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INVESTIGATING THE STRENGTH AND POROSITY CHARACTERISTICS OF SOME FIRED CLAYS IN EDO AND DELTA STATES

S.A. Agbalajobi[1] and I.S. Omoijuanfo[2]
[1]Department of Mineral Resources Engineering, Kwara State Polytechnic, Ilorin, Nigeria
[2]Department of Mines, Federal Ministry of Power and Steel, Abuja, Nigeria
Email: wisdammy@yahoo.com

ABSTRACT
Investigation aimed at determining the strength and porosity characteristics of some fired clays in Edo and Delta States was carried out. Eighteen different clay samples were taken from six locations in both states. Three samples were taken from each location, analyzed and the result averaged. The six locations were Afuge/Ojavu, Usen/Arhenwen, Uguoriahi/Ovbere in Edo State and Ozarra/Ewebi, Ozalla/Ezeko and Iguoriakhi/Ogbomoba in Delta and Edo State. The clay samples were mixed repeatedly, quartered and analyzed to test their porosities and fired strength characteristics, using American Standard Thermal Analysis Method at the Soil Science Test Laboratory of the Ahmadu Bello University, Zaria. The results of the analysis showed that clay deposits in Afuze/Ojavu, Usen/Arhenwen, and Uguoriakhi/Ovbere in Edo State are good for brick works. They have low porosities ranging from 0.95% to 24.31% and high fired strength. On the other hand, clay deposit from Ozarra/Ewebi, Ozalla/Ezeko and Iguroriakhi/Ogbomoba in both Edo and Delta State are good for pottery. They have high porosities ranging from 13.0% to 38.74% and low fired strength.
Key Word: Clay, refractory, porosity, pottery, fired strength, temperature

INTRODUCTION
Material designated as clays are fine-grained, natural, earthy argillaceous material (Grim, 1953). Most common clays are based on the mineral Kaolinite ($Al_2Si_2O_5$ $(OH)_4$), when mixed with water, clay becomes a plastic substance that is formable and mouldable. Kaolin clay group, which is represented chemically as $Al_2O_3SiO_2.2H_2O$, is important material used in manufacture of ceramics. When heated to a sufficiently elevated temperature (firing), clay fuses into a dense, strong material. Thus, clay can be shaped while wet and soft, and then fired to obtain the final product. The strength and porosity characterisations of the selected samples are essential indicator of a strength classification of medium to high strength. Further characteristics on the firing behaviour confirm the suitability for wide range of refractory and ceramic wares application ranging from vitrified whiteware to brickwares, coloured vaze and tiles. Clays are versatile industrial raw materials needed for the manufacture of domestic and industrial products such as pottery and ceramic wares, bricks, electrical insulators, paper, paint, ink, drugs, soaps, toothpaste, roofing and floor tiles. They also find applications in the manufacture of cement, plastics, fertilizers and insecticides. The use of clay products for construction and building purpose has greatly aided many developed and developing nations to execute housing policies. Clay products such as ceramic wares, burnt bricks, roofing and floor tiles are cheaper and more durable building materials than cement, especially under tropical condition (Nnuka and Enejore, 2001).

Clay is the family name of a powdery form of a rock which has been broken into fine particles by the action of millions of years of decomposition by the forces of nature. It is a product of the continuous weathering of the earth surface. The formation of clay from rock is a most common event, taking place daily everywhere in the world. Weathering breaks up the granite rock and enables the water to wash away the soluble soda, potash, or lime parts of the feldspar. The formation of clay from parent rock is primarily a chemical processes by which fine particles are separated from coarse grains. One of the commonest processes of clay formation is the chemical decomposition of feldspar. Granite contains alkali feldspar, quartz, plagioclase feldspar and some biotile with hornblende (Clews, 1969). Clays are usually classified into two basic types according to their geological origin, primary clay (Kaolins) and secondary clay. They are then sub-divided by particle size and variation of impurities inherent in the native form of the clay. The forces of nature and numerous geological upheavals have caused the various impurities in the form of the minerals and metal compounds have been added, and others, being soluble, have been leached out. Thus, it is a variation of the impurities in the basic formula that accounts for the different types of clay, and consequently, of clay bodies. A theoretical formula for this substance is as shown (Omowunmi, 2007).

$Al_2O_3.2SiO_2.2H_2O$.. (1)

EXPERIMENTAL METHODS

Location

The clay samples were collected from various deposits in Edo and Delta Stated, these areas were classified into six locations Afuze/Ojavu (Edo State), Usen/Arhenwen (Edo State), Uguoriakhi/Ovbere (Edo State), Ozarra/Ewebi (Delta State), Ozalla/Ezeko (Edo/Delta State) and Iguoriakhi/Ogbomoba (Delta/Edo State). The samples were air dried and sieved through 100mesh. Test pieces for various experiments were rammed into standard sizes ATSM C326, 2001), Dried and fired before determination of different parameters.

Equipment

The names of the equipment used are listed as follows: disc mill, drying oven, mechanical vibratory shaker, mould and transverse tester, ceramic kiln, strength tester, venial calliper.

Fired Strength

The test pieces of clay samples were thoroughly mixed and rolled in bars on the transverse tester machine. Each as a length of test piece, a in cm and across sectional area b cm and thickness of the bar t cm in cm^2. Five test pieces were fired in a kiln at different temperatures of 800ºC, 850 ºC, 900 ºC, 950 ºC, 1000 ºC, 1050 ºC, 1100 ºC, 1150 ºC and 1200 ºC respectively and then cooled to room temperature. The five test bars were supported one after another at the two adjustable points of the transverse tester and a load is applied half way between the supports. The load is a bucket, which was gradually filled with water, until the test bar breaks. The weight of the water W is noted. The experiments were repeated for the five test bars and the average results were taken. The tranverse strength (Kg/cm^2) was estimated by using the formular (Chime and Onvekweku, 1979).

$T = \frac{3\ x\ W_2\ X\ a}{2\ x\ b\ x\ t^2} \left(\frac{kg}{cm^2}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (2)$

Note that: $W_2 = \frac{L_1\ X\ W_1}{L_2}\ (Load\ applied\ to\ the\ test\ bar) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (3)$

Where,

T	=	Tranverse Strength in kg/cm^2
t	=	Thickness of the bar in cm
W_1	=	Weight of water in kg
W_2	=	Weight of load in kg
a	=	Length of test bar in cm
b	=	Breadth of test bar in cm
L_1	=	Length between pivot and load
L_2	=	Length between pivot and load W_2

Porosity

Test pieces were oven-dried for 24hours and then fired in a kiln at different temperature intervals of 800ºC, 850 ºC, 900 ºC, 950 ºC, 1000 ºC, 1050 ºC, 1100 ºC, 1150 ºC and 1200 ºC respectively, cooled and transferred into a 250ml breaker, filled with water. The specimens were allowed to soak in boiled water for an hour and then left standing for 24hours. The soaked weight was recorded. The porosity was determined according to the ASTM Standards C 20/2007.

$$P = \frac{W_s - W_d}{W_d}\ x\ 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (4)$$

When: P = Porosity in %, W_s = Weight when soaked in Kg, and W_d = Weight when dry in Kg.

Chemical Analysis

The chemical analysis of the samples was carried out using Atomic Absorption Spectrophotometry (AAS) method. The percentage compositions of the various constituents are as shown in Table 1.

Loss on Ignition

50g of each sample was dried at 110°C and cooled in the desiccators. A porcelain crucible was cleaned, dried and weighed (m_1) to nearest 0.001g. The dried sample was introduced into the crucible and the crucible together with the clay sample ions weighted (m_2) to an accuracy of 0.001g. The crucible containing the clay sample was placed in a muffle furnace and heated to a temperature of 900°C for three hours. The crucible and its contents were cooled in a desicccator and then weighed to nearest 0.01g. The Loss on Ignition (LOI) was calculated by using the formula (Omowumi, 2001).

LOI = $100\%\ \frac{m_2 - m_3}{m_2 - m_1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (5)$ Where;

m_1 = mass of porcelain crucible

m_2 = mass of sample and porcelain crucible

m_3 = mass of fired clay sample and porcelain crucible

Table 1: Chemical Composition of Clays

Sample Location	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	LOI
Afuze/Ojavu	53.44	43.32	2.09	1.49	0.18	0.12	0.05	0.06	14.12
Usen/Arhenwen	47.12	36.08	1.46	1.32	0.15	0.09	0.08	0.04	13.71
Uguoriakhi/Ovbere	56.55	29.11	1.01	1.68	0.12	0.04	0.02	0.09	10.25
Ozarra/Ewebi	51.87	41.23	0.67	1.32	0.16	0.10	1.00	0.3	16.72
Ozalla/Ezeko	46.54	37.85	1.62	1.36	0.15	0.08	0.04	1.2	13.63
Iguoriakhi/Ogbomoba	56.55	39.22	1.47	0.39	0.30	0.20	0.01	0.04	12.41

Table 2: Reference Data on the Chemical Composition of Fireclay

Sample Location	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	LOI
*Fireclay	57.0	26.70	1.6	1.1	0.2	0.7	0.1	2.0	12-15

*Chester (1973)

RESULTS AND DISCUSSION

The chemical composition and firing characteristics of the samples obtained during the study are presented in Table 1 and Table 2 gives the standard results according Chester, 1973. The fired strength of clay samples for different temperature ranges is presented in Fig. 1. And the result of porosity of clay samples at different temperature is as presented in Fig. 2.

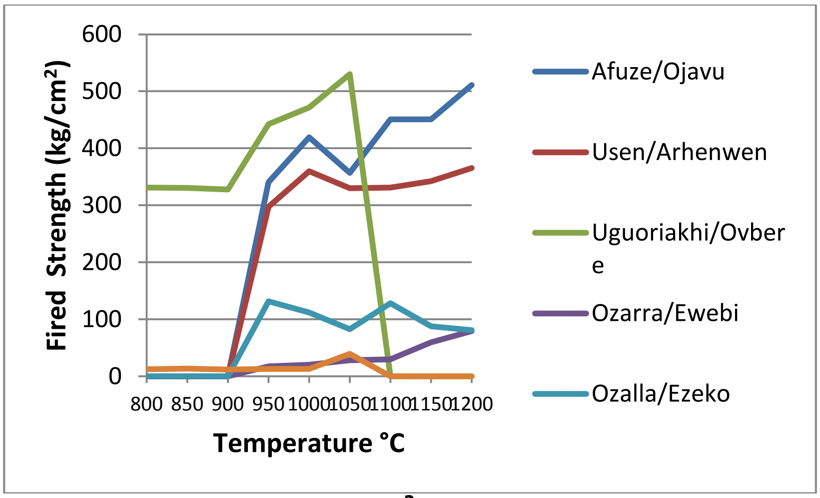

Fig. 1: Fired Strength ((kg/cm^2)) of Clay Samples at Different Temperature (°)

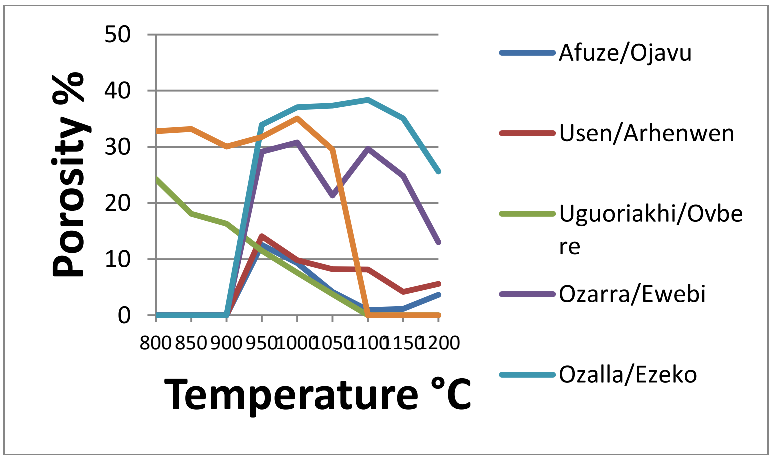

Fig. 2: Porosity (%) of Clay Samples at Different Temperature (°)

DISCUSSION

The firing strength and porosity characteristics of the samples obtained during the study are presented in Fig. 1 and Fig. 2 respectively. The strength behaviour of investigated clays at Afuze/Ojavu (Fig. 1) was found to increase at firing temperature above 900°C. This is expected because the clay is fine-grained and rich in fluxes. The loss in strength at 1050ºC is due to the loss of chemically bond water as well as volatiles from its rather high carbonate content Usen/Arhenwen clay is lean in feldspar, contain no lime and magnesia but has very high clay minerals and ferric oxides. The high strength can be attributed to its high clay content, the particles of which are micro crystalline and have greater surface area of reaction and the possibility that during firing (Fig. 1). The apparent loss of strength between 1000°C and 1100ºC can be attributed to the collapsing of clay molecules and re-crystallization with subsequent changes in specific gravity. The rate of dissolution of the more refractory components slowed down as the viscosity of the molten matter increased. The overall effect was reduction of the rate of vitrification and densification, and reactivity at a much later high enough temperature.

Uguoriakhi/Ovbere bush test clays have the greatest amount of fluxes (Feldspar, Lime and Magnesia). These combined easily with silica and alumina to form eutectics. The degree of liquid formation varies with the type of grain size distribution of the fluxing material and the overall composition of the body (Fig. 1). The development of strength was gradual and gentle up to 900ºC; liquid formation due to the fluxing effect of high alkali content became very vigorous. Below 1000ºC, the alkalis are very powerful fluxes while lime and magnesia become effective above 1000 ºC. Iguoriakhi/Ogbomoba clay is very weak (Fig. 1), the poor rate of vitrification, the clay is basically kaolinitic. Due to the coarser nature of the clay, its feldspar content have little effect at the operating temperature, except at 1000ºC and 1050°C, when there was an increase in strength. With Ozalla/Ezeko bush clay (Fig. 1) the strength drops progressively from 950°C to 1050ºC.

Brick and Pottery Clay

The changes in fired strength at different temperatures of all the clay samples are presented in Fig. 1, which can be classified as bricks and pottery clay. Afuze/Ojavu, Usen/Arhenwen, Uguoriakhi/Ovbere in Edo State are good for brick works. They have low porosities ranging from 0.95% to 24.31% and high fired strength. On the other hand, clay deposit from Ozarra/Ewebi, Ozalla/Ezeko nd Iguroriakhi/Ogbomoba in both Edo and Delta State are good for pottery. They have high porosities ranging from 13.0% to 38.74% and low fired strength.

Porosity

The values for Afuze/Ojavu, Usen/Arhenwen, Uguoriakhi/Ovebere and Ozarra/Ewebi clays fall within the standard values of 20-30% according to Chester (1973), which are good for refractories materials for furnace lining is presented in Fig. 2.

Loss of Ignition

The values obtained for Afuze/Ojavu, Usen/Arhenwen, Ozarra/Ewebi, Ozalla/Ezeko and Uguoriakhi/Ogbomoba clay are within the range recommended for kaolinic clay which have value in the range of 12-15% as shown in Table 1. Uguoriakhi/Ovbere sample has value lower than the recommended value and this may be due to high content of organic matters in the sample.

Chemical Composition

The chemical composition of the various clay samples closely follow those established for fire clay (Table 1).

CONCLUSION AND RECOMMENDATION

The investigations on the fired strength and porosity characteristics of the clay samples show that pottery clay samples have high percentage porosity figures while the brick clays have low percentage porosity figures. Reverse is the case for fired strength, the brick clays have higher strength than the pottery clay. The clay samples can be grouped as acidic refractories because their silica content is higher than 40% (Gleason and Crenshaw, 2003). Other properties such as Shrinkage, cold crushing strength, bulk density, modulus of rupture, refractoriness under load and slag resistance should be determined.

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