.

Work Procedure

A known quantity of clay deposit was weighed, crushed in a laboratory ham-crusher. The different samples were molded with the required amount of water at a measure of 10d/200g powdered materials.

TEST WORK

Compositional Analysis

The chemical of the sampled raw materials was carried out using the Atomic Absorption Spectrophotometer (AAS) and the result is presented in Table 1. The fired clay/transverse strength, cold crushing strength (CCS), porosity, percentage water absorption, bulk density and shrinkage tests were carried out for specimens fired at temperatures of 1100, 1200, 1300, 1400, and 1500^{o}C.

Table 1: Chemical Composition of Osiele Clay (%)

Types of Oxide (raw material)	Percentage (%)
SiO_2	40.84
Al_2O_3	45.23
FeO_3	1.60
TiO_2	0.98
MgO	0.86
CaO	0.05
Na_2O	0.02
K_2O	0.04
LOI	0.36

Determination of Bulk Density

The test specimens prepared as above were weighted to the accuracy of ±0.00 (g) (dried weight). After which the specimens were individually transferred to a beaker and heated for 30 minutes to assist in releasing the trapped air. The specimens were cooled and soaked weight (Ws) taken then suspended in water and the suspended weight (Ss) taken. The bulk densities were calculated (Blare *et al*., 1999).

$$BD\left(g/cm^3\right)\frac{DPW}{W_S - S_S} \ldots\ldots\ldots\ldots (1)$$

Where: D is dried weight in (gm), Ws is soaked weight (gm), aid S_8 is suspended weight also in (gm) and PW = density of water (1gcm^3).

Refractoriness

Five (5) cylindrical test specimens were heated in heat furnace one after another to the following temperature respectively, 1,100, 1,200, 1,300, 1,400, and 1,500^{o}C for a soak time of two hours. The specimens were observed one after other for the following textural characteristics: cracks, charge in color, fissures and distortion.

Determination of Apparent Porosity

For each of the specimens, five test cylindrical shape of 50 cm x 50 cm size after firing were tested. The dry weight (D) of each specimen was measured, after which the specimen was transferred into and suspended in a vessel of cooling water for 20 minutes. After this time the boiling was discontinued and the hot water was replaced by cold water. After 30 minutes in cold water, the weight was measured. The soaked specimen was weighed in air (W). The apparent porosity is evaluated from the equation (Crouch *et al*., 2002):

$$A_P = \frac{W - D}{W - S} \times 100\,\% \ldots\ldots\ldots\ldots (2)$$

Determination of Permeability to Air

The specimens were air dried for 24 hours and then dried at 110^{o}C for 12 hour in an oven. The permeability testing machine consists of a cylindrical arrangement in which a bell jar is put in place to displace a certain volume of air, which is equal to the volume of water placed in the cylinder. A manometer was connected to measure the pressure during the displacement of air.

The samples were completely scaled on the sides and the lower surface was exposed to an orifice. The cylinder was filled with 200 cm^3 of water to displace equal volume of air and the pressure difference between the surfaces was measured by the manometer.

Permeability was calculated from (reference Birkeland, P.W. *et al*., 1999):

$$P_A = \frac{V \times H}{A \times P \times t} \text{.........................(3)}$$

Where:

P_A	=	Permeability to air cm^3/min.
V	=	Volume of air displace cm^3
H	=	Height of specimen cm
A	=	Cross section area of specimen (ΠR^2) cm^2
t	=	time taken min.
P	=	Pressure of air cm of H_2O

Determination of Cold Crushing Strength (CCS)

The specimen were placed in a compressive testing machine and load applied axially by turning the hand wheel at a uniform rate till failure occurs using a well calibrated scale. The cold crushing strength is obtained from the formula (J.W. Brown *et al*., 1990).

$$CCS = \frac{Maximum\ Load}{Cross\ sectional\ area\ KN/m^2} \text{.............(4)}$$

Determination of Thermal Shock Resistance

The specimens were inserted into a furnace that is kept at 110^{o}C. This temperature was maintained for 10 minutes. The specimens were removed one after the other and then cooled for 10 minutes. The specimens were returned to the furnace for a further 10 minutes. The process was continued until the pieces were readily pulled apart in the hand. The number of cycles before fracture was recorded for each test specimen (Gupta *et al*., 2005).

RESULTS AND DISCUSSIONS

The physical properties of Osiele Clay produced from 100% fire clay are shown in Table 2. It could be seen that the total shrinkage, density, fired and cold crushing strength increased as the firing temperature increase. This is an indication that Osiele Clay can be effective with little or no additive. The apparent porosity of bricks produced from 100% fire clay is found to be within the normal range of fired bricks.

The water absorption decreased as the temperature increased. The good cold crushing strength values of the clay is due to suspected higher bond of the clay particles. The bulk density values of clay made from 100% fire clay fall within the acceptable range of 1.7 to 22 g/km^3 for dense fired bricks. The change in firing colours of the clay is attributed to the presence of iron-oxide and titanium in the base material. The results of the analysis carried out on Osiele are shown in Figures 1-3. It could be seen that percentage apparent, percentage shrinkage and cold crushing strength increase as firing temperature increase.

Table 2: Physical Properties of Osiele Clay.

Measured properties	Temperature (^{o}C)				
	1100	1200	1300	1400	1500
Bulk density (g/cm^3)	2.38	2.46	2.53	2.59	2.61
Apparent density (%)	1.82	1.99	2.24	2.56	2.75
Water Absorption (%)	19.37	15.22	11.00	9.05	9.94
Dry Shrinkage (%)	7.66	9.53	12.25	14.57	15.68
Fired Shrinkage (%)	1.85	2.38	3.36	3.99	4.25
Total Shrinkage (%)	9.51	11.91	15.61	18.56	19.93
Cold crushing strength (kg/cm^2)	247.06	310.07	358.54	386.25	419.13
Firing colour	White Brown	White Brown	Yellowish Brown	Ash	Ash
Crack formation	No crack	No crack	Slight crack at the bottom	Slight crack at the top and bottom	Cracked but showed deformation on all edges

Figure 1: Firing Temperature versus Percentage Apparent.

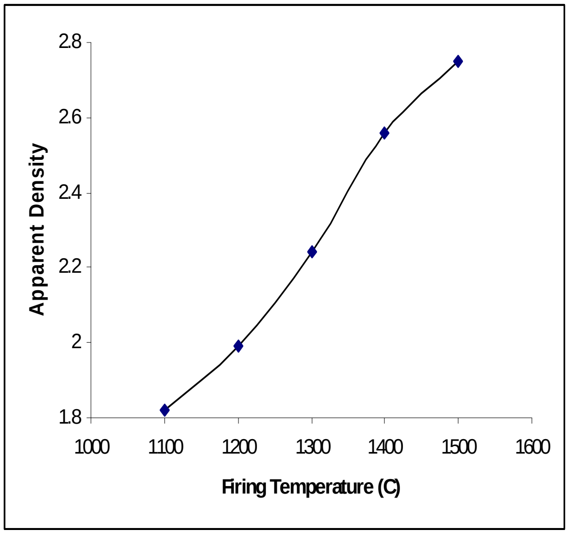


Figure 2: Firing Temperature versus Percentage Shrinkage.

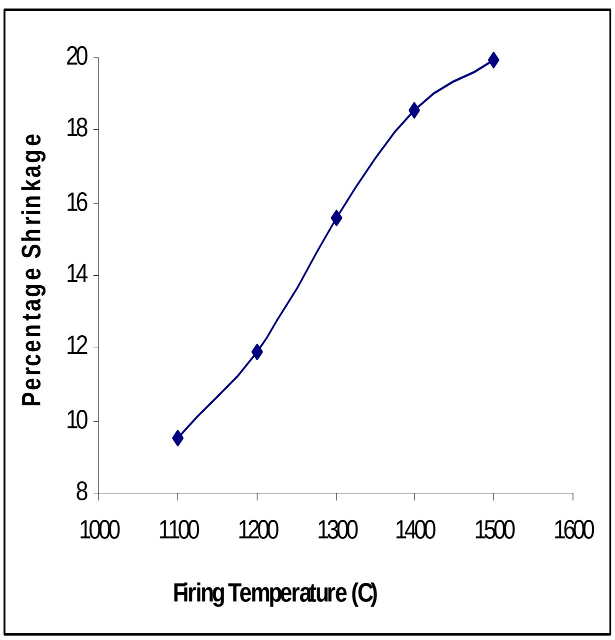
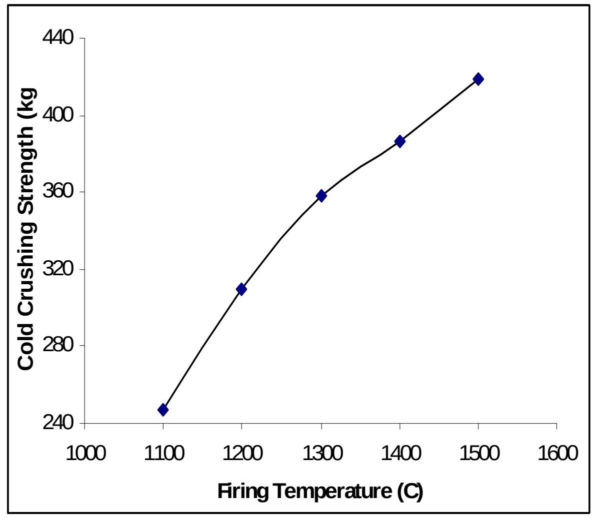


Figure 3: Firing Temperature versus Cold Crushing Strength.



CONCLUSION AND RECOMMENDATIONS

From the results of this study, it can be seen that the physical properties of Osiele Clay compare very favorably with those for international standard fire clay refractory bricks. This clay possesses good refractory properties for lining of rotary, cupola and crucible pot. More research work is recommended for the crucible pot making.

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ABOUT THE AUTHORS

Prof. Aiyedun, P.O. is a Professor of Mechanical Engineering, Federal University of Agriculture, Abeokuta. He is a registered Engineer and a Fellow of the Nigerian Society of Engineers. He holds a Ph.D. In Metallurgy and Material Engineering. He was a former Dean, College of Engineering, Federal University of Agriculture, Abeokuta-Nigeria. His research interest is in the area of steel production and material engineering.

Dr. Engr. Olokode, O.S. is a Senior Lecturer and Acting Head of Mechanical Engineering Department, Federal University of Agriculture, Abeokuta. He holds Ph.D. from both the Imperial College, London and Federal University of Agriculture, Abeokuta.

Engr. Fakolujo, S.O. is a qualified engineer in Metallurgy and Material Engineering. He is the Chief Lecturer and Head of metallurgical department, Yaba College of Technology. He is currently completing his Ph.D. (Materials) in Canada.

Engr. Anyanwu, B.U is a Senior Staff in the Federal University of Agriculture, Abeokuta. He is a registered Member of the Nigerian Society of Engineers.

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