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Physical Characterization of Ukpor and Ahoko Clay Deposits for use as Industrial Raw Material

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Abstract: The physical properties of some Nigerian clays were studied in order to determine their suitability for a variety of industrial applications. From the analysis, the specific gravity of Ukpor and Ahoko clays were 1.89 and 2.26 respectively and the Plasticity Index 26.05% and 22.45%, drying shrinkage was 18.90% and 8.2% and particle size distribution 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.

Introduction

Clay may be defined as a natural, earthly fine grained material that develops plasticity when mixed with a limited amount of water. It is formed by weathering of certain silicate rocks. Clay term is also used to designate the smallest particle in sedimentary rocks and soils. The maximum size of particle in clay size grade is commonly considered to be two microns (0.002mm), [9]. Clay is composed essentially of silica, alumina and water with appreciable quantity of iron. Alkaline and alkaline earth metals are also present. There are two types of clays that are recognised, the silicate clay of temperate region and the iron and aluminium hydroxide clay found in the tropics and semi tropics. Until recently, there was no analytical technique with which to determine the precise nature of the component of the element of clay and soil. X-ray diffraction techniques developed in the 1920s followed a few years later by improved microscopic and thermal procedure, established that clay composed of a few group of crystalline mineral called clay mineral. Examples are kaolinite, bentonite, illite, etc. Small amounts of amorphous material occur in some clay.

The clay mineral component provides the essential characteristic and properties of clays. However, kaolinite and bentonite clays are widely used in various industries as sorbent. The sorptive characteristics of clays are exploited when they are used in contaminant barriers system [3].To use clays effectively; their surface characteristics need to be known. Wide variety of physical characteristics of clay such as plasticity, specific gravity, particle size distribution, drying shrinkage, colour, refractive properties and colloidal properties make them suitable for a wide variety of industrial applications. They are used for example in the ceramic industries for the manufacturing of white ware, porcelain, refractories and other clay products. Some are used as reinforcing agent in plastic, paint, adhesive and rubber manufacturing. Their colloidal properties in water make them suitable for use as drilling mud, which is of great importance to oil industries. Ukpor and Ahoko clay found in Anambra state (Nnewi LGA) and Kogi State (Abaji) of Nigeria are suspected to contain some essential clay minerals. However, their physical characteristics such as its plasticity, dry shrinkage, particle size distribution, specific gravity and its water content have to be known to determine its area of application. Preliminary studies have revealed that these clays can be used for household utensils [10]. It is, however possible to extend these uses through a systematic characterisation of these properties. This study is one of such attempt. Thus this work is aimed atdetermining the physical properties of the clays and comparing them with standard values and also to determine their various areas of utilization. This will include the determination of their particle size distribution, moisture content, plasticity, specific gravity and drying shrinkage. Clays are widely used as sorbents, catalysts, fillers, filter aid and are largely available in Nigeria and their uses should be enhanced rather than depending on importation. It therefore becomes necessary to know their physical properties which in turn determine their areas of application.

Literature review

. The formation of clay minerals by weathering process is determined by nature of the parent rock, climate, topography, vegetation and the period that these factors have operated. Climate, topography and vegetation influences weathering process by the control and direction of movement of water through the weathering zone [6]. When the dominant movement of water is downward through the alteration zone, any alkalis or alkaline earth metals tend to be leached and primary mineral containing these components are first degraded and then broken down. If the leaching is intense, then after the removal of the alkalis and alkaline earth metals the aluminium or silica may be removed from alteration zone. This will depend on the pH (index of acidity-alkalinity) of the downward-seeping water. The pH of such water is determined in turn, by the climate and cover vegetation. In the development of clay mineral by natural hydrothermal process, the presence of alkalis and alkaline earth metals influence the resulting product in the same manner.

Methodology

The clay samples were purified by removing debris and other foreign materials. The resulting sample was passed through 0.2mm sieve. The procedures have been reported elsewhere [4]. The physical properties characterised were particle size distribution using hydrometer method, plasticity limit, specific gravity, and drying shrinkage using standard methods.

Specific gravity test: A pycnometer bottle was weighed empty and approximately 10g of 2mm sieved clay sample was added to the bottle and weighed. The pycnometer bottle was then half filled with distilled water and boiled gently on a hot plate. The bottle was shaken occasionally to expel entrapped air. After cooling, the flask was weighed and value obtained was recorded. The flask was emptied and filled with distilled water of the same temperature and weight recorded. Thereafter, the specific gravity was obtained.

Liquid Limit Test (Using cone penetrometer): The sample was weighed after drying and passed through 425 μm sieve. The sample that passed through the sieve was placed on flat plate and mixed thoroughly with distilled water using the palette knives until the mass became a thick homogeneous paste. The paste was allowed to stand in the airtight container for about 24 hours to allow the water to permeate through the clay sample mass. The sample was removed from the container and remixed for at least 10 minutes. More distilled water was added to the sample. The thoroughly mixed clay was then put into the cup using palette knife. The excess clay sample was stuck off with bevelled edge to give a smooth surface. The cone was lowered so that it just touched the surface of the clay. The initial reading of the gauge was noted to the nearest 0.1mm. The cone was released for a period of 5sec. After the cone had been locked in position, the gauge was lowered to the new position of the cone shaft and reading was noted. The cone was lifted up and cleaned carefully. A little more wet soil was added to the cup and the process was repeated. The moisture content sample was taken from the area penetrated by the cone and moisture content was noted.

Plastic Limit Test: The clay sample was passed through a 425 μm sieve. After sieving, curing took place. The clay was placed on a glass plate and kneaded to about 6mm diameter into a thread like form of about 3mm diameter manually (the use of the hand). An excessive length beyond the width of the hand was detached. This was read several times. The thread was then gathered and placed in a tin container, weighed, dried overnight using an oven, cooled and weighed. This was repeated once and the moisture content was calculated from the average.

Drying shrinkage test: The clay samples were sieved using 425 μm sieve. The sample was placed on the flat glass plate and mixed thoroughly with distilled water using a palette knife. This was continued, till a smooth homogeneous paste about the liquid limit was created. A thin film of silicon grease was applied to the inner part of the mould of drying shrinkage and then the homogeneous paste was placed in the mould and levelled with a palette knife. The length was measured and placed in an oven to dry slowly. The length of the dried soil was measured after it was allowed to cool. The drying shrinkage was then determined

Particle size distribution: using hydrometer test: About 50g of air-dry 2.00mm sieved clay sample was weighed into a 500ml beaker. The clay was saturated with water and 50ml of 10% calgon solution was added and allowed to stand for 10minutes. The suspension was transferred to a cup and made up to the mark with distilled water. The suspension was stirred vigorously for 2 minutes with an electric high-speed stirrer. The suspension was transferred into the sedimentation cylinder and made up to mark with distilled water. 3 drops of amyl alcohol was added to remove froth. A hydrometer was placed gently into the column, and at 40 seconds, the first hydrometer reading was taken. The suspension was distributed again and allowed to stand undisturbed for 2 hours. After 2 hours the second hydrometer reading was taken. A blank sample containing reagent but no clay was prepared and the hydrometer readings were also taken for the samples. The equation below was used.

$$C = R - RL + 0.36T \qquad (1)$$

where C = corrected hydrometer reading in g/L, R = soil hydrometer reading, R_L = Blank hydrometer reading and T = Room temperature.
The 40 seconds reading is a measure of silt and clay in suspension while the 2-hour reading is a measure of clay in suspension. The silt content is calculated by subtracting the clay content from the sum of silt and clay.

Results

Tables 1- 4 show the results obtained for specific gravity, liquid limit, plastic limit, drying shrinkage, particle size distribution, and moisture content.

Table 1 Results of specific gravity of the clays

Samples	Weight of empty bottle (g)	Weight of bottle + sample (g)	Weight of bottle sample + water (g)	Weight of bottle + water (g)	Specific gravity
Samples	Weight of empty bottle (g)	Weight of bottle + sample (g)	Weight of bottle sample + water (g)	Weight of bottle + water (g)	Specific gravity
A	25.25	35.24	80.35	74.77	2.26
B	24.77	34.76	79.65	74.94	1.89

Table 2 Results of average LL, PL, PI of the clays

Sample	Average liquid limit (%)	Average Plastic Limit (%)	Plasticity Index (%)
A	52.00	29.55	22.45
B	43.00	16.95	26.05

Table 3 Results of particle size distribution of the clays

Sample	% Clay	% Silt	% Sand
A	51.04	14.00	34.96
B	49.04	53.84	0.288

Table 4 Result of drying shrinkage of the clays

Sample	Old length (cm)	New Length (cm)	Drying Shrinkage (%)
A	16.50	13.48	18.90
B	15.00	13.77	8.20

(Where Samples A and B are Ahoko and Ukpor clays respectively.)

Discussion of Results

Table1 shows the results obtained for specific gravity of the clays (physio-chemical properties). Ahoko clay and Ukpor clay have specific gravities of 2.29 and 1.89 respectively. The standard value of specific gravity of kaolin clay is 2.68 [1]. Ukpor and Ahoko are kaolin clay but the slight deviation may be due to presence of coarse impurities or the presence of other clay mineral. Table 2.0 shows the average liquid limit, average plastic limit and average plasticity index of Ukpor and Ahoko clay. The average liquid limit was obtained from the graph of cone penetration against moisture content. For Ahoko, the average plastic, liquid limit and plasticity index are 29.55%, 52% and 22.45%. For Ukpor, average plastic limit, liquid limit, and plasticity index are 16.95%, 43.00% and 26.05% respectively. The plasticity index suggests the order of plasticity of the clays. The plasticity index of Ukpor clay is higher than that of Ahoko clay. The plasticity indexes of the clays meet the plasticity requirement of kaolin clay. Table 3.0 reveals that Ahoko clay contains more clay than silt and sand. The percentage silt, sand, clay is 14%, 34.96% and 51.04%. Ukpor clay contains more of silt than sand and clay. The percentage silt, sand and clay are 53.84%, -0.288% and 49.04% respectively. Table 4.0 shows the drying shrinkage of Ukpor and Ahoko
clay are 18.9% and 8.2%. The clays can be classified under clays with low sensitivity towards drying. Ahoko clay falls within the typical range for kaolin which is (7-9%).

Conclusion

From the research it can be concluded that Ukpor and Ahoko clay have similar physical properties with only a slight difference in the measured values. The result obtained from the analysis shows that Ahoko clay has higher content of kaolinite mineral since all the result obtained from the analysis were close to the standard value of the parameters analysed. The clays obtained from the two locations have great industrial utilisations. Due to their plasticity, the clays can be used for household utensils. They can also be used in paper industries as filler and coating material. Ahoko clay has shrinkage within the range for kaolin.

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