

Determination of Moulding Properties of Locally Available Clays for Casting Operations

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Abstract

Our researched focused on determining the molding properties of two locally available clays used in casting operations. Samples of clays were collected from three locations in Nigeria and experimental tests were carried out as regards their physical and bulk properties. From the experimental findings it was discovered that Ire clay (golden), Ire (purple) and Erusu clay showed appreciable moisture contents ranges from 1.20% - 4.26%. Also for the chemical composition, all the samples fall under Aluminosilicate type of clay because of their high value of Aluminum Oxide and Silicon Oxide. Lastly, the suitability of these clays for better casting quality were determined, as well as recommendation for its various uses in moulding operation was also considered.

Keywords: *Visual inspection, sieve analysis, refractoriness, cold crushing strength, moisture content, porosity.*

Introduction

Apart from petroleum, gas and coal resources, the exploration, mining and exploitation of Nigeria mineral resources have not received sufficient attention. Delving into geological survey of Nigeria soil, it was reported that clay as one of the major Nigeria minerals deposits cover an estimated proven reserves of billions of tones, and these days mineral are discovered all over the states in the country (Raw Material Research and Development Council Lagos 1990 First Edition). One of the best-known applications of clay is in the manufacture of such articles as pottery. Another major application of kaolinite is in the paper industry where it may be used either as filler or for coating paper. The metallurgical industry employs clay mixed with sand to form moulds that are used for casting operation. In the oil industry, clays are used in the drilling of oil wells and also as important constituent of catalyst for refining petroleum and also in the separation of gasoline, gas and coke.

A lot of project research has been carried out about the conversion of clays for industrial uses. A material is refractory in nature if it has

a very high melting point in addition to its physical, chemical, mechanical and thermal properties that make it suitable for use in furnaces, kilns, reactors, and other high temperature vessels. Omowumi (2001) in his investigation concluded that the properties of refractory clay samples from Onibode, Ara-Ekity, Ibamajo and Ijoko compare favourably with imported fire clay refractories. Hassan and Adewara (1993) found that Onibode refractory clays are suitable for the production of refractory bricks for furnace building. Matthew (1977) investigated the properties and processing of synthetic foundry mixtures prepared from Kankara clay. He found that Kankara clay was suitable for use in preparation of synthetic foundry sand. Akinbode (1996) carried out an investigation on the properties of termite hills as refractory material for furnace lining. In his report, Matthew observed that the refractory properties of termite hill possesses a close relationship between porosity, density, dimensional change and permeability of the known refractory materials for furnace lining. Aniyi and Adewara (1986) investigated the refractory properties of clay from Kankara and found that the clay was suitable for the production of

refractory bricks possessing good shrinkage. Abolarin *et al.* (2004) investigated the properties of local refractory materials from Kuru, Alkalari, Barkin-ladi and Bauchi locations in Nigeria. They discovered that refractory clays from Alkalari and Barkin-ladi are suitable for furnace construction due to higher thermal shock resistance, crushing strength, bulk density and refractoriness values. Research work by Irabor (2002) revealed that kaoline clays from Kankara, Jos and Oshiele are of the residual variety suitable for paper, paint and pharmaceutical manufacture. Experimental analysis on the refractory properties of local clay materials for furnace building by Obi (1995) revealed that all the clay samples were classified as low alumina with kaolinitic nature. An investigation carried out by Hussani (1997) on the refractory properties of bricks produced from five Nigerian clays revealed that all the samples were found to possess good refractoriness (P.C.E) with excellent firing shrinkage value that fall within 3-5% range of the imported bricks. Work done by Agha (1998) on the refractory properties of six samples of Nigerian clays revealed that the clays were high in silica content and low in alumina content. They also exhibit different refractory characteristics with respect to thermal shock resistance, refractoriness, porosity, permeability, bulk density, modulus of rupture and water absorption. Hassan (1985) investigated the effect of additives like saw dust, graphite and asbestos on Kankara clay. He discovered that a good thermal insulating fire clay brick could be produced from this clay by the addition of graphite and saw dust (15%). Loto and Akeju (1994) determined the durability of the bonding property (that is the number of time that the synthetic moulding sand could be reused). Additives such as sodium carbonate, cassava flour and coal dust were added in order to determine their synergetic effect on the clays bonding durability performance.

Materials and Methods

Visual Inspection

This was done to determine the physical appearance of the samples. Sample A – dull golden colour, Sample B – golden colour and Sample C – purple colour.

Sieve Analysis

Two hundred grams of the ground clay samples were poured into prearranged sieve (of mesh size 850, 710, 500, 300, 180, 125 and 63 microns) on a vibrator. The timer on the vibrator was set at 15 minutes and the motor was switched on. At the end of the sieving period, the mass of the clay retained on each sieve was determined. The percentage retained and passed was then calculated using the following equations:

$$R = \left[\frac{M_1}{M_0} \right] 100\%$$

and

$$P = 100 - R$$

Where,

M_0 = Mass of each sample of clay

M_1 = Mass of clay retained on sieve

R = Percentage of clay sample retained

P = Percentage of clay sample passing through sieve

Refractoriness Test

Test cones were prepared by mixing each clay sample aggregate with sufficient quantity of water to make the clay become plastic and molded by hand into a cone shape. The samples were dried and fired to a temperature of 900°C in a muffle furnace. Pyrometric cones designed to deform at 1300°C, 1400°C, 1500°C were placed round the samples and the temperature raised to above 1000°C at 10°C per minute. The heating was discontinued when the test cone bent over and leveled with the base of the disc. The pyrometric cone equivalent (P.C.E) of the samples was recorded to be the number of standard pyrometric cone corresponding in the time of softening to the test cone.

Cold Crushing Strength

Cylindrical test pieces were cut out from each of the original refractory specified

with a cut off wheel, about 50mm wide and 50mm high. They were then air dried for 24 hours and oven dried at a temperature of 110°C for 12 hours and then fired in a furnace at a temperature of about 1200°C for 6 hours. They were then cooled to room temperature. Each specimen was then taken to the tensiometer where load was applied axially to the piece until crack was noticed. The load at which the specimen cracked was noted, which represents the load required for determining cold crushing strength of the test specimen. Cold crushing strength was then determined using equation 5

$$C.C.S = \frac{P}{A}$$

Where,

C.C.S = Cold Crushing Strength

P = Applied Load

A = Area of Load Application

Moisture Content

The clay slabs of the samples were weighed with the container as M_{11} and then dried for 24 hours after which it was weighed again as M_{22} . The weight of the container is measured as M_{33} . The mass of moisture is taken as $(M_{11} - M_{22})g$ and mass of dry sample taken as $(M_{22} - M_{33})g$. The percentage moisture content was calculated from equation 3.

$$\% \text{moisture content} = \left[\frac{M_{11} - M_{22}}{M_{22} - M_{33}} \right] 100\%$$

Porosity Test

Specimens measuring 6.5 x 6.5 x 4cm were prepared from burn refractory bricks and cleansed from any dust or loose particle. The specimens were then dried in an oven at 110°C to a constant weight (W_D) with accuracy of 0.001g. The dried specimens were suspended in water, cooled to room temperature and this weight (W_S) noted. The specimens were removed from water and water particles wiped off from their surface by lightly blotting with a wet towel and weighed in air (W_A), the apparent porosity (P_a) was then calculated using equation 4.

$$P_a = \left[\frac{W_A - W_D}{W_A - W_S} \right] 100\%$$

Chemical Analysis

To determine the chemical composition, the method employed was x – ray fluorescent. 1 gram of clay sample was added to 10 grams of lithium tetraborate anhydrous solution ($Li_2B_4O_7$) which act as a fluxing agent. The constituents were mixed inside a crucible which was already cleansed with methylated spirit to prevent contamination and heated up to 500°C for 8 minutes and allowed to cool at room temperature. The fused sample which was a tinted glass was analyzed by the x – ray fluorescent and diffraction method.

Loss on Ignition Test (L.O.I)

Organic combustible matter present as impurity leads to gas evolution and reduces the refractoriness of the sand. Twenty grams of oven-dried clay from each sample was cooled in the dessicator. The porcelain crucible was cleaned, dried and weighed to an accuracy of 0.001g (M_4). The dried test clay sample was weighed to an accuracy of 0.001 (M_5). The crucible containing the clay sample was placed in a muffle furnace and heated to a temperature of 800°C. The crucible and its content (test clay) were allowed to cool in desiccators and then weighed to an accuracy of 0.001g (M_6). The ignition loss was calculated from the relationship given below:

$$\text{Loss on ignition} = \left[\frac{M_5 - M_6}{M_5 - M_4} \right] 100\%$$

Where,

M_4 = Mass of dried porcelain crucible

M_5 = Mass of sample clay and porcelain crucible

M_6 = Mass of heated clay sample and porcelain crucible

Clay Content

A known mass of each clay sample of 25grams was measured and transferred into a beaker of 500cm³. A volume of water was added to each sample to make up to 2/3 of the volume in the beaker. Then the addition of deflocculant Na_2CO_3 anhydrous solution of about 166ml and the mixture was given a warm temperature. The mixture was stirred

vigorously with a spatular, the deflocculating agent acts as a coagulant of the clay particles and thereby maintain the colloids of the solution. After stirring, it was allowed to settle for about five minutes, the solution of sodium carbonate together with suspended clay particle was siphoned off from the water/clay suspension continuously and allowing for a settling period of about five minutes. This process was continued until perfectly clear water was obtained in the upper region of the beaker. The remaining water just above the residue was completely siphoned. Then the residue was transferred to a filter paper for proper draining and it was further dried on the evaporating dish to about 100oC for some minutes and reweighed. The percentage of clay content was then calculated using this formula.

$$\text{Percentage clay contents} = \left[\frac{M_7 - M_8}{M_7} \right] 100\%$$

M_7 = initial mass of the clay sample

M_8 = final mass of the clay sample

Results and Discussion

Sieve Analysis

Sample A was highly retained at the 850µm sieve while samples B and C were highly retained at 850µm showing good proportion of clay being refined.

Porosity

The apparent porosity was determined, only sample C was found to be in the normal range 20 – 30% for dense fire bricks, while samples A and B were found to be below the normal range. Samples A and B were good as insulated bricks.

Refractoriness

The value of samples A and B were found to be exactly 1500°C while sample C was found to be greater than 1500°C. The temperature for sample C is an indication of very good refractoriness, because the normal range for a fire clay brick is 1580°C – 1750°C.

Besides all, the clay sample withstood casting temperature of aluminum cast products.

Cold Crushing Strength

The values obtained; Sample A – 350kg/cm², Sample B – 394.74kg/cm² and C – 256.41kg/cm² are comparable to standard values of high duty silica bricks. This shows that the bricks have been properly fired. It can transport flange and flux readily without damages to the edges and corners. It also shows the ability of the clay to withstand abrasion and loading.

Chemical Composition

Table 2 shows the chemical composition of the clay samples. From its chemical composition, all the sample fall under Aluminum-silicate type of clay because of their high value of aluminum-oxide and silicon-oxide which are highest among other chemical composition of the clay.

Clay Content

From clay content test, it was found that specimen C has the highest value of clay followed by specimens A and B. This shows that they all have appreciable clay content and from this the mouldability strength and plasticity can be deduced.

Moisture Content

The plasticity and strength of clay depend on the amount of water present in the clay; water present in a value of 1.2 – 4.26% activates clay in sand, causing the aggregates to develop strength.

Conclusion

This work went a long way in investigating the molding properties of some locally available clay sample for casting operations. From the overall experimental analysis carried out, it was observed that all the samples have appreciable and reasonable moisture content values. Erusu clay golden

4.26%, Ire clay golden 2.06% and Ire clay purple 1.20%.

The sintering temperature for Erusu clay, Ire clay golden and Ire clay purple were 1500°C, 1500°C and > 1500°C respectively. This implies that Erusu and Ire clay golden can be used to melt metals not exceeding 1500°C while sample C is recommended for construction of furnace because it possesses a refractoriness temperature above 1500°C.

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Table 1. Property of Clay Samples

Property	A	B	C
Sieve Analysis	35.10	30.00	32.88
Refractoriness	1500°C	1500°C	>1500°C
Cold Crushing Strength	350kg/cm ²	394.74kg/cm ²	256.41kg/cm ²
Porosity	9.97%	18.61%	29.4%
Loss on Ignition	11.82	7.81	9.81
Clay Content	72.44%	61.44%	79.64%
Moisture Content	4.26%	2.06%	1.20%

Table 2. Chemical Composition of Clay Samples

Sample	Locality	Al ₂ O ₃	SiO ₂	Fe ₂ O ₃
A	Erusu Clay	17.32	51.53	7.19
B	Ire Clay Golden	15.94	55.14	7.59
C	Ire Clay Purple	18.19	56.96	6.39