CHARACTERIZATION AND EVALUATION OF REFRACTORY PROPERTIES OF SOME CLAY DEPOSITS IN SOUTHWEST NIGERIA

By

M. O. H. AMUDA, G. I. LAWAL & F. O. MAJOLAGBE

Department of Metallurgical and Materials Engineering
University of Lagos, Lagos, Nigeria.

ABSTRACT

Clay samples from Onibode, Ibamajo, Lisabi and Ijoko deposits in south west, Nigeria were obtained, characterized and blended in various proportions. The basic clays and their blends were subjected to refractoriness, thermal shock resistance (TSR), cold crushing strength, bulk density, porosity and permeability, and linear shrinkage tests.

The basic clays displayed reasonable refractory properties and these compared favourably with standard values except for the thermal shock resistance and permeability. The blends of 80/20, 50/50 of the various clay sample improved the TSR and the permeability. Onibode – Ibamajo and Ijoko – Ibamajo blends particularly gave excellent values that make them suitable and recommendable for furnace lining where high refractoriness, thermal shock and good permeability properties are required.

Keywords: *Characterization, refractory, properties, clay, deposits.*

1.0 INTRODUCTION

Refractories are inorganic compounds majorly of clay background that are used in lining furnaces, kilns and other high-temperature chambers where they are exposed to high temperature between 1500^{0}C and 3000^{0}C. They are capable of withstanding physical, chemical and erosive action of molten metal, slags and gases in the furnace without deterioration. These class of materials are used in large quantity, essentially, as heat retaining systems in metallurgical, mineral processing, glass, cement and petrochemical industries. For instance, with the revamped development of the iron and steel industry via the rehabilitation of the various inland rolling mills and the envisaged completion and commissioning of the multi billion dollar Ajaokuta steel complex in mid 2005 to produce 1.3 million tonnes of liquid steel, there will be a great increase in consumption of refractory materials. Ajaokuta is estimated to require 36,000 tonnes per annum (Hassan, 2000). Besides, the four refineries in Nigeria were recorded to have gulped about $850M for their turn around maintenance (TAM) in the last five years. The critical unit in the TAM process is the fluid catalytic cracking (FCC). This unit is lined with enormous quantity of various grades of refractory linings. These refractory materials are at present sourced by importation (Borode et al, 2002). Thus, if this valuable input in the metallurgical and process industries is sourced locally, it will enhance capacity building in meeting the technological requirement of the country and equally conserve greatly, the foreign exchange earnings. The major materials for ordinary refractory bricks, mortals, ramming mass and gunning mass are clay.

Abundant deposits of clay have been reported across major geological belts in the country. Great use have been made of Nigeria clay as a potter material for ages (Oniya, 1967). However, not much have been done on the possibility of assessing the potential of the vast clay deposits as a refractory material particularly in this period of economic crisis. The few ceramic firms available in the country are engaged in the production of structural clay products for the built environment. However, some works had been done at different times on evaluating basic refractory parameters in some clays from certain deposits with a view to determining their suitability for adoption as refractory raw-material, for different metallurgical and process situations (Hassan, and Adewara, 1993, Imasogie and Aramide, 2003, Omowunmi, 2003). These were spot and restrictive works by taking at times representative samples and evaluating their refractory properties with clays from other geographical zones in the country.

This work picked four different clay deposits from southwest, Nigeria characterized them and evaluated their refractory properties.

2.0 EXPERIMENTAL METHODS

2.1 Sourcing of Materials

The basic raw material used in this work are clays procured from four different geographical locations in South west, Nigeria. These deposits are Onibode (Ogun state), Ibamajo (Ondo state), Lisabi and Ijoko (Ogun state) and the clays are thus called Onibode, Ibamajo, Lisabi and Ijoko clays respectively.

2.2 Programme of Work

The clays from the various deposits were crushed in a laboratory jaw-crusher and ground to fine grains of 100 mesh. The different samples were blended and moulded with the required amount of water at a measure of 10cl/200g powder material. The test samples were then prepared into test laboratory sizes of rods 5.08cm length and 5.08cm diameter.

The prepared test samples were air-dried and later oven dried at 110^0C for 24 hrs before firing at 1100^0C for another 24hrs and subsequently placed in a dessicator.

2.3. Test Work

2.3.1 Compositional Analysis

The clays from the various deposits were prepared for compositional analysis via the atomic absorption spectometry (AAS) based on the methods described by the Manual of AAS (7). The chemical constituent of the various clay samples are as presented in Table 2.1.

2.3.2 Determination of Bulk Density

The test samples prepared as above were weighed to the accuracy of 0.001_g (dried weight). After which the samples were individually transferred to a beaker and heated for 30minutes to assist in releasing the trapped air. The samples were cooled and soaked weight (Ws) taken. The samples were then suspended in water and the suspended weight (Ss) taken. The bulk density was calculated from

$$B_D\ (g/cm^3) = \frac{D\rho w}{Ws - Ss} \qquad \text{.....(I)}$$

Where D is dried weight in (gm), Ws is soaked weight in (gm) and Ss is suspended weight also in (gm) and ρw = density of water ($1g/cm^3$). The test was repeated for the various clay and clay blends and the average of the evaluated values recorded.

2.3.3. Determination of Refractoriness

The orton standard cone method (ASTM Manual, 1957) was deployed. Test cones were made from each of the clays and their blends. Each of these test cones was mounted on a refractory plague along with a standard cone of known refractoriness.

The cone was then inserted into the furnace and temperature raised to 1000^0C. The temperature was raised at the rate of 25^0C per hour till the maximum temperature of 1700^0C was attained. The standard orton cone and the test pieces were arranged then observed for sign of crack and the number of the best matching standard orton cone is quoted as the pyrometric cone equivalent temperature of the material.

2.3.4 Determination of Apparent Porosity

The prepared test samples were transferred into a 250ml beaker in empty vacuum desiccator. Water was added until the test samples were completely immersed and soaked in boiling water for 30 minutes agitated frequently to release trapped air bubbles. The samples were afterward transferred into an empty vacuum desiccator to cool.

The apparent porosity is evaluated from the equation:

$$Ap = \frac{W - D}{W - S} \times 100\% \qquad \text{...........(II)}$$

Where W is soaked weight, D is dried weight and S is the suspended weight in grms.

2.3.5 Determination of Cold Crushing Strength

The samples were placed on a compressive testing machine and load applied axially by turning the hand wheel at a uniform rate till failure occurs using a well calibrated scale. The cold crushing strength is obtained from the formula:

$$CCS = \frac{\text{Maximum load}}{\text{Cross Sectional area}} \ KN/m^2 \quad \text{.......... (III)}$$

2.3.6 Determination of Thermal Shock Resistance

The test samples were inserted into a furnace that is kept at 1100^0C. This temperature was maintained for 10 minutes. The samples were removed one after the other and then cooled for 10 minutes. The specimens were returned to the furnace for a further 10 minutes. The process was continued until the pieces were readily pulled apart in the hands. The number of cycles withstand before fracture were recorded for each test sample.

3.0 RESULTS

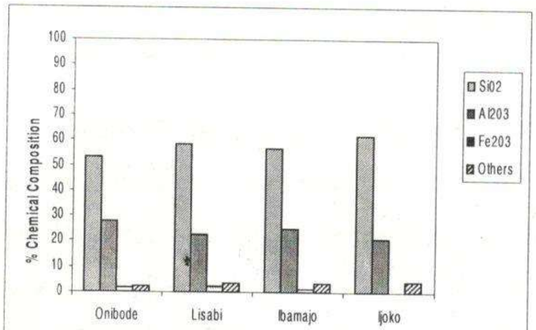


Figure 3.1 Percent Chemical Composition of Various Clay Samples

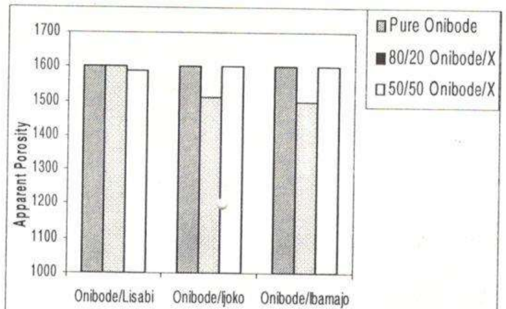


Figure 3.2a. Refractoriness Chart for Onibode and its blends

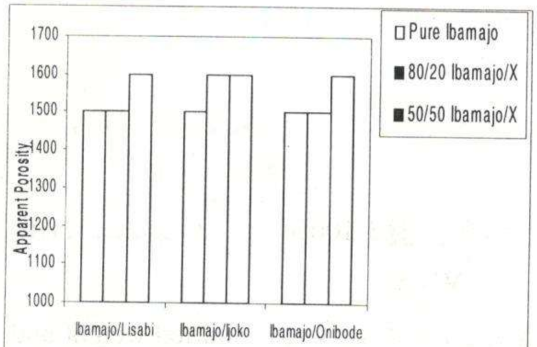


Figure 3.2b. Refractoriness Chart for Ibamajo and its blends

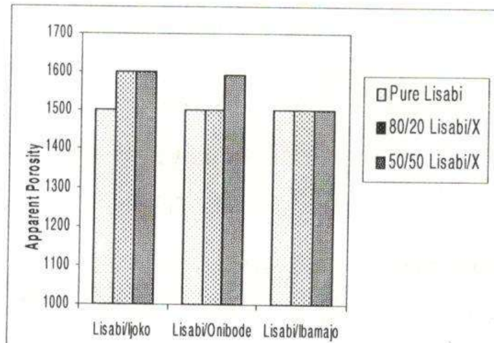


Figure 3.2c Refractiness Chart for Lisabi and its blends

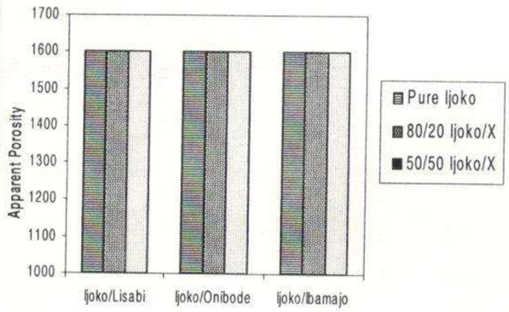


Figure 3.2d Refractoriness Chart for Ijoko and its blends

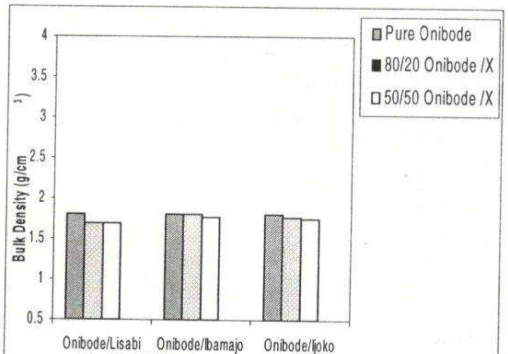


Fig. 3.3a Bulk Density Chart for Onibode and its Blends

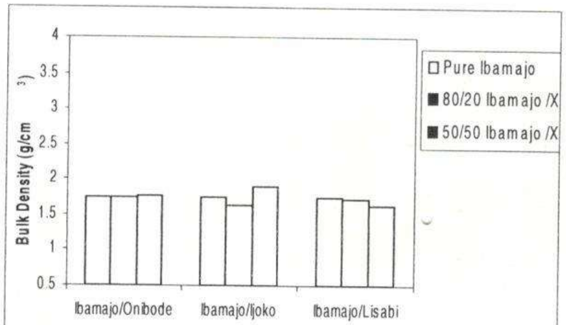


Fig. 3.3b Bulk Density Chart for Ibamajo and its Blends

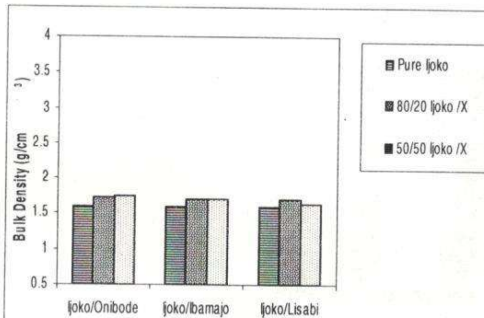


Fig. 3.3c Bulk Density for Ijoko and its Blends

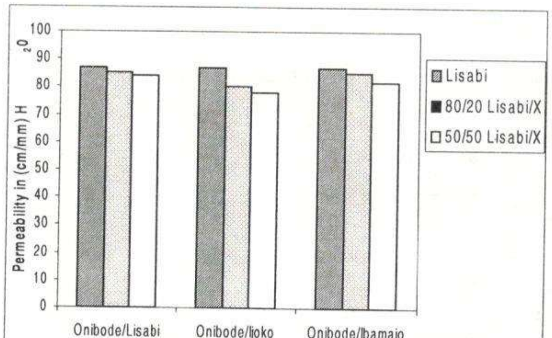


Figure 3.4a. Permeability Chart for Onibode and its blends

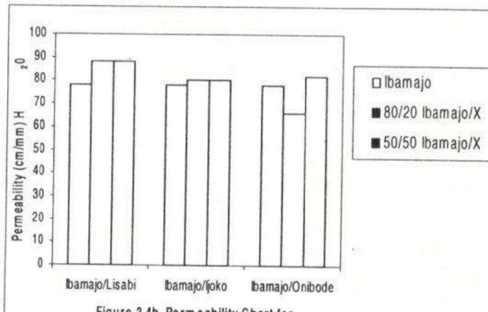
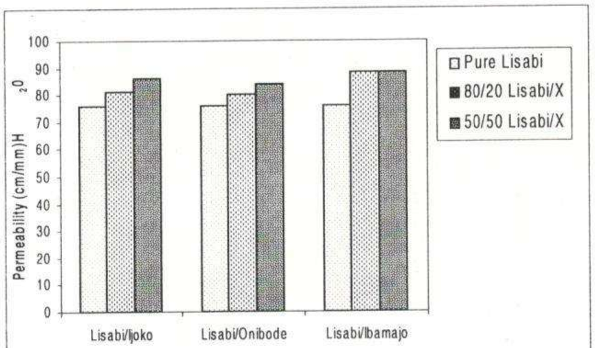


Figure 3.4b. Permeability Chart for Ibamajo and its blends



Figue 3.4c. Permeability Chart for Lisabi and its blends

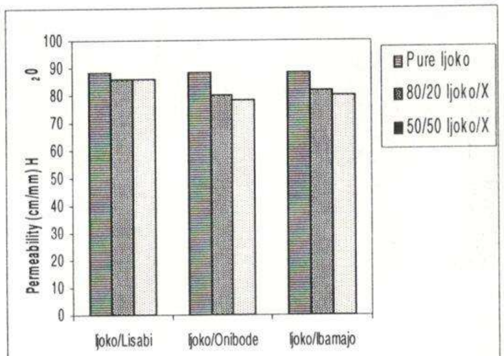


Figure 3.4d. Permeability Chart for Ijoko and its blends

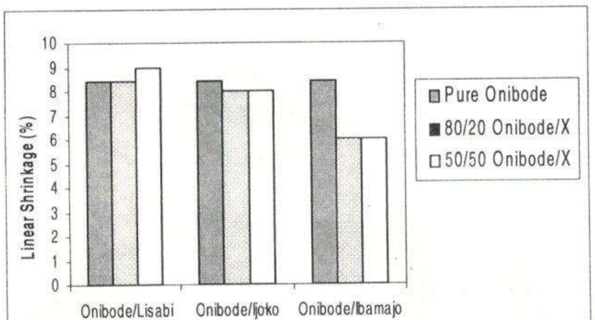


Figure 3.5a. Linear Shrinkage Chart for Onibode and its blends

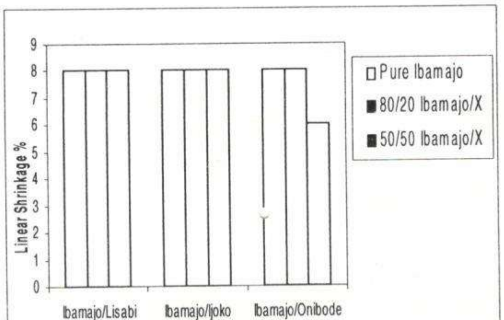


Figure 3.5b. Linear Shrinkage Chart for Ibamajo and its blends

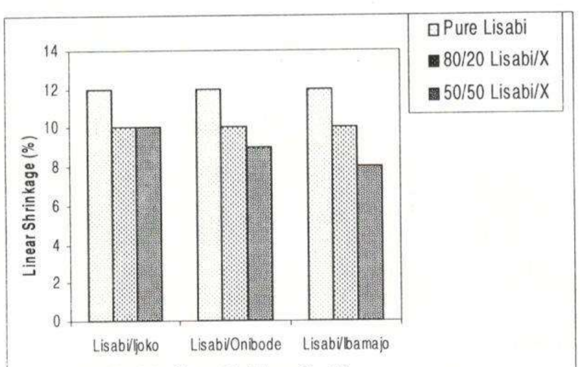


Fig. 3.5c. Linear Shrinkage Chart for LIsabi and its blends

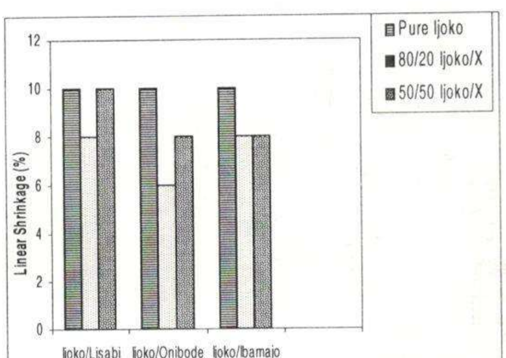


Figure 3.5d. Linear Shrinkage Chart for Ijoko and its blends

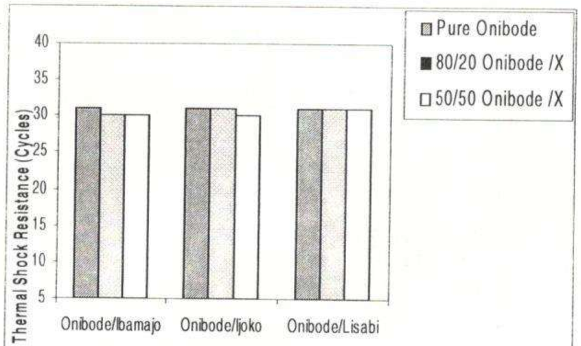


Fig. 3.6a Thermal Shock Resistance Chart for Onibode & its Blends

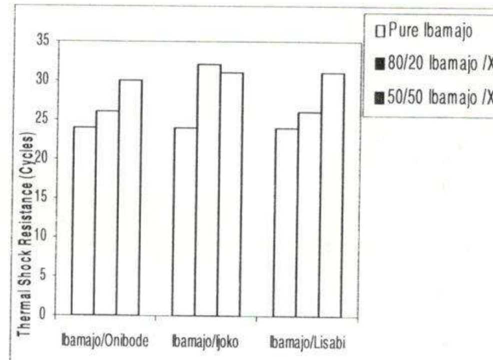


Fig. 3.6b Thermal Shock Resistance Chart for Ibamajo and its Blends

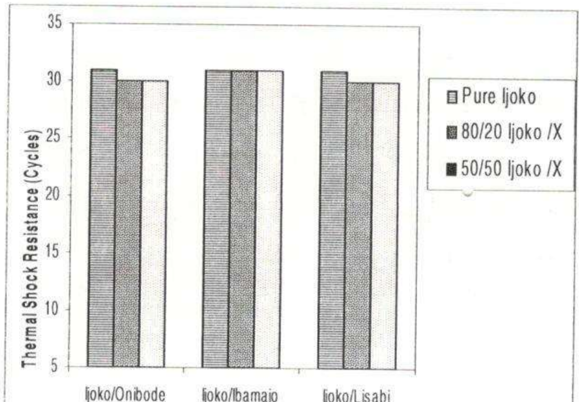


Fig. 3.6c Thermal Shock Resistance for Ijoko and its Blends

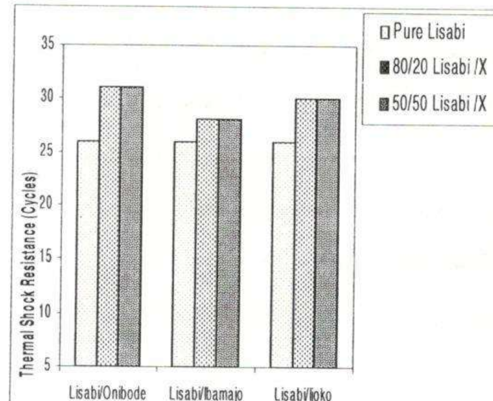


Fig. 3.6d Thermal Shock Resistance for Lisabi and its Blends

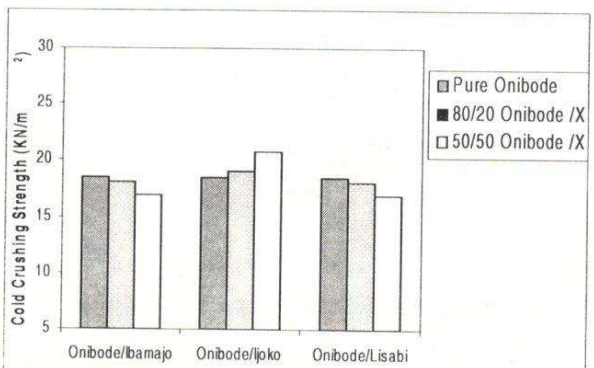


Fig. 3.7a Cold Crushing Strength Chart for Onibode and its Blends

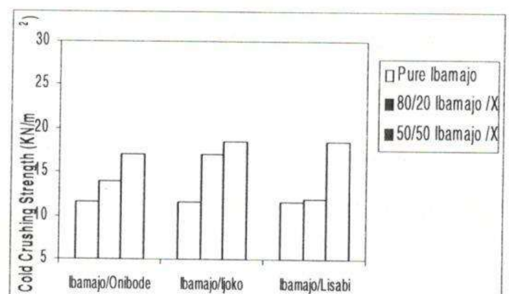


Fig. 3.7b Cold Crushing Strength Chart for Ibamajo and its Blends

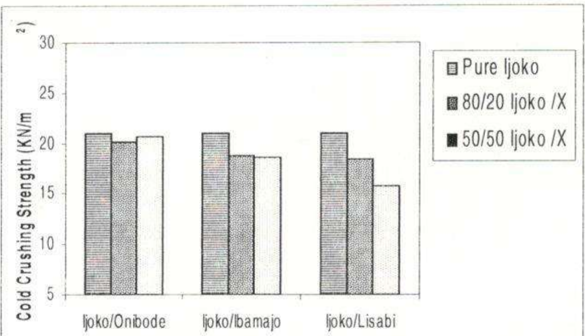


Fig. 3.7c Cold Crushing Chart for Ijoko and its Blends

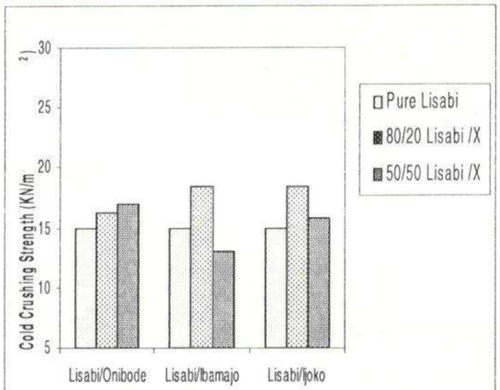


Fig. 3.7d Cold Crushing Chart for Lisabi and its Blends

4.0 DISCUSSION OF RESULTS

The chemical analysis of the various clay samples from the AAS result is displayed in Table 3.1 and Figure 3.1. The silica content of all the clay samples is greater than 50% and the aluminum content is generally less than 30%. Iron I Oxide being 1.38% average. The clay samples belong to the family of aluminosilicate and are semi acid refractories because the alumina content falls within the classification given by Chesti in 1986.
The refractory properties of the basic clays and their blends are as given in Figure 3.2 (a-d) through Figure 3.7 (a-d).

The standard range of refractoriness is 1580-1750^{0}C. (Chesti 1986,). Onibode and Ijoko clays showed refractoriness within the standard refractoriness range. Lisabi and Ibamajo have their refractoriness below the standard. The result of the blends showed that the refractoriness of these clays can be improved by adding 50% Onibode, or 20% Ijoko clay. Ijoko clay has the best influence on the refractoriness of any material.

The standard bulk density for densed firebrick is within the range 1.7-2.1g/cm^3 for general refractories and 2.20-2.30g/cm^3 for high alumina refractories. (Chester, 1973). Ibamajo and Onibode bulk density values falls within the classification of densed firebrick refractories whilst Lisabi and Ijoko does not exactly fall within the classification range. However, result of the blended samples showed that Lisabi can be densed firebrick when mixed with about 20% Ibamajo and 20% Onibode clays respectively whilst Ijoko clay can be made densed firebrick when mixed with 50% Ibamajo and 20% Onibode respectively.

Refractories generally have standard permeability in the range 25 – 90cm^2/min cm of H_20. The four clay samples and their blends fall within the upper range (between 76cm 88cm^2/min cm of H_20) and as such can be described as being highly permeable. Permeability in refractory is related to apparent porosity which is the ratio of volume of open pores to bulk volume of material.

A comparison of the linear shrinkage of the clay samples revealed their relative quality in reference to standard values for refractories in literature.

The linear shrinkage of Onibode, Ibamajo and Ijoko clays falls within the documented standard for fireclay (7-10%) (Chesti, 1986). The various blends also exhibited commensurate linear shrinkage. However, Lisabi displayed a relatively low linear shrinkage resistance (12%). This apparent poor shrinkage property of Lisabi clay is attributable to its relatively high ferric oxide content (2.24% compared to the average value of 1.38%).

The thermal shock resistance for standard refractories is in the range 25-30 cycles (De Bassy, 1972). The thermal shock resistance (TSR) for Onibode and Ijoko is between 30-31 cycles. Lisabi and Ibamajo had 26 and 24 cycles respectively. In reference to the standard refractories, Onibode and Ijoko could be described as excellent, Ijoko as fair and Ibamajo poor. The blends of all the four clay samples had good thermal shock resistance.

The cold crushing strength of all the clay samples except Ibamajo compared favourably with standard values given by De Bassy, in 1972. Ibamajo clay is improved upon by blending with 20% Ijoko clay, 50% Lisabi or 50% Onibode clay respectively.

5.0 CONCLUSION

The clays from the four deposit is analyzed as semi acidic aluminosilicate.

The four basic clays individually exhibited good refractoriness, and excellent thermal shock resistance, and moderate porosity.

The cold crushing strength of Onibode, Lisabi and Ijoko are quite remarkable. Ibamajo, however, displayed relatively low cold crushing strength compared with the minimum value of 15000KN/m^2.

The blends of Ibamajo and Ijoko clays produced a refractory with better cold crushing strength, thermal shock resistance and permeability when compared with Ibamajo clay; and a refractory of higher bulk density when compared with Ijoko clay.

The Ibamajo/Onibode blend displayed similar properties with the Ibamajo/Ijoko blend but with a better linear shrinkage characteristics. Thus, the blends of Ijoko/Ibamajo and Onibode/Ibamajo are recommended for furnace lining since Onibode and Ijoko clays, individually, exhibited good refractory properties; and the influence of their various blends reinforced the refractory properties.

These mixtures, therefore, will be a superior refractory compared with pure Onibode or Ijoko clay.

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TABLE 2.1 CHEMICAL COMPOSITION OF CLAY SAMPLES (%)

Clay samples	*Oxides*							
	$S0_2$	Al_20_3	Fe_20_3	$Ti0_2$	C_a0	$Mg0$	Na_20	K_20
Onibode	53.16	27.56	1.72	0.88	0.05	0.18	1.06	*0.17*
Ibamajo	56.71	24.80	1.41	1.27	0.02	0.06	2.00	*0.14*
Lisabi	58.29	22.79	2.24	0.55	0.01	0.86	0.01	*2.1*
Ijoko	*62.84*	*20.76*	*0.15*	*1.36*	*0.01*	*0.01*	*2.70*	*0.05*

TABLE 2.2: THE VARIOUS BLENDS

Clay Blends	*Ratio*	
	80/20	***50/50***
Onibode/Lisabi	x	*x*
Onibode/Ijoko	x	*x*
Onibode/Ibamajo	x	*x*
Ibamajo/Lisabi	x	*x*
Ibamajo/Ijoko	x	*x*
Ibamajo/Onibode	x	*x*
Lisabi/Ijoko	x	*x*
Lisabi/Onibode	x	*x*
Lisabi/Ibamajo	x	*x*
Ijoko/Lisabi	*x*	*x*
Ijoko/Onibode	*x*	*x*
Ijoko/Ibamajo	*x*	*x*