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Investigating the Refractory Property of Jalingo Clay Deposit

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Abstract

Some clay deposits from Kona in Jalingo local government of Taraba state were investigated for suitability of use as refractory raw material for brick production and furnace linings. Refractory brick test specimens were prepared by standard methods. The chemical properties were determined using the thermo scientific niton – model xl 3t Gold D^+ XRF Analyzer. The physical test conducted were, Cold crushing strength on a hydraulic compression testing machine, Bulk density using the volumetric technique, the Porosity was determined using the immersion principles. Thermal shock was determined by heating and cooling method. Refractoriness was determined using pyrometric cone equivalent method and permeability using the richel permeability machine. The results of the chemical analysis show that the silica(SiO_2) contents for the clay samples were 75.21% and 77.57 for Kona white clay and Kona black clay respectively. The alumina(Al_2O_3) contents were 11.77% and 12.17% for Kona white clay and Kona black clay, respectively. The temperature obtained were 1300°C for both the white and black clay. The analyses showed that the clay can be used as low melting clay. The implication of their usage is limited to nonferrous materials only.

Keywords: *clay; Porosity; Refractory*

1. INTRODUCTION

Refractory is defined as quality of materials to retain their strength at higher temperatures [1]. They can be used inside the furnace, kilns, incinerators and reactors. These materials should be chemically and physically stable at higher temperature .They must resist thermal shock and be chemically inert with specific values of thermal conductivity and coefficient of thermal expansion [2]. Refractories belong to the class of ceramic materials which are employed for high temperature applications, usually above 1100°C [2].Most refractories are made from naturally occurring high melting point oxides such as SiO_2, Al_2O_3, MgO, Cr_2O_3, ZrO, and refractory materials include aluminosilicate, dolomite, magnesia, silica, chrome, chrome-magnesite, carbon, etc[3].

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Refractories are usually classified in terms of the ranges of temperature at which they are used. Thus, low refractory are those below 1770°C; medium refractory 1770-2000°C and high refractory above 2000°C [4]. Similarly, in terms of their chemistry, there are three types of refractory materials, acidic, basic and neutral refractories[1]. Appropriate materials selection is required for the production of refractory materials of specified property[5]. The best-known refractory is the fireclay which belongs to the aluminosilicate group of refractory materials and clay in nature.[6]. Clays are fine particle size materials comprising of clay minerals, which are basically hydrated aluminosilicates. Clay mineral groups are kaolin, smectite, palygorskite, sepiolite, illite,chlorite, and mixed-layered clays[3]. Properties of these clays vary in their structure and composition. They also contain non-clay minerals such as quartz, feldspar, mica, calcite, dolomite etc. Clays of various kinds and grades abound throughout Nigeria’s sedimentary basins and on the basement. A good number of clay deposits in the country have been studied [3].The abundance and availability of clay and low cost guarantee their continuous application in the refractory industries.Foundry activities are still emerging in the northern part of the country, however for effective growth in technology, the knowledge of metal making is paramount. To achieve high quality metal, an excellent refractory must be in position. Refractory clay materials obtain from single site cannot posses all the required properties that will make it a perfect refractory material, hence it becomes imperative to select clays based on the physical and chemical analysis of the samples[7]. The selected refractory clay will have to be beneficiated with refractory clay from other site and be properly blended with other additives to improve their physical, thermal and chemical properties of the final products[8]. Table 1 shows different properties of different clay types used as refractory materials. A lot of research works

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have been carried out to determine the potential of local refractory materials across the geopolitical zones of Nigeria, which needed to be properly used to guide for exploration and application of these material[5]. However in the north East, there are only few research with regards to clay as refractory materials despite the huge deposit of the material on the land. The refractory needs of Nigeria is greatly enormous. It was estimated that the Ajaokuta Steel Company and Delta Steel Company will at full capacity require 43,503 and 25,000 tons/year of refractories for their activities respectively. These products are sourced from abroad[1]. It was noted that small-scale industries in Nnewi and in some parts of the country have recently embarked on the fabrication of spare parts that needed the application of refractory materials [9]. These spare parts are fabricated using high temperature furnaces that require linings. It was reported [10] that in 1987 alone, Nigeria imported 27 million metric tons of refractories. A lot of foreign exchange is being spent on the importation of refractory materials into the country annually. Therefore, there is need to develop the local refractory materials for their application in the required industries[5]

Table 1 Summary of different clay types properties

Percentage Composition						
Clay type	Silicon Oxide ($Si0_2$)	Aluminum Oxide (AL_20_3)	Iron(iii)Oxide ($F_{e2}0_2$	Calcium Oxide (Cao)	Potassium Oxide (K_20)	Loss on ignition (LOI)
Low melting	35-80	7-21	3-12	0.5-3	1-5	3-15
High melting	53-73	16-29	1-9	0.5-2.6	0.7-3.2	4-12
Refractory	46-62	25-39	0.4-2.7	0.2-1.0	0.3-3.0	8-8

Source: Yami,2006

3. MATERIALS AND METHODS

The primary materials needed for this work was potter clay samples which were obtain from Kona ward in Jalingo local government of Taraba State . Kona Garu is on the northern fringe of what was once a vast jukun confederacy situated approximately 35km southeast of river Benue, and 10km north of Jalingo city, northeastern Nigeria[11]. It is roughly located between latitude 10°50′ and 8° 90′ North and longitude 11° and 12° East of the meridian and covers a landmass of about 1025sq kms with an estimated population of over 30,000 persons [11]**.** The choice for location was informed due to the economic importance of the clay deposit in those areas which were used for pottery and burn bricks production. The samples were collected randomly from three sampling points from the study area at a depth of 3.5ft in accordance with the ASTM 2004 D1452. 1000g were collected at each of the three sampling points, making 3.0 Kilograms of the sample. Mercury were used during testing of the bulk density of the samples and Water were also used in preparation of the samples. Clay samples were mined and dried at room temperature to evenly reduce the moisture content and enhance grinding. The dried sample were ground to powder form with 1.13mm mesh . Some parts of the samples were taken for Physical property tests while the remainder were further ground to finer particles using 0.5mm mesh and then used for Chemical analysis. The samples were weighed and dried in an oven at 110°C for two hour to ensure complete evaporation of the moisture content. Samples were moulded from the powdered clays mixed with 8 percent water to form a homogeneous plastic paste. A rectangular mould of steel plate, of 100mm by 50mm by16mm were used according to [12],[13]. A hydraulic press was used to compact the mixture. The prepared samples were dried in a furnace at a temperature of 110°C. The temperature was increased by 100°C gradually in intervals of ten minutes until the temperature of 1200°C was attained. The samples were then soaked at 1200°C for 8 hours and allowed to cool in the furnace for 24 hours according to [14].

3.1 Chemical Analysis

The samples were prepared for the chemical Analysis and was carried out with thermo scientific niton model XL3t Gold B^+ 950 X-ray spectrophotometer designed for the elemental analysis of wide range of samples. The samples for the analysis were weighted and grounded to powder with 0.5mm mesh. The samples were individually loaded on the XRF sample container and the XRF gun was place on the sample and voltage (52.00 keV maximum) and at (10,000 count/sec) maximum is applied to produce the x-ray to excite the sample for a preset time of 180 seconds. The spectra from the sample were analysed to determine the concentration of the elements.

3.2 Physical Property Test

3.2.1 Porosity $p = \frac{w-D}{w-S} \times 100$ (1)

Where P= porosity D= Dry weight of the sample S= weight of sample suspended immersed in water. W= weight of sample suspended in air after being soaked in water.

3.2.2 Bulk density

Bulk Density $BD = \frac{w1}{w2} \times d$ (2)

Where w_1= wet of sample dry w_2= wet of sample in mercury and d= density of mercury = 13.5312 at 26.5°C

3.2.3 Firing shrinkage

Firing shrinkage = $\frac{L1-L2}{L1} \times 100$ (3)

Where L_1 = initial length before firing { diagonal length 10 cm} L_2 = Final length after firing

The theoretical refractoriness of a clay sample was calculated using equation below as reported by [14].

Refractoriness= $\frac{(360+\%Al2O3)}{0.228} - Ro$ (4)

Where Ro is the sum of all other elements apart from alumina and silica in the composition

3.2.5 Cold crushing strength

$CCS = \frac{load(L)}{Area(A)}$ (5)

Where Area= length(L)× breadth (B) and (L) is the load.

3.2.6 Loss on Ignition:

The loss an ignition were calculated using the formula:-

$LOI = \frac{M2-M3}{M2-M1} \times 100$ (7)

Where,
M_1 = is the weight of the crucible (g)
M_2 = the weight of clay and crucible (g)
M_3=the weight of dried clay and crucible (g)

3.3.4 Refractoriness

4. RESULTS

Table 2.Result on Chemical Composition of the clay samples

S/N	Sample Location	SiO_2%	Al_2O_3%	Fe_2O_3%	CaO%	MgO%	K_2O%	TiO_2%	LOI %
1	Kona(white clay)	75.21	11.77	4.42	1.240	1.12	5.27	0.01	11
2	Kona(black clay)	77.57	12.17	3.27	0.005	N.D	5.14	0.008	10

Table 3- Results on Physical properties of the clay sample

S/N	Location	Bulk Density g/cm^3	Apparent Porosity %	Linear Shrinkage %	Thermal Shock Resistance cycles	Cold Crushing Strength *kg/cm^2*	Refractoriness Exp/Theo °C	Permeability	LOI %
1.	Kona (black Clay)	2.24	18.39	5.4	1	252.25	1300/1619	51	11
2.	Kona (White clay)	1.69	27.54	3.2	1	267.48	1300/1624	71	10

4.1 Discussion

4.1.1 Aluminum oxide content

Aluminum oxide content for Kona white clay and Kona black clay were 11.77% and 12.17% respectively, it was reported that samples with values ranging from 13-30% weight can be described as moderate alumina clays [15]. The higher the aluminum oxide content, the higher the refractoriness[3]. Kona clays does not satisfy the condition for either high or moderate alumina based on the values obtained. This could be the reason why the refractoriness of the samples could not reach the international accepted values of 1500°C-1700°C for fireclays.

4.1.2 Silica(SiO_2) content

Based on the Silica (SiO_2) content, Kona white clay and Kona black clay were 75.21% and 77.57% respectively. It was reported that SiO_2 range from 55-75% for fireclay and 51-70% for refractory brick [16]. By implication, all the clay samples can be used as fireclay in terms of SiO_2 content.

4.1.3 Iron III oxide content

Kona white clay and Kona black clay has 4.42% and 3.27% Iron III oxide content respectively. The standard value for Fe_2O_3 content is 0.4-2.7 % for refractory clay and 1.0- 9.0% for high melting clay as obtainable in table 1. High Fe_2O_3 is not desirable in refractory material.

4.1.4 Calcium oxide content

The values obtained for Calcium oxide content were 1.24% and 0.005% respectively. It was reported by [6], the standard value for CaO content in a refractory clay and high melting clay is 0.2-1.0% and 0.5 -2.6% respectively, however, based on this Kona(white clay) satisfies conditions for high melting clays.

4.1.5 ***Magnesium oxide content***

kona (white clay) fall within the categories of high melting clay with laboratory value of 1.12%. The standard recommended value for magnesium oxide content is 0.2- 1.0% for refractory clay and 0.5 -2.6% for high melting clay as reported by[17].

4.1.6 Potassium oxide content

Potassium oxide content for Kona white clay and Kona black clay were 5.27% and 5.14 % respectively. It was reported that the K_2O content should be less than 2% for fireclay[13]. This however shows that the higher percentage of K_2O in all the samples account for the lower refractoriness of the clay materials in the study area. Making the potassium oxide of low quantity will enhance the refractory property of those materials in studies[18].

4.1.7 Firing shrinkage

It was reported that the recommended shrinkage for fireclays is 4-10% [16]. Higher shrinkage may result in warping and cracking of the brick and this may cause loss of heat in the furnace[20]. Kona black clay has shrinkage of 3.2% but Kona white clay has 5.4% a little bit higher shrinkage but within the recommended values for fire clays which is 4-10% [19] .The controlling factor for thermal expansion are the particle size and chemical composition of the clay. High alkalis results to corse nature of the clay. Studies according to[7] showed that higher shrinkage means higher moisture content which means finer grains. This shows that kona (white clay),and kona (black clay) could resist the penetration of corrosive vapour and fumes without deformation if used as furnace linings, as reported by[7].

4.1.8 Bulk Density

The bulk density of the clay samples are 2.24% and 1.69% and does not fall within the recommended value of 1.71-2.1 for fireclays[6]. Kona black clay bulk density is lower than the standard value while Kona (white clay) have 2.24g/cm^3 which is above the recommended value of 2.1 g/cm^3 as reported [3].

4.1.9 Cold Crushing Strength

The result shows that all bricks have poor cold crushing strength values of 252.25 kg/cm^2 and 267.48kg/cm^2 which were much lower than the recommended value of 15000kg/cm^2 minimum reported by[17]. The crushing strength can be improved by addition of quartz and other additive and properly blended in a standard proportion.

4.1.10 Apparent Porosity

Kona (white clay) has 27.54% and fall within the standard value of 20-30% as reported by [17], while Kona black clay which has 18.39% porosity, and lower than the recommended value as above mentioned. Kona (white clay) can be used in lining of open hearth furnace if properly blended to take care of other properties.

4.1.11 Thermal Shock Resistance

The studies revealed that all the samples do not meet the requirements of 25 to 30 cycles as reported by[6]. This shows that their use is limited to lining of ladles, slag pots and other low temperature application.

4.1.12 Permeability Test

Permeability is function of gases or liquid passing through the bricks. The permeability of the samples were 51and 71 for Kona white clay and kona black clay, and falls within the limits of internationally accepted range of 25-90 on large orifices.

4.1.13 Refractoriness

All the clay samples have refractoriness of 1300°C.These shows poor refractoriness, fireclay should have refractoriness in the range of 1500°C- 1700°C as reported by [6].

4.1.14 Loss on Ignition

The values of loss on ignition of refractory materials are often required to be low. Kona white clay and kona black clay has 11% and 10% loss on ignition. The upper limit for refractory clay is 18% as reported by [6], and lower is 12% as reported by[3]. It was reported that for low melting clay, a recommended ranges of 3-15% is allowed while for high melting clay, 4-12% is acceptable [17].

CONCLUSSION

The result of the chemical analysis shows that the silica content for the clay samples were 75.21% and 77.57 for Kona white clay and Kona black clay respectively. The alumina content were 11.77% and 12.17% for Kona white clay and Kona black clay respectively. The temperature obtained were 1300°C. It was also found worthy of note that the clays can be used in production of insulating bricks. Insulating bricks are those light weight bricks which have low thermal conductivity by virtue of which they prevent heat from escaping through the furnace walls. The temperature need may be upto 1000°C [20]. Jalingo clay deposit in Kona have shown appreciable properties of high melting clay. This shows that they can be used for lining of heat treatment furnace, melting furnace for low melting metals, liquid metal ladles, however, the level of impurities must be reduced if not completely removed. The application of these work under review can be channeled toward the nonferrous metal Industries. Among the important nonferrous metals are copper, zinc and lead. The ore of these are usually sulphides and in all the three cases, the ore is concentrated by mechanical means and then rosted to get rid of sulphur[20].

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