CHARACTERIZATION OF UGWU-ABORI CLAY DEPOSIT FOR INDUSTRIAL AND COMMERCIAL USES

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Abstract
Ugwu-Abori clay deposits in Ugwogo Nike Enugu State Nigeria has been characterized for its industrial and commercial uses. The chemical analysis was carried out using Atomic Absorption Spectroscopy (AAS). Particle size analysis and other physical properties tests such as shrinkage, porosity, modulus of rupture, moisture content, refractoriness, plasticity, water-absorption, thermal shock resistance and cold crushing strength were carried out using international accepted standard techniques. The results of the chemical analysis showed that the clay has SiO_2 (60%), and Al_2O_3 (25%) as its predominant oxides with PbO_2 (0.99%) and Na_2O (1.09%) as minor oxides. The physical properties tests conducted at firing temperatures of 900^0C, 1000^0C, 1100^0C and 1200^0C respectively showed that shrinkage has (13.92%), porosity has (25.10), bulk density has ($2.18g/cm^3$), refractoriness has (1580^oC), apparent density has ($2.58g/cm^3$) and cold crushing strength has ($14.36KN/mm^2$) at firing temperature of 1200^0C. The clay deposits therefore can be used for the production of ceramics refractory bricks for lining of furnaces for ferrous and non-ferrous metals.
Keywords: Characterization, Ugwu-Abori, Clay Deposit, Industrial and Commercial Uses

1.0 Introduction

Clay is defined as a natural earthly fine granular material which acquires plasticity on being exposed or mixed with limited quantity of water and which has maximum size of about two microns or it is a fine grained rock which when suitably crushed and pulverized becomes plastic when wet, leather hard when dried and on firing is converted to a permanent rock like mass [1]. Clays are complex alumino-silicate compounds containing attached water molecule[1].

Clay refractories are mainly produced from clay that has alumina, (Al_2CO_3) and silica (SiO_2) contents between 18-44% and 50-70% respectively [2]

Refractories are materials which can withstand high temperatures normally above 1580^0C and the physical and chemical action of molten metal, slag and gases in furnace without deformation, failure or change in composition under their own weight [3]

The production of various refractory products utilizes raw materials such as a kaolinite (Al_2O_3. $2SiO_2$. $2H_2O$), magnesite ($MgCO_3$), chromite ($FeOCr_2O_3$). The major type of refractories found in Nigeria's manufacturing company is mainly aluminosilicate and magnesite refractory product[4].

Stability at high temperature both physical and chemical is the primary requirements for refractory materials. The ability of a refractory to withstand high temperature in service is known as refractoriness and its degree in any particular refractory depend on the amount of alumina (Al_2O_3) present, which is usually high for alumina content [5]. The percentage of the minerals (Fe_2O_3, MgO, CaO, Na_2O etc) in the clay ultimately determine the area of application of the clay such as in bricks, floor tiles, cement etc[6].

2.0 Materials and Method

2.1 Materials

The clay sample used for this research work was collected from Ugwu-Abori clay deposit in Ugwogo Nike Enugu, Nigeria. The clay materials were collected at depth intervals of 10cm with the aid of a shovel, digger and handpicked to reduce the possibility of contamination. 45kg of clay materials were collected, weighed in weighing balance and place in a bag. The sample was dried, pulverized and sieved before analysis.

2.2 Method

The chemical analysis of the clay was carried out using Atomic Absorption Spectrometer (AAS) and Ultraviolent Visible Range Spectroscopy (UV-VIS). The physical properties tests carried out include plasticity and plasticity ratio; moisture content, total shrinkage, modular of rapture, water absorption, apparent porosity, apparent density, bulk density, cold crushing strength; thermal rock resistance, loss on ignition and refractoriness. For each of the tests, five (5) specimens were used and the average taken and recorded.

Plasticity and plasticity ratio

Five (5) specimen were produced using cylindrical mould and a plastomer was used in deforming them.

$$Modulum\ of\ plasicity = \frac{x_1}{y_1}$$

$$Plasicity\ ratio = \frac{x_2}{y_2}$$

Where x_1 = original height of deforming load

y_1 = deformed height of load

x_2 = original height of sample

y_2 = deformed height of sample

Moisture content: Five cylindrical specimens (1.5cm dia. x 10cm length) were weighed green and their weight recorded. They were then dried in air for two weeks and later oven dried at a temperature of 110^{0}C for twenty four hours. The dry weight of the specimens was measured and recorded.

$$Moisure\ content = \frac{W_w - d_w}{W_w}\ x\ \frac{100}{1}$$

Where W_w = wet weight

d_w = dry weight

Green, Dry and Fired Strength; Five rectangular specimens (1.5 x 3.5cm) were taken and recorded. They were oven dried for two days and a rupture testing machine was used to test for the strength at green, dry and fired state. The fired strength was tested after firing the specimens to temperatures of 900^{0}C, 1000^{0}C, 1100^{0}C and 1200^{0}C respectively.

$$modulus\ of\ Rupture\colon \frac{3pl}{2bh}\ or\ \frac{8pl}{\pi d^2}$$

Where: p = applied load (kg)

I = distance between supports constant (cm)

b = width of the specimen at the point of rupture(cm)

h = height of the specimen at the point of rupture

d = diameter of the cylindrical specimen.

Apparent porosity, water absorption, apparent and bulk density tests. Rectangular specimens (5cm x 7cm) were prepared and their weight noted. They were dried for two weeks, oven dried and their new weight recorded. They were fired to temperatures of 900^{0}C, 1000^{0}C, 1100^{0}C and 1200^{0}C respectively. Their weights at each stage of firing were recorded. The fired specimens were soaked in water for twenty-four hours and the weight taken and recorded. They were calculated as follows:

$$Apparent\ porosity\ = \frac{S_w - F_w}{S_w - S_{sw}}\ x\ \frac{100}{1}$$

$$Water\ absorption\ = \frac{S_{sw} - F_w}{F_w}\ x\ \frac{100}{1}$$

$$Apparent\ density\ = \frac{F_w}{F_w - S_{sw}}\ x\ \frac{100}{1}$$

$$Bulk\ density\ =\ \frac{F_w - dl}{S_w - S_{sw}} x \frac{100}{1}$$

Where: S_w = soaked weight

F_w = Fired weight

S_{sw} = Suspended weight

$dl = Density\ of\ water$

Linear dry and fired shrinkage: Rectangular specimen (5cm x 7cm) were produced and marked 5cm lengths. Temperatures of heating ranges was inscribed on the specimens to be fired. They were dried in air for two weeks and oven dried for forty hours. The change in the 5cm length mark was measured. They were then fired to temperatures of 900^0C, 1000^0C, 1100^0C and 1200^0C respectively and the change in the 5cm length mark was recorded at each temperature.

$$a. Dry\ Shrinkage\ (\%) = \frac{wl - dl}{wl} x \frac{100}{1}$$

$$b. Fixed\ Shrinkage\ (\%) = \frac{wl - fl}{dl} x \frac{100}{1}$$

Where wl = wet length (cm)

dl = dry length (cm)

fl = fired length (cm)

Permeability: Five specimens were prepared using standard specifications of 508cm diameter and 5.08cm length/height. They were dried in air for two twenty hours and oven dried for ten hours. Permeability meter was filled with 2000cm^3 of water in a bel jar put in place. The orifice was opened and then taken for 2000cm^3 of water to displace equal volume of air through the specimen taken. The pressure difference was measured using manometer.

$$p = \frac{vxh}{pxAxt} or \frac{vh}{pAt}$$

Where p = permeability meter

V = volume or air passed through the specimen (cm^2)

h = height of specimen

A = cross-sectional area of the specimen.

p = pressure head under which the air has passed

t = time of flow in seconds.

$$or\ p = \frac{30072}{pxt}\ or \frac{30072}{pt}$$

Thermal shock resistance: The test was carried out using 50mm x 50mm specimens. They were inserted into a muffle furnace and heated to 900^{0}C and held for 10 minutes. They were removed quickly from the furnace, and placed on fire bricks and allowed to cool for ten minutes, after the 10 minutes cooling, they were then returned to the furnace and the process repeated for 30 cycles. They were seen at the end of the 30 cycle not to have deformed or cracked.

Refractoriness: Pyrometric cone equivalent test was used to determine refractoriness. Specimen with 50mm pyramid height and 15mm rectangular base were used. They were put inside a refractory plague with two seeger cone of 12 and 13 and oven dried at 110^{0}C. The temperature equivalents for the two Seeger cones were 1337^{0}C and 1349^{0}C respectively. They were put in a furnace and temperature raised at the rate of 100^{0}C per minute until the two Seeger cones bent over level with the base. Upon observation, it was note that the specimen had not deformed at all let alone melting. The firing was continued until temperature of 1400^{0}C was attained, yet the specimen remained under-formed.

The refractoriness was estimated using Shuen's formular.

$$refactoriness, K(\,^0C) = \frac{360 + Al_2O_3\ x\ Ro}{0.228}$$

Where, Al_2O_3 = % alumina in the clay

RO = sum of all other oxides be sides silica

360, 0.228 = constants.

Cold crushing strength (C.C.S.): Specimens of 6.2mm cube were moulded, and dried for three weeks for proper diffusion of the internally held water. They were fired slowly to a temperature of 900^{0}C, 1000^{0}C, 1100^{0}C and 1200^{0}C respectively. They were held for six hours at the various temperature ranges before cooling to room temperature and storing in a decicator. They were placed in a compressive tester and load was applied axially until fracture occurred and load at fracture was recorded.

C.C.S. (N/m^2) =

Loss on ignition: 50g of the clay sample was oven dried 110^{0}C and cooled in a desicator. The dried sample was put inside the crucible and the weight of the crucible and the sample were recorded (m^2). The crucible with its content was put into a muffle furnace, fired to a temperature of 1000^{0}C and held for three hours. The crucible and its contents were cooled in a desicator and then re-weighed (m^3)

$$L.O.I. = \frac{m_2 - m_2}{m_2 - m_1} \, x \frac{100}{1}$$

3.0 Results and Discussion

The results of the research are presented in Tables 3.1-3.5 and figures 3.1 – 3.3. Table 1, shows the result of granulometric particle size analysis of the Ugwu-Abori clay deposits. From Table 1, it was shown that the clay has fine particle size <5.0mm of about 65% and fairly coarse particle of about 35% respectively. This showed that the clay is siliceous with fairly large sized particles. This property of a clay material is very important because it affect other properties such as porosity, plasticity, percentage water absorption, shrinkage, strength etc.

Table 2 shows the chemical composition analysis of Ugwu-Abori clay deposits obtained using Atomic Absorption Spectroscopy (AAS). It was observed that alumina and silica are the predominant oxides in the clay sample with 25% and 60% respectively while sodium oxide, potassium oxide, and manganese etc occurred in minor quantities. From the results, the clay has a characteristics composition of fire clay refractories with general composition standard range of 55-75% SiO_2 and 25-44% Al_2O_3[7]. The percentages of all the oxides of the clay except PbO_2 fell within the specified standard [8]. The clay could therefore be used for important applications such as in rotary kiln lining, heat-treatment furnaces, refractory bricks etc.

The estimated refractoriness of the clay was 1580^{0}C using shuen's formular [8]. The estimated refractoriness of Ugwu-Abori clay deposits fell within the acceptable standard range of 1500-1700^{0}C for fire clay refractory material [9].

The results of the physical properties of Ugwu-Abori clay are shown in Tables 3.3 and 3.4 and Figures 3.1-3.3. The Tables 3.3 and 3.4 shows that the shrinkage, porosity, modulus of rupture, density and cold crushing strength fell within the international standard organization (ISO) specifications for alumin-osilicate refractories of the fire-clay class [10]. The apparent density, shrinkage, bulk density increased with the increase in firing temperature. The percentage water absorption and apparent porosity decreased with increase in the firing temperature. The higher a clay material is fired, the more it loses its absorbed moisture and constitutional water, thereby increases the shrinkage and reduces porosity. Also at higher temperatures, the low melting point constituents of the clay body tend to melt, oxidize and fuse to the highly refractory constituents thereby closing the pores and increase the formation of a denser body and strength due to strong formation[10].

Table 3.1: Granulometric particle size analysis

Size (mm)	Quantity (%)
50 – 20	24
2.0 – 0.5	18
0.5 – 0.1	27
< 0.1	37

Table 3.2: Chemical composition of Ugwu-Abori clay deposits

Oxides	L.O I	MgO	Al_2O_3	Na_2O	K_2O	Fe_2O_3	MnO	PbO_2	SiO_2
Composition(%)	5.24	2.62	25	1.09	1.18	2.20	1.14	0.99	60

Table 3.3: Physical properties of Ugwu-Abori clay deposit

Property	Temperature ^oC			
	900	**1000**	**1100**	**1200**
Total shrinkage (%)	6.31	8.54	11.50	13.92
Fired shrinkage (%)	2.20	3.42	4.36	4.36
Apparent density (g/cm^3)	2.38	2.48	2.52	2.58
Apparent porosity (%)	33.68	29.50	27.04	25.10
Bulk density (g/cm^3)	1.60	1.82	2.12	2.18
Water absorption (%)	15.70	13.62	10.15	8.34
Modulus of rupture (MOR) (kaf/cm^3)	48.20	63.10	67.80	85.74
Cold crushing strength (KN/mm^2)	8.23	10.52	12.15	14.36

Table 3.4: Other physical properties

Property	Quality
Plasticity ratio	1.22.1
Thermal shock resistance	28
Green strength (kgf/cm^2)	24.33
Moisture content (%)	18.2
Estimated Refractoriness ^0C	1580

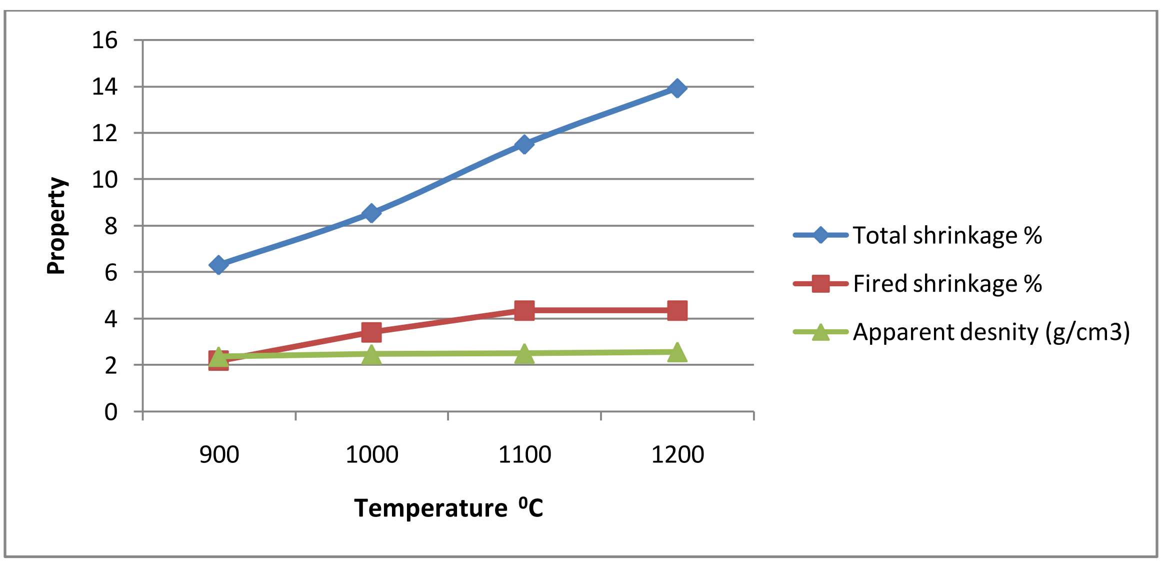

Fig 3.1: Total shrinkage, Fired shrinkage and Apparent density against firing temperatures.

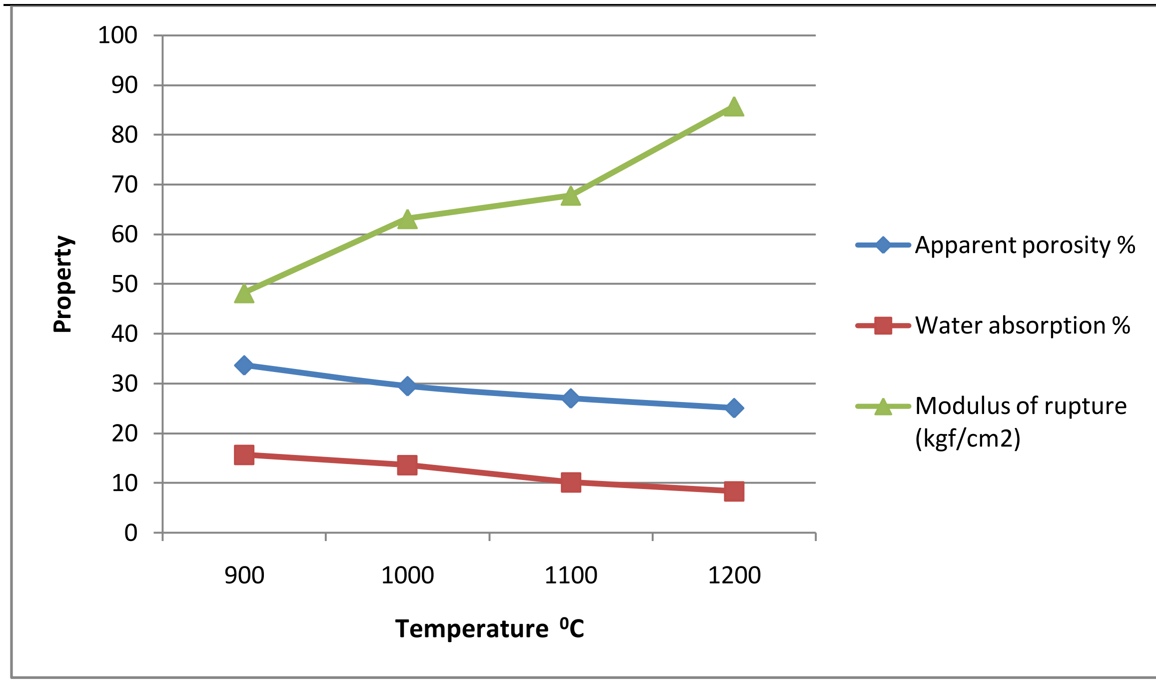

Fig 3.2: Apparent porosity, water absorption and modulus of rupture against firing temperatures.

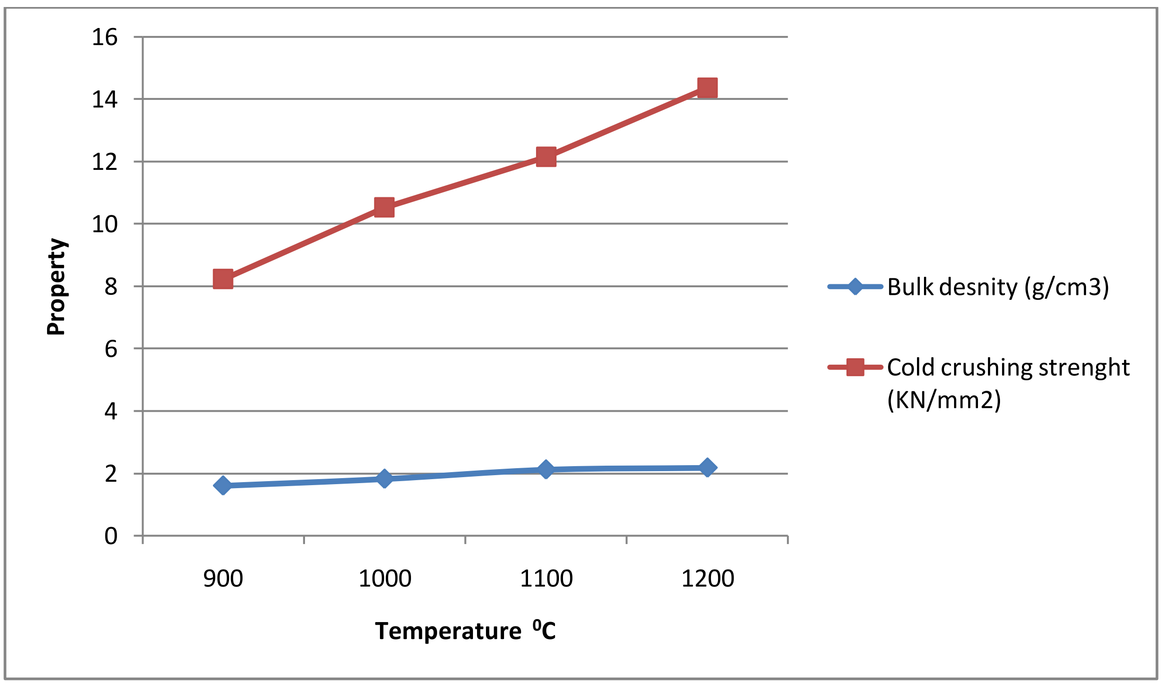

Fig 3.3: Bulk density and cold crushing strength against firing temperatures.

4.0 Conclusion

The study has revealed that Ugwu-Abori clay deposit has alumina and silica as its predominant oxides. This will ease off the importation of ceramic, refractory bricks materials and improve the local content of our ceramic product. The clay deposit if exploited, harnessed and utilized, can help in the nations quest for rapid industrial and economic development.

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