KKU Engineering Journal

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Physic-chemical characterization of "Namu" clay for industrial use

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Received November 2013

Accepted February 2014

Abstract

Clay in Namu, Plateau State Nigeria, was characterized physio-chemically to ascertain its use industrially. From the results, the moisture content (db) of Namu clay was 3.95%, dry clay content 77.15%, pH level of 6.83, liquid limit 56.47%, plastic limit 23.14%, plasticity index 33.33 %. Other results are cold crushing strength of 385 kg/cm^3, loss on ignition 17.64%.The clay changes from brown to golden brown on firing. The linear shrinkage increases with firing temperature, while there is steady decrease of water absorption with increase in temperature. Particle size distribution with Plasticity chart for classification showed that the samples are clays. Comparing with the 'A-Line' classification chart which plots Plasticity Index (%) against Liquid Limit (%) showed that Namu clay can be classified as an inorganic clay with medium to high degree of compressibility. The results show that the physical properties of the clays are within the specifications for kaolin clays and are suitable for industrial uses.

Keywords: Clays, Refractoriness, Plasticity, Mouldability, Industrial

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1. Introduction

Clay minerals are well known and recognizable to mankind for a long time. Clay is a naturally occurring material which composed primarily of fine-grained minerals, which is usually plastic at appropriate water contents and will harden when dried or fired [1] Clay occurs abundantly in soils, sediments, sedimentary rocks, and hydrothermal deposits [2]. They have varying chemical composition which depends on both the physical and chemical changes in the environment where clay deposits are found [3]. They are composed mainly of silica, alumina and water, frequently with appreciable quantities of iron, alkalies and alkali earths [4]. There are basically two types of clay: expandable and non-expandable clay [5]. Expandable clay swells when water is added to it and can become liquid when or if enough water is added to it. There are lots of deposits of clay stretching across every part of Nigeria, though their properties vary from site to site as a result of geological differences. Paradoxically, much of the clay requirement of the nation is imported from the United Kingdom, USA and Japan [6].

The present economic reality calls for internal sourcing of raw materials to meet the ever increasing demands. The important properties of clay are plasticity, colour, clay strength, drying and firing shrinkages. The percentage of the minerals oxides (Fe_2O_3, MgO, CaO, Na_2O etc) in the clay ultimately determine the areas of applications of the clay such as in tiles, bricks, floor, paper etc, while the quantity of the alkali metal oxides (Na_2O, K_2O, CaO etc) indicate their suitability for making ceramic products [7]. The specific clay minerals are identified by several techniques including thermal differential analysis, scanning electron microscope, infrared spectrometry and X-ray diffraction. Chemical analysis is an essential step to establish the nature of minerals [8].

Large deposits of residual clay in Namu, Plateau state, Nigeria and its environment has been discovered by the inhabitant since earlier settlers. The people of these communities have been largely depended on the crudely processed clay products such as clay pots as well as bricks for mud houses. Despite the huge occurrence of clay in these communities, the properties of the deposits remain largely unknown. Therefore, this study is primarily focused at examining the properties of the clay deposits in order to assess their usability and ascertain its suitability for Industrial purposes.

2. Materials and methods

For a comprehensive assessment of the clay samples in the study area, five samples were collected from five different locations within the study area. Samples were collected at depth of 2 - 3 m. The samples after removing the impurities, were ground to increase the surface area. The grinded samples were packed in sample bags for test and analysis. The five samples collected were thoroughly mixed together before grinding was carried out. The clay specimens were subjected to standard tests. Chemical parameters studied are clay content using Na_2CO_3 as deflocculant and pH value. Physical properties determined include visual inspection, sieve and hydrometer analysis, plasticity (Atterberg's limit) and natural moisture content. Other tests carried out are refractoriness, cold crushing strength, apparent porosity, water absorption, loss on ignition, fired linear shrinkage, bulk density and modulus of rupture after firing at different temperatures.

3. Results and discussion

3.1 Granulometric composition

The result of the particles size distribution (Table 1) shows that the average particle sizes of more than 2 mm is 1.05%, 0.063 to 2 mm is 10.25%, 0.002 to 0.063 mm is 31.55% while less than 0.002 is

57.15%. These values are relatively high and good for their plasticity and mouldability [9]. Using the USDA textural triangle for textural classification; the deposit is found to be essentially clay as shown in Figure 1.

3.2 Moisture content

Moisture content is a fundamental factor in determining the suitability of a clay sample for brick and ceramic making. The amount of water content in the clay determines its plasticity and strength. The clay examined has an average moisture content of 3.95%. This low water content at 115^{o}C matched the high water absorption value at high temperatures.

Table 1 Granulometric composition of the clay

Size (mm)	Quantity (%)
Greater than 2 .00	1.05
0.063 – 2.00	10.25
0.002 – 0.063	31.55
Less than 0.002	57.15

Table 2 Chemical properties of clay

Property	Quantity value
Clay content	77.15%
pH value	6.82
Moisture content	3.95%

3.3 Clay content

The average percentage clay content was found to be 77.15% (Table 2) determined by using deflocculant sodium bicarbonate (Na_2CO_3) which act as the coagulant of the clay particles from water/clay suspension. The significant clay content in the samples rather than silts will favour easy mouldability and high plasticity.

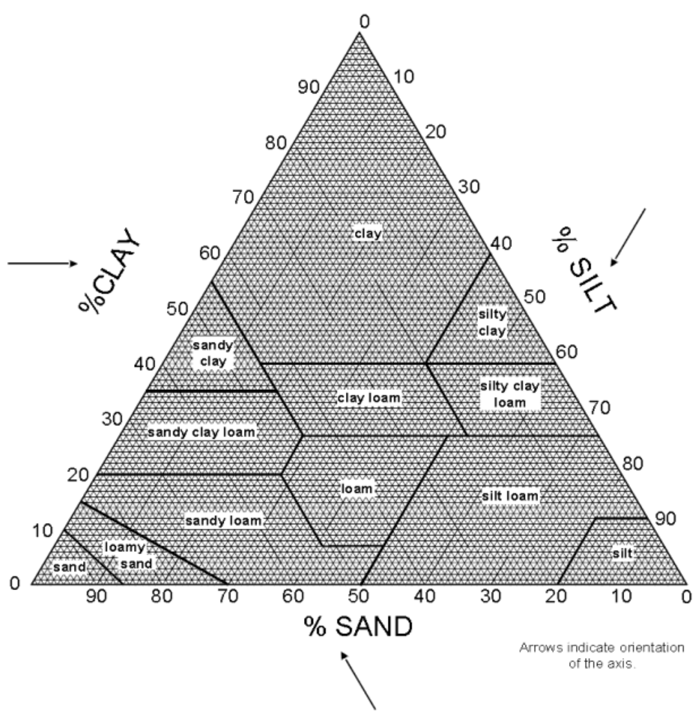
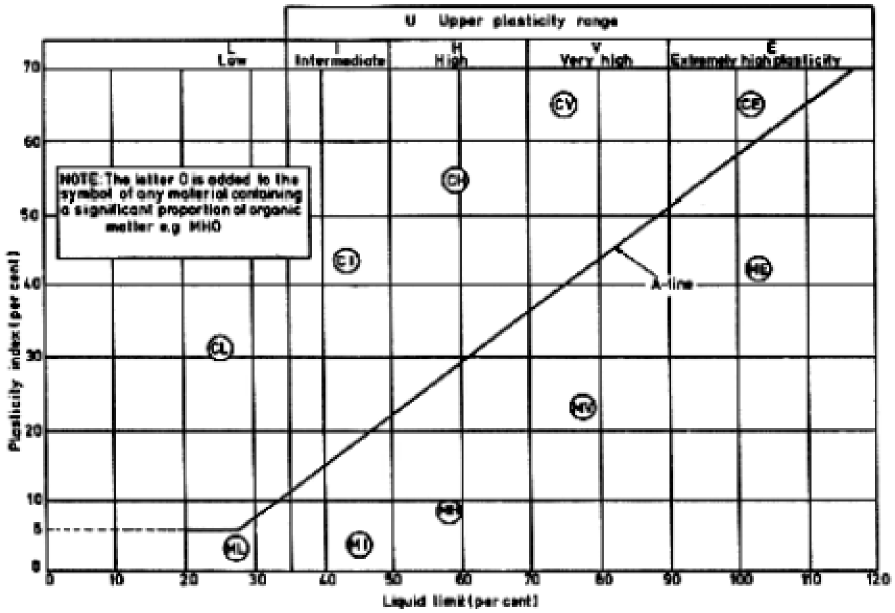


Figure 1 The textural triangle [10]



Where: C = Clay and M = Silt

Figure 2 A-Line classification chart [11]

Table 3 Moulding and firing characteristics of the clay

Property/Temperature (°C)	900	1000	1100	1200
Fired Linear Shrinkage	6	6.5	7	8
Apparent Porosity (%)	23.14	16.24	9.715	5.18
Water Absorption (%)	14.44	10.35	5.19	2.47
Bulk Density (g/cm^3)	1.51	1.62	2.07	2.28
Modulus of Rupture (kg/cm^3)	354.61	420.67	580.17	850.11
pH	6.82			
Loss on Ignition (%)	17.64			
Liquid limit (%)	56.47			
Plastic limits (%)	23.14			
Plasticity index (%)	33.73			
Moisture Content (%)	3.95			
Cold Crushing Strength (kg/cm^3)	385			
Refractoriness (°C)	1520			

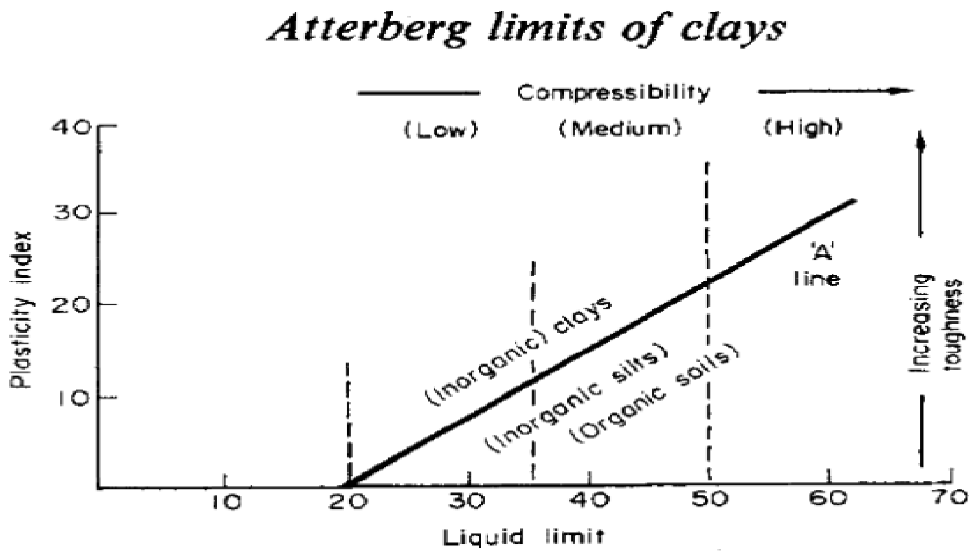


Figure 3 Plasticity chart for classification of cohesive soils [12]

3.4 pH results

The clay samples is essentially acidic with pH of 6.82. It basically depends on the process of formation, which is a function of pH of soil water, during the processes. The low pH of the clay favours the formation of kaolinite group of clay minerals.

3.5 Change of color on ignition

The existence of ferric oxide in clay changes the color of the fired brick it either enhances the beauty of the beauty of the fired product or discolors it, depending on desire color. The change to reddish brown color after firing shows that ferric oxide is present in the clay.

3.6 Plasticity

The clay has an average liquid limit, plastic limits and plasticity index of 56.47, 23.14 and 33.33 respectively (Table 3). The plastic limit of the clay is within the range of 10 – 60% for clay used in ceramic production [13]. Using Cassagrande chart the clay falls within the high plasticity and compressibility with inorganic clay group. Comparing with the 'A-Line' classification chart which plots Plasticity Index (%) against Liquid Limit (%) (Figure2). The aim is to determine if the fine soil is silt or clay. Clay plots above the A-line and silt below it. From the chart Namu clays can be classified as clay of high plasticity.

3.7 Cold crushing strength

The average cold crushing strengths (CCS) obtained is 385 $Kg/cm^{3.}$ It is higher than 150 kg/cm^3 minimum value recommended by (De Bussy, 1984) for high duty silica bricks. CCS is the measures of the ability of the clay to withstand abrasion and loading. It shows that the clay can withstand handling, loading and transporting without much damage to the corners and edges of the bricks if fired properly.

3.8 Apparent porosity

The presence of pores in clay affects the strength by reducing the cross-sectional area expose to an applied load. They also act as stress raiser or concentrator especially in brittle clays[15]. There are a lot of factors that affect the porosity of refractory raw materials, especially fireclays, some of the factors include the clay composition, size, ramming pressure, shapes of particles, and the reaction that is taking place during firing. Porosity is a measure of ease with which liquid and gas slip through a material, it is also a sign of volume shrinkage. The apparent porosities were examined at various firing temperatures and the result is shown in Table 3. The result of 23.13% was found to be in the normal range of 20 – 30% for dense firebricks at 900°C. Manual ramming method used in this investigation which reduces densification also contributes to high porosity recorded. Beyond this temperature, some of the smaller particles disintegrate and verification proceeds leading to decreases in porosity as reported by [9].

3.9 Water absorption

The water absorption varies with the apparent porosity values as shown in Table 3. The average percentage of the water absorption capacity of the fired sample at 900°C, 1000°C, 1100°C and 1200°C are 14.44%, 10.35%, 5.19% and 2.47% respectively. The steady decrease with rising temperature indicates that the fired clay samples are resistant to moisture penetration at higher firing temperature, which leads to reduction in the water absorption ability as the particles contract together thereby decreases porosity.

3.10 Refractoriness

The refractoriness of the clay is 1520°C (Table 3), this temperature is lower for a fire clay brick since between 1580°C – 1750°C is recommended [13]. The relatively low refractoriness of the clays suggests that the deposits may not be able to withstand higher temperature casting, but can handle other metallic cast products with temperatures lower than 1500°C

3.11 Loss on ignition

The loss on ignition of the clay 17.64% as shown in Table 3 is higher than the range of 12 – 15% recommended for kaolinitic clays, as suggested in [16] for used as refractory material. The higher value obtained may also be due to the content of organic matters present in the clay.

3.12 Fired linear shrinkage

From Table 3, it can be seen that the linear shrinkage of the clay increases with increasing firing temperature of the furnace. The value acquired at the highest temperature of the test was high. This may be due to the fineness of the particles, since finely grain materials shrink more than those of coarser grain [12]. Mineral composition such as presence of mica and quartz (or other alkali – bearing minerals) also affect the volume shrinkage.

3.13 Bulk density value at different firing temperatures

This property is important in the transportation or handling of a refractory material. Some of the factors known to affect this property include particle size, treatment during manufacturing and the nature of the materials in the clay The bulk densities of the clay samples at different temperatures as shown on Table 3 are in the range of 1.6 – 2.4 g/cm^3 reported by [17] except the values at 900°C. This clearly suggests that the clay should be fired at a temperature greater than 900°C for the desired density. Changes in many other properties results from changes in bulk density and is a means of identifying the acceptable firing condition, the higher the bulk density the better the firing characteristic of the clay. The optimum temperature for firing the clay is 1200°C.

3.14 Modulus of rupture

The value obtained for modulus of rupture is within the acceptable recommended value (Table 3). At temperature above 1000^{0}C, the amount of liquid formed will increases and on cooling, this liquid formed will solidified to form glass, which acts as a cement to bind the mass together, thereby conferring great strength on the body [16].

4. Conclusion

The characterized clay in Namu, Plateau State Nigeria shows that the moisture content of the clay is 3.95%, dry clay content 77.15%, pH level of 6.83, liquid limit 56.47%, plastic limit 23.14%, plastic index 33.33 %. Other results are cold crushing strength of 385 kg/cm^3, loss on ignition 17.64%.The clay changes from brown to golden brown on firing. The linear shrinkage increases with firing temperature, while there is steady decrease of water absorption with increase in temperature. Particle size distribution with Plasticity chart for classification showed that the samples are clays. The results show that the physical properties of the clays are within the specifications for kaolin clays. Classification of the clays in terms of their degree of compressibility using the Plasticity chart (figure 3). From the chart the clays is classified as inorganic clays with medium to high degree of compressibility.

Namu clay deposit characterized is suitable for ceramics manufacture, production of refractory bricks for lining of walls of furnaces for non – ferrous metals production, soaking pits, ovens, kilns, ladles and heat treatment furnaces. The clay can also be used in agricultural industries.

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