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Characterisation of Omoku and Ogoni Clay in Rivers State Nigeria for Use as Industrial Raw Material

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Abstract- Clays in Omoku and Ogoni Rivers State Nigeria were characterized to establish its use industrially. From the analysis, the specific gravity of Omoku and Ogoni clays were 2.38 and 2.18, liquid limit 56.00% and 40.25%, plastic limit 24.50% and 19.32%, plastic index 31.50% and 20.93%, drying shrinkage 14.31% and 09.46%, bulk density 2.55(g/cm^3) and 2.56(g/cm^3) and apparent porosity 30.61% and 26.92% respectively and the particle size distribution with Plasticity chart for classification of cohesive soils showed that the samples are clays. The results show that the physical properties of the clays are within the specifications for kaolin clays and are suitable for industrial uses.

Keywords- *Clay, Kaolin, Raw Material.*

I. INTRODUCTION

Clay is a general term including many combinations of one or more clay minerals with traces of metal oxides and organic matter [1]. Clay minerals are typically formed over long periods of time by the gradual chemical weathering of rocks, usually silicate-bearing, by low concentrations of carbonic acid and other diluted solvents. These solvents, usually acidic, migrate through the weathering rock after leaching through upper weathered layers. In addition to the weathering process, some clay minerals are formed by hydrothermal activity.

Clay deposits may be formed in place as residual deposits in soil, but thick deposits usually are formed as the result of a secondary sedimentary deposition process after they have been eroded and transported from their original location of formation. Clay deposits are typically associated with very low energy depositional environments such as large lakes and marine basins [2].

Depending on the academic source, there are three or four main groups of clays: kaolinite, montmorillonite-smectite, illite, and chlorite. Chlorites are not always considered as a clay, sometimes being classified as a separate group within the phyllosilicates. There are approximately 30 different types of "pure" clays in these categories, but most "natural" clays are mixtures of these different types, along with other weathered minerals [2].

There are two general types of clay: expandable and non-expandable clay [3]. Expandable clay swells up when water is added to it and can become liquid when or if enough water is added to it. Non-expandable clay called Bentonites is used to make drilling mud in the petroleum industry. Non-expandable clay is used in the ceramics industry to make bricks, tiles, pottery and porcelains. The important properties of clay are plasticity, colour, clay strength, drying and firing shrinkages [4]. Primary clays, also known as kaolins, are located at the site of formation. Secondary clay deposits have been moved by erosion and water from their primary location [5].

Clays exhibit plasticity when mixed with water in certain proportions. When dry, clay becomes firm and when fired in a kiln, permanent physical and chemical changes occur. These reactions, among other changes, cause the clay to be converted into a ceramic material. Raw materials used in the traditional ceramics industry can be classified as clay (plastic) and non-clay (non-plastic) minerals. Clays are the chief raw material for many commercial structural ceramic products such as wall tiles, roofing tiles, building bricks, and white wares [6]. Because of these properties, clay is used for making pottery items, both utilitarian and decorative, and construction products, such as bricks, wall and floor tiles. Different types of clay, when used with different minerals and firing conditions, are used to produce: earthenware, stoneware and porcelain [2]. The applicability/acceptability of clay is however dependent on an appreciable knowledge of its mineral content and chemical composition [7-8].

Kaolins clays are important materials having major geological and industrial significance. The kaolin minerals kaolinite, halloysite, dickite and nacrite are essentially of similar chemical composition but they have important structural and stacking differences. The most common kaolin mineral is kaolin-ite [$Al_2Si_2O_5(OH)_4$]. Several factors including the geological conditions of formation, the total min-eralogical composition of the kaolin deposit, and the physical and chemical properties may affect the industrial application of this material [9]. Kaolin deposits can be of hydrothermal, residual or sedimentary origin. The first two are classified as primary and the third as secondary [9]. The mode of formation of the kaolins depends on the mineralogy, chemistry and morphology of the kaolin minerals, which may affect their physical and chemical characteristics and their ultimate industrial applications [10].

Clays are natural products which can be used in industry, crude or treated, by physical and chemical Methods [11]. They have found acceptance in ceramics porcelain, dinner wares, architectural tiles and enamel [12]. They are used for example in ceramic industries for the manufacture of white ware, porcelain, refractories and other clay products [13].

There are vast deposits of clay spread across every region in Nigeria, though their properties differ from site to site on account of geological differences. Ironically, the bulk of clay requirement of the nation is imported from the United Kingdom, USA and Japan [14]. The present economic state imposes the need for internal sourcing of raw materials to meet up increasing demands [4]. To use clay effectively; their surface Characteristic need to be known. Wide variety of physical characteristic of clay such as plasticity, specific gravity, particle size distribution, drying shrinkage etc. make them suitable for a wide variety of industrial application [11]. Therefore the aims of this work were to characterize clay samples of omoku and ogoni in Rivers State Nigeria to determine their use as industrial raw material and improve their market value.

II. MATERIAL AND METHODS

A. Sample Collection

The clay samples were obtained from Omoku and Ogoni in Rivers State Nigeria from various points by random sampling in order to have a good representation of the site. The samples were brown and black in colour and dry in appearance. About 2kg of the dried samples were grinded manually in a mortar using pestle and were sieved through 2.0mm and 425μm sieve. The sieved portions were collected as sample for analysis.

B. Specific gravity

The specific gravity of the clay samples were determined using ASTM D 854-00 – Standard Test for Specific Gravity of Soil Solids by Water Pycnometer and this expression were used to determine it [15]:

$$G_s = \frac{W_0}{W_0 + (W_A - W_B)} \quad (1)$$

Where:
G_s = specific gravity
W_0 = weight of sample of oven-dry soil (g) = W_{PS} - W_P
W_p = Weight of empty pycnometer
W_{ps} = Weight of pycnometer + dry clay
W_A = Weight of pycnometer filled with water
W_B = Weight of pycnometer filled.

C. Atterberg limit tests

Atterberg limit tests conducted are the liquid limit (LL) and plastic limit (PL) using ASTM standard test method D 4318. The plasticity index (PI) was calculated based on the arithmetic difference of the LL and PL of the clay.

D. Determination of porosity, shrinkage tests, bulk density.

50g of 425 μm sieved sample was poured into a plastic basin and moistened with distilled water using palette knives until a thick homogenous paste about the liquid limit was created. The sample was cast in brass moulds coated with thin film of machine oil (The oil was to facilitate easy removal when dry). The length was measured and placed in an oven to dry slowly. The expression for wet-dry shrinkage was obtained as [16]:

$$wet - Dryshrinkage = \frac{OriginalLength - DryLength}{Original\ Length} * 100 \quad (2)$$

The dried weigh samples were then immersed in water. Bubbles were observed as the pores in the samples were filled with water. After 8 hours, the samples were weighed and the soaked weight recorded as well as the suspended weight. They following expression were used to determine the bulk density and apparent porosity:

$$BulkDensity = \frac{Dry\ Weight}{Dry\ Weight - Suspended\ Weight} * 100 \quad (3)$$

$$Apparent\ Porosity = \frac{Soaked\ Weight - Dry\ Weight}{Soaked\ Weight - Suspended\ Weight} * 100 \quad (4)$$

E. Determination of Particle Size Distribution

The particle size distribution of the bulk samples was determined by Hydrometer Method [17]. Using sodium hexametaphosphate as dispersant.

The formula [17] for calculation of the percentage of original sample still in suspension is:

$$P = \frac{\left[\left(\frac{100000}{W}\right)G\right](R_c - G_L)}{(G - G_L)} \quad (5)$$

Where
P = % of soil remaining in suspension
W = oven dry weight of sample
G = specific gravity of soil particles
G_L= specific gravity of liquid (= 1)
R_c = hydrometer reading corrected by the"composite correction factor" related to temperature.
$R_c = R – R_L$

Where R is the reading in the soil suspension and R_L is the difference between the hydrometer reading in distilled water at the same temperature as the settling column, and the hydrometer reading in a column of the dispersing agent plus hypochlorite.

III. RESULT AND DISCUSSION

A. Specific gravity

The specific gravity values of the clay samples from the analysis are:

Omoku clay = 2.38
Ogoni clay = 2.18

These values of the specific gravity Omoku and Ogoni clay fall within the standard for a Kaolin clay [18-19].

B. Atterberg limit tests

Atterberg limit tests of Omoku clay and Ogoni Clay are shown in the "Fig.1" below. The LL, PI and PL values are 56.00%, 31.50% and 24.50% for Omoku clay and 40.25%, 20.93% and 19.32% for Ogoni clay respectively (fig. 1). This implies that Omoku clay has high LL, PL and PI compare to Ogoni clay.

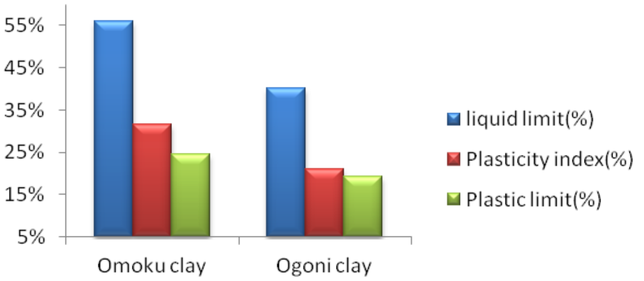

Fig.1. Atterberg limit

Classification of soil on type of plasticity using the Liquid limit based on the British Soil Classification System for Engineering Purposes [20]. As shown in Table 1. Below; Omoku clay can be classified as clay of high plasticity and Ogoni as clay of intermediate plasticity.

TABLE 1. PLASTICITY TABLE

Type of Plasticity	**Liquid Limit**
Low plasticity	w_L = < 35%
Intermediate plasticity	w_L = 35 - 50%
High plasticity	w_L = 50 - 70%
Very high plasticity	w_L = 70 - 90%
Extremely high plasticity	w_L = > 90%

(British Soil Classification [20].)

Where: Liquid limit = (w_L)

Comparing with the 'A-Line' classification chart [20]. Which plots Plasticity Index (%) against Liquid Limit(%) "Fig.2" below. The main aim is to determine if the fine soil is either silt or clay. Clay plots above the A-line and silt below it. From the chart both clays can be classified as upper plasticity range clay with Omoku clay as clay of high plasticity and Ogoni as clay of intermediate plasticity therefore the Clay minerals have the capacity to take in moisture and still retain some cohesion.

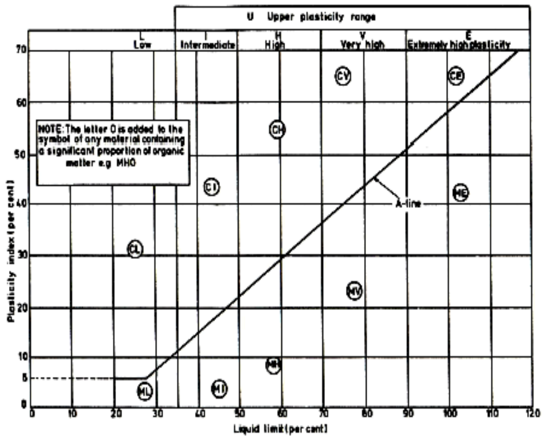

Fig. 2. 'A-Line' classification chart [20]

Where:

C = Clay and M = Silt.

Classification of the clays in terms of their degree of compressibility using the Plasticity chart "fig.3" below for classification of cohesive soils [21]. From the chart both clays are classified as inorganic clays. Omoku clay has high degree of compressibility and Ogoni clay having medium compressibility.

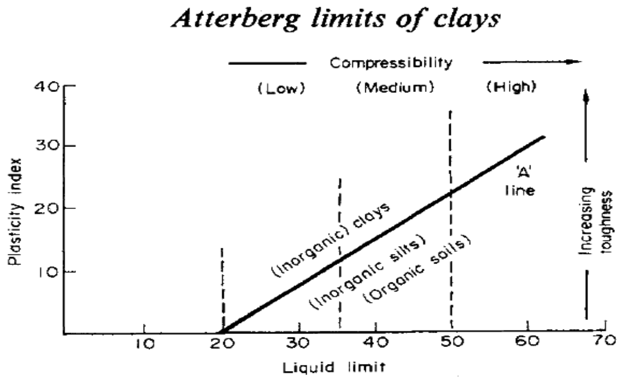

Fig.3. Plasticity chart for classification of cohesive soils (after A. Casagrande)

The PL and PI values show that the kaolin from both areas is of medium plasticity. According to the clay workability in "fig.4" below. The Ogoni and Omoku clay falls in the category of kaolinitic clays that are suitable for brick and pottery making. Ogoni clay falls within Kaolin clay with optimum moulding properties while Omoku clay falls within kaolin clay with acceptable properties.

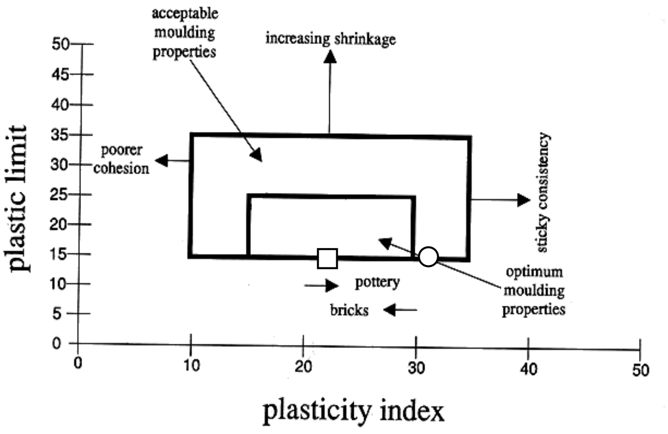

Fig. 4. Representative kaolin samples plotted on the clay workability chart of Bain & Highly [22]

Where:
☐ = Ogoni clay.
○ = Omoku clay.

C. Determination of porosity, shrinkage tests, bulk density.

Apparent porosity is the percentage of the clay samples that is said to be void. From the analysis the apparent porosity of Omoku clay is 30.61% while that of Ogoni clay is 26.925%, thereby revealing that they could be used for absorption of heavy metal from solution.

Drying Shrinkage is the rate at which the clay reduces in length and weight when dried and fried. From the Drying shrinkage chart "fig.5" below; Omoku clay has a high drying shrinkage compare to Ogoni clay, therefore Ogoni clay can be used as brick clay as it is within the ASTM -Allowable Value for ceramic tiles on sale, 15% maximum for total shrinkage [6]. While the drying shrinkage of Omoku clay exceeds the ASTM - allowable value.

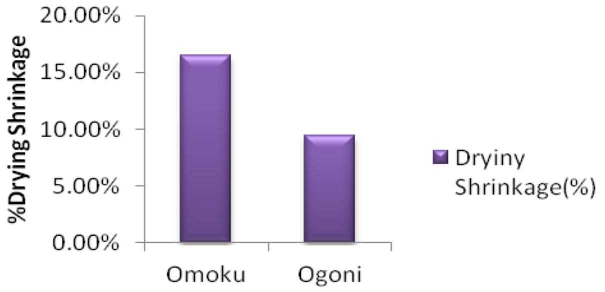

Fig. 5. Drying Shrinkage Chart

Bulk density is an important property of a steel work silica brick, from the analysis the bulk density of the clays are:

Omoku Clay: 2.55g/cm^3
Ogoni Clay: 2.56g/cm^3

Therefore the bulk density of the clay samples was within the range of 02.1 – 02.6 g/cm^3 of Kaolin clay [23]. And this makes them suitable for siliceous fireclays [24].

D. Determination of Particle Size Distribution

From the Hydrometer analysis, the result of particle size distribution is shown in "fig.6" below and comparing with the soil textural chart [17]. Omoku clay can classified as sandy clay and Ogoni clay as silty clay.

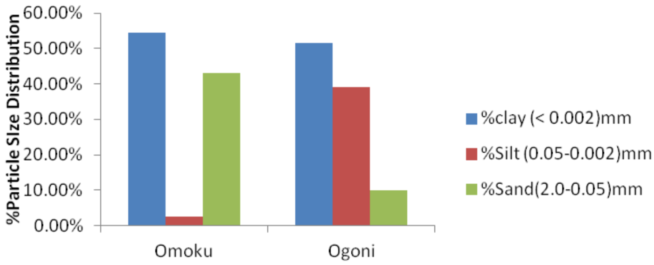

Fig. 6. Particle Size Distribution Chart

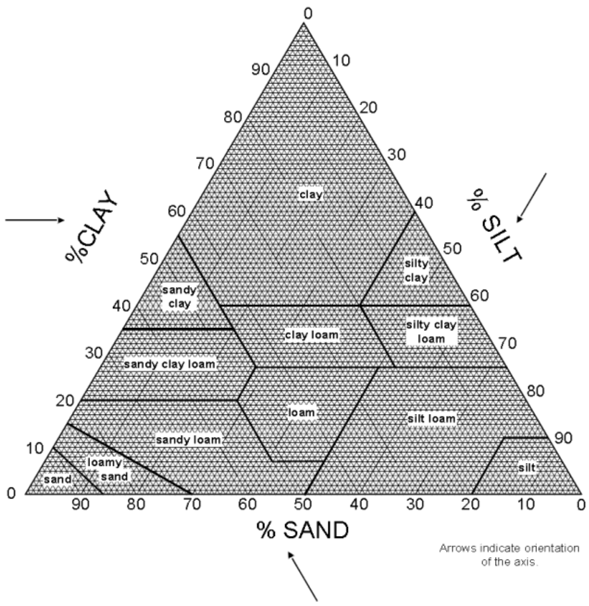

Fig. 7. The Textural Triangle [17]

IV. CONCLUSION

The investigation revealed that the characteristic clay mineral abundant in the clay sample is Kaolin. From the specific gravity and the A Line classification chart both clays are classified as inorganic clays. The Liquid limit, Plastic limit and Plastic index of Omoku clay are higher than Ogoni clay. The physical properties also showed that the clay samples could serve as good refractory materials for local industries.

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