Investigating the Potentials of Jalingo Clay for Industrial Uses

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***Abstract*— The objective of this research is to investigate the industrial potentials of Jalingo clay. Chemical analysis using Atomic Absorption Spectrophotometer (AAS) as well as a number of physical tests was carried out on the clay samples to determine its suitability for use in different industries. The results of the chemical analysis show Jalingo clay contains 61.4% of silica (SiO_2) and 19.1% alumina (Al_2O_3) as the major components. Results of physicals tests include; specific gravity of 2.74, bulk density of 2.02g/cm^3 , apparent porosity of 14.32, firing shrinkage 9.2% refractoriness of 1300^{o}C, modulus of rapture 27.64 – 38.92KgF/cm^2 , and thermal shock resistance of 21 cycles. The results obtained shows that Jalingo clay can be used for manufacturing floor tiles and brick due to its high silica content. The refractoriness of Jalingo clay, which falls short of the standard, can only be used in the processing of materials which melting points do not exceed 1300^{o}C.The thermal shock resistance of the Jalingo clay would also restrict its use to lining of ladles and slag pots.**

Keywords*— *Jalingo, Clay, Refractory, Fireclay, Industrial uses.

I. Introduction

The term "clay" refers to a naturally occurring material composed primarily of fine-grained minerals, which is generally plastic at appropriate water contents and will harden when dried or fired. Although clay usually contains phyllosilicates, it may contain other materials that impart plasticity. Associated phases in clay may include materials that do not impart plasticity and organic matter [1].

Clays have varying chemical composition depending on both the physical and chemical changes in the environment where clay deposits are found. Clay is composed mainly of silica, alumina and water, frequently with appreciable quantities of iron, alkalis and alkali earths [2].

Properties of clay minerals include plasticity, shrinkage under firing and air drying, fineness of grain, colour after firing, hardness, cohesion, and capacity of the surface to take decoration [3]. Clay rocks can be identified by their very fine grain size and have different properties depending on which particular clay minerals they contain.

Clay materials are basically divided into three groups; those that contain mainly Kaolinites which are white, greyish-white or slightly coloured becoming darker and plastic when moistened with water. The second group are those that contain mainly Montmorillonite and the third group of clays are the intermediate product of disintegration of mica into kaolin [4]. Generally, potassium feldspar breaks down to form kaolinite; micas weather to give illite, and ferromagnesian minerals break down to form montmorillonite.

Clays are of immersed geological, industrial and agricultural importance [5]. The percentage of the minerals (Fe_2O_3, MgO, CaO, Na_2O, etc) in any clay ultimately determine the areas of application of the clay such as in bricks, floor, tiles and that metal oxides (Na_2O, K_2O, CaO, etc) indicate their suitability for making ceramic products [6]. Depending on the physical and chemical characteristics, clays may find application in a number of industries such as plastics, paint, ceramics, ink, catalysts, pharmaceutical and fibre glass among others [7]. Refractory clays which are used in high temperature processes for example are composed mainly of alumina, while that used in the manufacture of floor tiles contains predominantly silica. Red clays used for the manufacture of terra cotta products are actually natural mixtures with a complex composition. They generally contain kaolinite, illite and/or other clays rich in alkaline, sand, mica (formula $Si_3Al_3O_{10}(OH)_2$), goethite (FeO(OH)) and/or hematite (Fe_2O_3), organic matter and, very often, calcium compounds [8]. The clay deposits found in Jalingo are however used almost exclusively for pottery, determination of its physical and chemical characteristics would help in expanding its use in industries that are suited to the properties determined.

II. MATERIALS AND METHODS

Materials

Fresh clay samples were collected from Jalingo local government area of Taraba state, North East Nigeria by digging with a hoe, shovel and digger to a depth of about 1.0m. The location from where the clay samples were obtained is the same as where local pottery makers get theirs. The sample was then prepared for chemical and physical analysis by adopting the procedure used in preparing Ibamajo clay [9].

Method

Chemical Analysis

The chemical analyses of the clay samples were done using an Atomic Absorption Spectrophotometer (AAS). The samples were prepared for analysis according to the procedure outlined for Ngwo white clay [2].

Loss on Ignition LOI

100g of the clay sample was oven dried at 110^{o}C and allowed to cool. 20g of the dried sample was placed in a porcelain crucible and further heated in a muffle furnace at 900^{o}C for 3 hours. The loss on ignition was calculated using the equation;

$$\frac{Dry\ Weight - Fired\ Weight}{Dry\ Weight} \times 100 \qquad (1)$$

Firing shrinkage

Standard slabs were made from clay samples and marked along the length of the slabs. A veinier calliper was used to measure the distance between the markings. The slabs were air dried for 24 hours followed by oven drying at 110ºC for 6 hours. The slabs were then fired at 1100ºC in a muffle furnace for 6 hours also. The distances between the markings after firing were measured, again with a venire calliper. The firing shrinkage was then calculated using the following equation;

$$\frac{Fired\ Length - Dry\ Length}{Fired\ Length} \times 100 \qquad (2)$$

Refractoriness Test

Pyrometric cone equivalent P.C.E method was adopted for measuring the refractoriness of the clay. Test cones were prepared by mixing clay sample aggregates with sufficient quantity of water to make the clay plastic, which was then hand moulded into cone shapes. The samples were dried and fired to a temperature of 1000ºC in a muffle furnace. Pyrometric cones designed to deform at 1300ºC, 1400ºC, and 1500ºC were placed round the samples in the muffle furnace and temperature raised to above 1000ºC at 10ºC per minute. The heating was discontinued when the test cone bent over and levelled with the base of the disc. The pyrometric cone equivalent (P.C.E) of the samples was recorded as the number of the pyrometric cones that has bent over to a large extent similar to the test cone. The temperature was then read off from the equivalent of the cone number.

Modulus of rupture (MOR)

Standard clay bars dimension were prepared by using a wooden mould and air-dried for 48 hours. Six of the bars were temperature marked then charged into a muffle furnace separately along with American standard pyrometric cones of refractoriness 900°C, 1000°C and 1200°C and fired for approximately 10 hours, removed from the furnace and allowed to cool. Each batch of bars were broken at the center bending on a Denison strength testing machine at 7.0 cm span and modulus of rupture was calculated from the following equation;

$$MOR = \frac{3PL}{2bh^2} \qquad (3)$$

Where P is the breaking load, L the distance between support, b the breadth and h the height.

Thermal Shock Resistance

Test bars made from the clay samples with same dimension as that used in MOR test was thoroughly dried and placed in a cold furnace and heated at the rate of 10ºC per minute until the furnace temperature reached 1200ºC.This temperature was maintained for 30 minutes after which the test piece was removed from the furnace and cooled for 10 minutes. The test piece was recharged again for another 10 minutes at 1200ºC and then cooled again for 10 minutes.

Cycles of heating and cooling were repeated until fracture was noticed in the test bar.

Other tests to measure *specific gravity*, *bulk density*, and *apparent porosity* of the clay were also carried out according to the methods outline in analysing Ibamajo [9] and Dukku clays [10] and recorded accordingly.

III. EXPERIMENTAL RESULTS AND DISCUSSION

Table 1 shows the results obtained after analysing the clay samples using Atomic Absorption Spectrophotometer (AAS), the results obtained were compared to international standards for fireclays and refractory bricks. Table 2 presents the results obtained after subjecting Jalingo clay to aforementioned physical tests, the results are also compared to international standards.

Table 1. Results of physical test on Jalingo clay as compared to international standards

Component	Jalingo Clay	Fireclay*	Refractory Bricks*
SiO_2	61.40	55-75	51-70
Al_2O_3	19.10	25-45	25-40
Fe_2O_3	1.86	0.5-2.0	0.5-2.4
CaO	1.08	--	--
MgO	0.85	<2.0	--
K_2O	1.24	<2.0	--
Na_2O	1.11	--	--
Ti_2O	1.13	--	--
LOI	11.28	12-15	--

*[10]

Table 2. Results of physical test on Jalingo clay as compared to international standards

Property	Jalingo Clay	Fireclay*	Refractory Bricks+
Specific gravity	2.74	2.0 - 2.9	2.0 - 2.9
Bulk density	2.02 g/cm^3	1.71-2.1	1.71-2.1
Apparent porosity	14.32%	20-30%	30%
Firing shrinkage	9.20%	7-10%	4-6%
Refractoriness	1300ºC	1500-1700	1500-1700
MOR	27.64 – 38.92 KgF/cm^2		1.4 –105KgF/cm^{2}#
Thermal Shock Resistance	21	25-30	

[3], + [9], * [10].

Chemical Analysis: Form the chemical analysis it was found that the predominant components are silica (SiO_2 61.4%) followed by alumina, (Al_2O_3 19.1%) this could be an indication of kaolinite clay. Such type of clays can be used for manufacturing floor tiles [4]. The silica content of the clay sample falls within the standard range for fireclays and refractory bricks. This means that it can be used for lining of heat treatment furnace melting furnaces for low melting point metals, liquid metal ladles and portions of blast furnaces [10]. In addition, high silica value makes such a clay material potential source for brick production [4]. However, the alumina content of the clay sample falls short of the standard range for both fireclay and refractory bricks. For good refractory characteristics, clay should have a composition of Al_2O_3, between 30 and 50%, as alumina content is usually a measure of how suitable clays are as refractory materials. Clays to be used as refractory materials should also have a limited amount of Fe_2O_3, TiO_2 and CaO [7].

Loss on Ignition: This represents the amount of weight a material loses on firing; it is usually crystal-bound water or carbon material that burns away. The value of 11.28% obtained is lower than the range recommended for fireclays which have values in the range of 12-15% (Table 1). Losses on ignition values are often required to be low, because of its effect on the porosity of refractory bricks. The low value is an indication of low porosity value of the clay.

Specific Gravity: The specific gravity of the sample as shown in Table 2 is 2.74 and the value falls within the internationally accepted range of 2 – 2.9 for both fireclays and refractory bricks.

Bulk Density: The bulk density of the sample as shown in Table 2 is 2.02g/cm^{3}and the value falls within the internationally accepted range of 1.7—2.1g/cm^3 for both fireclays and refractory bricks.

Apparent Porosity: The value of 14.32% obtained is below the ranges for both fireclay and refractory bricks as indicated in Table 2. The effect of this is that at high temperature, thermal losses would be experienced. It has been established that thermal conductivity decreases in refractory materials as its porosity increases with the pores acting as non-heat conducting media. The low percentage of apparent porosity enhances the entrapping of gases in the material during operation. This will adversely affect the life span of the refractory material when in operation; the values may be increased with addition of fine grain of additives, such as, saw dust or rice husk [11].

Firing shrinkage (Linear Shrinkage)
The linear shrinkage of the clay under investigation was found to be 9.2%, which falls within 7 – 10% as shown in Table 2. The factors influencing thermal expansion in clays are the particle size and chemical composition, as some compounds are known to expand readily than others at the same temperature. Clays which have the greater amount of stability are supposed to be the best for use as refractories.

Refractoriness: The temperature obtained is 1300ºC which indicates poor refractoriness. Fire clay, refractory bricks should have refractoriness in the range of 1500 – 1700ºC (Table 2). This low value of refractoriness is expected high since alumina content is required for good refractory materials; Jalingo clay as shown in Table 1 contains high silica clay and low alumina (19.1%) which already mentioned, falls short of standards. The effect of this is that its use is restricted to the processing of materials which melting points do not exceed 1300ºC.

Modulus of Rupture: The modulus of rupture is the load bearing capacity of the clay. From Table 2, the modulus of rapture range from 27.64 – 38.92kgF/cm^2, as temperature increased from 900ºC to 1200ºC. This is within the acceptable standard of 1.4 – 105kgF/cm^2 [3]. The strength behaviour which increased with temperature could be attributed to bond formation in the glassy phase. The soda in the clay component would have combined to form some considerably low temperature melting compounds, which increase the strength of the bulk when cooled.

Thermal Shock Resistance: As can be seen from Table 2, the thermal shock resistance of the sample is 21; this is short of the acceptable range of 25-30 cycles. In practice this means the clay uses would be restricted to lining of ladles and slag pots which are early mended at shock intervals.

IV. CONCLUSION

The chemical composition of Jalingo clay makes it ideal for the manufacture of floor tiles and brick. The refractoriness of Jalingo clay, however falls short of the standard, thus can only be used in the processing of materials which melting points do not exceed 1300ºC.The thermal shock resistance of the Jalingo clay would also restrict its use to lining of ladles and slag pots which are early mended at shock intervals. Other uses of the clay could be for lining of heat treatment furnace melting furnaces for low melting point metals, liquid metal ladles and portions of blast furnaces. Even though Jalingo clay refractoriness is low, it can be blended with clays of considerable high amount of alumina to improve its refractoriness.

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