Characterization of Mayo-Belwa Clay

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Abstract

Mayo-belwa clay deposit in Adamawa state, Nigeria was characterized to establish its use industrially. The major properties investigated were drying and firing behavior, apparent porosity, bulk density, water absorption capacity, plasticity, modulus of rupture, shrinkage, and chemical compositions. The results from the analysis showed a chemical composition of 59.8%SiO_2, 7.08%Al_2O_3, 2.54%Fe_2O_3, 0.3% MgO, 4.39% Na_2O, 2.54% K_2O and 1.5% CaO. The clay has a moderate plasticity of about 2.83 kgf/cm^2, moderate shrinkage of 10.5%, modulus of rupture (strength) ranging from 22.56 kgF/cm^2 to 34.86 kgF/cm^2 and the color ranged from grey to red on firing. The properties signify that Mayo-Belwa clay is stoneware clay. It can be used for the production of stoneware, flowerpot, source of silica for floor tiles and brick making. It can also be used as a binder in the absence of standard binder like phosphoric acid.

Keywords

Mayo-Belwa Clay; Deposit Characterization.

Introduction

Clay is a fine textured earth that is plastic when wet but hard and compact when dry or a term used to refer to the finest grain particles in a sediment, soil or rock. Clay occurs most abundantly in nature in soils, sediments, sedimentary rocks and hydrothermal deposits [1].

There are two general types of clay: expandable and non-expandable clay [12]. 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. 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 bricks, floor, tiles, paper etc, while the quantity of the alkali metal oxides (Na_2O, K_2O, CaO etc) indicate their suitability for making ceramic products [2].

Nigeria has appreciable distribution of industries engage in metal and process industries hence the need for raw materials to support their growth. Clay products such as ceramics wares, burnt bricks, roofing and floor tiles are cheaper and durable building materials than cement especially under tropical conditions [2]. They should therefore be utilized to reduce over dependency on cement particularly in Nigeria.

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 [5]. The present economic state imposes the need for internal sourcing of raw materials to meet up increasing demands.

Presently the Mayo-belwa clay deposit in Adamawa state is used for earthenware pots. This paper is however aimed at extending its uses through characterization of the clay deposit in terms of the following objectives.

÷ Determination of physical properties, which include plastics index, colour and percentage apparent porosity.

÷ Determination of chemical composition (SiO_2, Al_2O_3, Na_2O, CaO, K_2O, MgO, Fe_2O_3 and loss on ignition).

Methodology

Clay Sample Collection

The clay samples were obtained from various points by random sampling. The samples were dark gray in color and dry in appearance.

Sample Preparation

About 2kg of the dried samples were grinded manually in a mortar using pestle but were not sieved through 30 mesh British test sieve because the particle size was tiny enough. The grinded portion was collected as sample for analysis.

Physical Analysis of clay samples

Determination of porosity, shrinkage tests, bulk density and color

The grinded sample was poured into a plastic basin and moistened with about 396ml of water added to the point of wedging (which is the state whereby moistened clay material remained packed into a ball-in-hand until intentional vibration causes the mixture to flow). The wedged sample was cast in brass molds coated with thin film of machine oil. The oil was to facilitate easy removal when dry. Eight-test clay bars of 7.5 × 3.5 × 1.5cm dimension were prepared. Two points of 5cm interval were marked on each of the molded clay using venier caliper. The bars were allowed to air-dry for 24 hours, and each sample weighed. The bars were dried in an oven at 110°C for 5 hours after which the marked distance was recorded as dry length. The expression for wet-dry shrinkage was obtained as:

$$\mathrm{Wet-DryShrinkage} = \frac{\mathrm{OriginalLength} - \mathrm{DryLength}}{\mathrm{OriginalLength}} \cdot 100$$

Then eight clay bars were charged individually into an electric furnace along with 4 pieces of American standard pyrometric cones of 900°C, 1000°C, 1100°C and 1200°C and fired approximately for 10 hours. At each temperature above, the samples bearing the same temperature were removed from the furnace, allowed to cool and each bar observed for color change, cracks formation, fired length and fired weight. The following parameters were determined from the following formulae as reported in [13]:

$$Dry - FiredShrinkage = \frac{DryLength - FiredLength}{DryLength} \cdot 100$$

$$PercenctageTotalShrinkage = \frac{5 - FiredLength}{5} \cdot 100$$

The 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 and recorded. They following expression were use to obtained result as follows:

$$ApparentDensity = \frac{DryWeight}{SoakedWeight - SuspendedWeight}$$

$$BulkDensity = \frac{DryWeight}{DryWeight - SuspendedWeight}$$

$$PercentageApparentPorosity = \frac{SoakedWeight - DryWeight}{SoakedWeight - SuspendedWeight} \cdot 100$$

$$PercentageWaterAbsorption = \frac{SoakedWeight - DryWeight}{DryWeight} \cdot 100$$

Modulus of rupture (MOR)

Eight test clay bars of 10 × 1.5 × 1.2 cm dimension were prepared. The dry samples were moistened and mixed to a workable state. The wedged sample was cast in wooden molds coated with thin film of machine oil. The bars were air-dry for 48 hours. Six of the bars were (temperature marked) were then charged into an electric 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 MOR was calculated from the expression as follows [13]:

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

where P= breaking load in KgF; L = Distance between support; b = Breath, h = Height.

Pfefferkorn Plasticity

50g of clay sample was put into a container and a little amount of water added to it. The moistened clay was molded into cylindrical shape by a cylindrical mould. The molded clay was deformed by dropping onto it from a fixed height a flat-headed plunger of know weight. The distance traveled was read from the graduated scale. The modulus of plasticity (MOP) for the clay sample was obtained from the expression:

$$\text{MOP} = \frac{\text{OriginalHeight}}{\text{DeformedHeight}}$$

Also, the percentage making moisture for the clay samples were obtained from the expression:

$$\%\text{MakingMoisture} = \frac{\text{WetWeight} - \text{DryWeight}}{\text{NetWeight}}$$

Chemical Analysis of Clay Samples

Preparation of State Solution

0.1g of the samples was weight into a Teflon crucible and moistened with Aqua regia (mixture of HCl and HNO_3 in the ratio of 3:1 by volume). 15ml of hydrofluoric acid was added and mixture covered and then heated in a fumed chamber at 100^{o}C until the solution became clear. The solution was allowed to cool and then transferred into a 250ml plastic (hydrofluoric acid attacks glass) volumetric flask and is made up to 250ml mark with distilled water. Different chemicals standard equipment and analytical methods were used the determined the % composition of the following oxides; SiO_2, Al_2O_3 Na_2O, K_2O, CaO, MgO and Fe_2O_3.

Loss on Ignition

0.5g of the clay sample in clean a dried platinum crucible was put into a furnace at 600^{o}C for 3 hours. It was then cooled in the desiccators and weighted. Weight lost is the loss due to ignition, which is given as follows:

$$\text{LOI} = \frac{\text{WeightLoss}}{\text{WeightofSampleMud}} \cdot 100$$

Results and Discussions

The results obtained for the above named tests and procedures are presented below.

Table 1. Shrinkage test for Mayo-Belwa

Temp ºC	Mayo-Belwa Clay					Total Shrinkage
	Original length (cm)	Dry length (cm)	Fixed length (cm)	% Dry Fired Shrinkage	% Wet Dry Shrinkage	
900	5	4.71	4.57	4.25	5.8	8.6
1000	5	4.76	4.51	5.25	4.8	9.9
1100	5	4.85	4.43	8.66	3.6	11.4
1200	5	4.92	4.41	10.37	3	11.9

Table 2. Results for % Apparent Porosity, % water absorption, apparent and bulk density, firing behaviour and colour variation - Mayo-Belwa Clay

Temp ºC	Apparent Porosity %	Water Adsorption %	Bulk Density g/cm^3	Apparent Density g/cm^3	Colour Formation	Crack Formation
900	24.72	15.48	2.25	1.78	Light red	Few crack
1000	20.28	11.28	2.26	1.80	More red	
1100	14.39	7.76	2.17	1.82	Very red	
1200	13.88	7.47	2.17	1.86	Dark red	

Table 3. Modulus of Rupture - Mayo-Belwa Clay

Temp (ºC)	Distance btw Support (cm)	Modulus of rupture kgf/cm^2
900	7	22.56
1000	7	32.63
1100	7	33.13
1200	7	34.86

Table 4. Modulus of plasticity and % Making Moisture - Mayo-Belwa Clay

Wet Weight (g)	Dry Weight (g)	Deformation Height (cm)	Original Height (cm)	Modulus of Plasticity (kgF/cm^3)	% Marking moisture
62.68	51.21	3.62	10.27	2.837	18.61
63.97	52.22	3.64	10.31	2.832	18.37
64.5	52.91	3.64	10.30	2.829	17.96

Table 5. Chemical Analysis Result

Clay Samples	% Composition							
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	LOI
Mayo-Belwa Deposit	59.8	17.08	2.54	1.50	0.34	4.39	2.89	14.0

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p. 123-130

Discussion

The result obtained for shrinkage test, (average of 10.5%) shows that the clay deposit lie within standard value for brick clay [6]. Shrinkage is the property of clay that is important for brick making hence the clay can be suitable for brick production.

Table 2 shows that the greater the apparent porosity the greater the water absorption capacity of the clay. The water absorption capacity of the clay has a very strong relationship on its drying behavior, as during drying this absorbed water must be driven out. This usually leads to a high drying shrinkage.

The color of the clay deposit varied from grey to red on firing as shown in Table 3. This could be attributed to the content of iron oxide of 2.54%. The ferrous iron impacted a red color on the fired sample due to conversion from ferrous to ferric compound. The color variation is considered usable for the manufacture of flowerpot and earthenware [7].

The modulus of rupture is the load bearing capacity of the clay. From Table 4, the MOR ranged from 22.56 kgF/cm^2 to 34.86 kgF/cm^2, as temperature increased from 900ºC to 1200ºC. The strength behavior was found to increase with temperature and this 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 on cooling. The value however falls with the range of 1.4 kgF/cm^2 to 105 kgF/cm^2 as given in literature [11].

The result from table 5 shown that the clay is has moderate plasticity. The clay has a good workability, that is, it can be worked into shape. This plasticity makes it good for many industrial products but the iron oxide and other impurities limits the use to stoneware. The results were comparable with that of Ukpor clay and it suggests that it can be used as a binder in the absence of standard binder like phosphoric acid [10]

The result for chemical analysis in table 6 shows a high silica content ($SiO_2 > 45.6\%$) which must likely mean that Mayo clay exist as quartz and comparing the result to that obtained for Oshiele clay, suggest their use as source of silica for the production of floor tiles [10]. The percentage alkali oxides (CaO, K_2O and Na_2O) is high and this explain the plasticity characteristics of the clay [2]. The alkali oxides (flux) especially with soda more than 3% and low aluminum content made the clay unfit for refractory production, paper and Ceramics.

Further comparing the Mayo clay with other type of clay, it proved to compare favorably with Jordan stoneware clay, which is used for the production of stoneware [7].

Conclusion

Mayo-belwa clay was characterized using standard techniques. The clay was found to have moderate plasticity of 2.83 kgF/cm^2, moderate shrinkage of 8-11%, the color characteristics ranged from grey to red on firing and good strength of 22.56 kgF/cm^2 to 34.86 kgF/cm^2. The clay can be said to be stone ware clay and can be used for the production of stone ware. It can also find application in the production of flowerpot and a source of silica for floor tiles. It can also be used as a binder in the absence of standard binder.

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