Investigation into the Refractory Properties of Tatiko and Beji Clays

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ABSTRACT

This study undertakes the characterisation and analysis of two clay samples obtained from Tatiko and Beji areas of Niger State, Nigeria to determine their suitability for use as refractories. Chemical analysis was carried out using atomic absorption spectrometry (AAS) methods and both clays were found to be of similar composition with high silica, moderate alumina and low ferric oxide content with trace quantities of magnesium and calcium oxides. The results of physical tests conducted show low cold crushing strength (15.8 and 16.6 KN/m^2 respectively for Tatiko and Beji), fair refractoriness (1300 and 1350 ^0C), but very good linear shrinkage (both below 1.4%) and fair thermal shock resistance (at 10 and 9 cycles). These properties make Beji and Tatiko clays good for handling low melting metals, paint, chalk and earthenware production.

Keywords- *Tatiko clay, Beji clay, refractories, alumina content, silica content.*

INTRODUCTION

Fired-clay bricks are by far the largest group of refractories in use in industry. These are primary materials that are used in the metallurgical industry for constructing the linings of all furnaces, for holding and transporting metal and slag, and for the linings of industrial flues or stacks that serve as conduits for the emission of hot gases. Since all these are extremely high temperature processes in excess of over 1500 ^0C, the options are not many for materials of construction that will adequately endure these conditions and ceramics are particularly appealing for such applications. Additionally, the use of clays is attractive in terms of cost and over the years, there has been wide-ranging research worldwide into the production of such materials from local clay sources to further lower the cost barrier.

Analysis of typical clays that serve as refractories show that they contain kaolinite ($Al_2O_3.2SiO_3.2H_2O$), chromite ($FeOCr_2O_3$), magnesite ($MgCO_3$) and other metal oxides and complexes in different proportions. Despite having a huge demand, Nigerian industries import most of their refractories with a demand of well over 300,000 tonnes in the year 2000.

Recently, there has been a huge amount of research done to investigate the suitability of clays from various parts of Nigeria for their use as refractories. Abolarin et al (2004) studied clay characteristics from Kuru, Alkaleri, Barkin Ladi and Bauchi while Onyeji (2010) analysed clay from Chanchaga. Ndanusa et al (2004) observed that most Nigerian clay deposits have high silica and low alumina content. Those from other parts of the world for example that investigated by Waing et al (2008) from the Mwetaung area of Myanmar contained far more alumina than silica.

In the current work, two samples of clay were obtained from Tatiko and Beji areas of Niger State in North Central Nigeria. Their characteristics and necessary properties required for use as refractory were studied. These were then used to manufacture refractory brick and the properties such as cold crushing strength, thermal shock resistance, and linear shrinkage were determined. If high enough quality refractory can be produced locally and commercially, we can substitute the imports, save foreign exchange for the country and support the development of the industrial sector.

EXPERIMENTAL PROCEDURE

The clay samples used in this study were collected from Tatiko and Beji areas of Niger State. These dry samples were pulverized and sieved with a mesh size of 1.13 mm. They were then mixed into a thick paste with water and moulded into bricks adequately compacted with a hydraulic press. The bricks were air dried for a period of 24 hours and then oven dried at a temperature of 110 ^{0}C for 12 hours. An electric muffle furnace was used to slowly fire the dried bricks after which slow cooling was done to room temperature.

Atomic Absorption Spectrophotometer (AAS) was used for the chemical analysis of the samples. Refractory properties that were determined to characterise the clays are: linear shrinkage, refractoriness, thermal shock resistance, permeability, porosity, bulk density and specific gravity. These properties have standard test procedures and are as described in BS 1902: Part 1 A (Chester, 1983; Ndaliman, 2007).

RESULTS AND DISCUSSION

Tables 1 and 2 summarise the results of the tests carried out.

Physical Appearance

The first sample, Tatiko clay has a light brown appearance while the Beji clay had a rather whitish appearance.

Chemical Composition

The chemical composition of the clays as determined non-destructively using AAS methods are shown in Table 1 below:

Table 1: Chemical Composition of the clay samples (%)

Location	SiO2	Al2O3	Fe2O3	MgO	CaO	LOI
Tatiko	54.40	20.28	1.34	0.41	0.001	12.05
Beji	52.23	22.83	0.87	0.45	0.02	11.75

The chemical content for both clays as presented in Table 1 show that they are high silicate clays with content between standard refractory percentages of 46-62%. As a result, Beji and Tatiko clays can find applications as lining for heat treatment furnaces, melting furnaces for low melting metals, aluminium ladles and portions of blast furnaces.

Aluminium oxide (Al_2O_3) or alumina content was determined to be moderate and within standard compositions as stated by Waing et al (2008) to be between 13-30% for typical refractory materials. Onyeji (2010) determined the alumina content for Nyikangbe clay to be 21.8%, together with a similar silica composition, and suggested the presence of free quartz and hence described such clays as kaolinite.

The percentages of other oxides were found to be in minor quantities. Particularly, low iron oxide content was obtained for the two clays which accounts for their light coloured appearances as against reddish appearances for high iron content clays. As a result, application for pottery purposes is not suitable for either clay; rather they may be used for the production of earthen wares, paints and chalk (Onyeji, 2010).

Linear Shrinkage

This is an indication of the firing efficiency of the clay sample. The values obtained for the two samples used in this study were 1.41% and 1.20% respectively for Tatiko and Beji clays. Omowumi (2001) quoted a recommended range of 4-10% for fireclay and Abolarin et al (2004) pointed out that lower values were more desirable as this means the clay is less susceptible to volume change as is the case with Tatiko and Beji clays. On the other hand the linear shrinkage of normal kaolin is between 7 and 10%.

Bulk Density

The average bulk densities determined for the clay samples were 4.00 g/cm^3 for Tatiko clay and 4.04 g/cm^3. These are quite dense when compared with values obtained for Gur and Yamarkumi clays (2.06-2.11 g/cm^3), Plateau and Bauchi clays (1.94-2.04 g/cm^3) and Nyikangbe clay (2.35 g/cm^3) as reported by Yami & Umaru (2007); Abolarin et al (2004) and Onyeji (2010) respectively.

Apparent Porosity

For both samples the apparent porosity at 110 °C were found to be within internationally defined normal range of 15-25% suitable for usage as fire bricks for insulation (see Table 2).

Thermal Shock Resistance

This property determines a material's ability to withstand heating and cooling cycles. The Tatiko and Beji clays withstood 10 and 9 cycles of heating (at 1000 °C) and cooling which were only fair. Those obtained by Mazen (2009) were above 20 cycles, up to 18 cycles by Ndaliman (2007), and 29 by Abolarin et al (2004).

Cold Crushing Strength

Cold crushing strength measures the ability of clays to withstand abrasion and loading. Values for properly fired High Duty silica bricks are above 18 MN/m^2. For Beji clay, the value obtained was 16.62 MN/m^2 while Tatiko clay produced a value of 15.81 MN/m^2. This means for them to be used for transporting slags and fluxes, adequate firing will be required.

Refractoriness

The highest temperatures reached were 1300 and 1350 °C for Tatiko and Beji clays respectively. These are much lower than the recommended range of 1500-1700 °C for fire clay refractories as quoted by Yami & Umaru (2007) who went further to attribute the low values to high silica content and as such, their use is restricted to non ferrous metals processing with melting points below 1400 °C.

Location	Bulk density, g/cm^3	Apparent porosity, %	Linear shrinkage, %	Thermal shock resistance, cycles	Cold crushing strength, MN/M^2	Refractoriness, ^0C
Tatiko	4.00	23.05	1.41	10	15.805	1300
Beji	4.04	21.30	1.20	9	16.620	1350

CONCLUSIONS

The chemical analysis of Beji and Tatiko clays show that both have similar compositions with high silica content, moderate alumina content, low ferrous oxide content and very low content of other metal oxides. The low iron content give them rather whitish appearances making them good candidates for paint, chalk, and earthenware manufacturing. However, their low cold crushing strengths and low refractoriness are not good enough to make excellent refractories for ferrous metals blast furnace lining but for low melting applications such as aluminium processing. Furthermore it is recommended that a geological survey of the sampled areas should be carried out to determine the extent of the deposits.

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