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UTILIZATION OF CLAY AROUND THE BANKS OF RIVER BENUE IN MAKURDI FOR USE AS A MEDIUM DUTY REFRACTORY MATERIAL

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ABSTRACT

An investigation of the physio-chemical and refractory properties of the clay deposits along the banks of river Benue in Makurdi has been carried out in this work. The physical and mechanical property investigation was carried out in accordance with ASTM stipulation. They include; linear shrinkage, apparent porosity, Flexural strength (M.O.R) and thermal shock resistance while refractoriness was estimated using the Shuen's formula. The chemical composition revealed an alumina, silica and iron contents of 23.8%, 57.6% and 8.85% respectively, percentage linear shrinkages were observed to be 7% and 10.5% for dry and fired shrinkages respectively, apparent porosity was found to be 23.62, M.O.R was found to be between 6.42 and 7.5 MPa and the thermal shock resistance test recorded failure at 13 cycles of heating and cooling from 8500C. The properties investigated prove that the bricks not only suitable for building and construction, but also in construction of bakery ovens, incinerators and driers.

KEY WORDS: ***Refractories, firebricks, medium duty refractories Makurdi clay.***

1.0 INTRODUCTION

Materials with stability even at elevated temperatures and in corrosive environments are often referred to as refractory materials. ASTM defines refractory materials as inorganic and non-metallic in nature and will retain their physical shape and chemical stability when subjected to conditions of heating to high temperatures. Titiladunayo & Fabetu (2011) and Ahmed & Abdullahi (2012) jointly lists these materials to include clays of alumino-silicate base, Silica, Chrome, Magnesite, Chrome-magnesite and not leaving out Zirconia, Nitrides and Carbides. However, the most abundant type of refractory materials are the Alumino-silicate clay. Titiladunayo et al., (2011) further defines clay as an anhydrous complex compound of alumina and silica in varying proportions containing varying amounts of impurities of trace minerals, organic matter and iron as the major impurity. The most important property of clay is its refractoriness and this however depends on the amount of impurities present as they act as fluxing agents which reduces the clay's refractoriness. The utilization of refractories in ovens, kilns, incinerators and furnaces depend on the ability of the said clay to withstand higher temperatures, maintain a good value of refractoriness under load (R.U.L) and its resistance to chemical attack. All these are subject to the ratios or proportions in combination of Alumina to Silica in composition of the clay.

Studies carried out on some Nigerian clays to determine their refractoriness by some scholars including Ahmed and Abdullahi (2012) showed that the most extensively investigated clay deposits in Nigeria are: Kankara Kaolin, Onibode, Manjohota, Warram, and Enugu clays. Others include Nsu, Ekebedi, and most recently, Vandeikya kaolin all in Nigeria. The information on these clay show good promise for quality and a wide range of applications but the exploitation and exploration of these clays for refractory purposes is still in its cradle. The demand for these refractories according to Amuda et al., (2005) puts Ajaokuta steel complex at an estimated 36,000 tons of refractories per annum. It has been identified that metallurgical processing alone accounts for bulk of refractories imported. Many other demands for refractories come from the production of chemicals from high temperature processes in chemical plants. Another major consumer is the glassmaking industry and others like the cement industry. Omowumi (2000), has said fire clay records the largest tonnage in use by the manufacturing sector in Nigeria, however, these clays vary widely in composition and properties. The main factors which are responsible for the phenomena is the significant difference in geology of the different regions of Nigeria. This is also a factor which influences the degree of impurity found in a particular clay. The clays are often in combination with some mineral elements that can be found in the regions the clays are located. All these, collectively determine the applications suitable for these clays as evident in clay and refractory classifications in various literature relative to their operating temperatures. Musa et al., (2012) asserts that the development and investigations into the suitability of the various clay deposits in Nigeria is justified by an ever-increasing need to meet the technological requirements of Nigeria and to preserve foreign exchange. This is also evidenced in the scale of research carried out on refractory materials for a wide range of application.

This work is however targeted at the evaluation of the refractory properties of the vast clay deposits along the banks of the River Benue that has however enjoyed extensive use by natives in burnt bricks production for building and construction. These bricks also have the potential for use as medium duty refractories for ovens and driers.

2.0 MATERIALS AND METHOD

2.1 Sample collection

Representative clay sample was collected from the riverbanks of the Makurdi portion of River Benue behind the Tipper garage in Makurdi, Benue State Nigeria. The sample was dug out using a shovel after scrapping the surface of the point of excavation to give a true representation of the clay around the river banks. Quartering was further used to achieve representative clay.

2.2 Equipment

The equipment used were a set of sieves, an electric kiln, Ratcliffe P5131 model, Hydraulic crushing strength testing machine, electronic weighing balance and a ceramic drying cabinet.

2.3. Sample preparation

The representative sample was soaked for five days to allow for oxidation of FeO and it was removed by decantation method. The sample was sieved using 757mm mesh. The shiny clay was then poured on a cemented floor left to dry and the resulting mass having dried for two days now became a plastic mass of somewhat stiff consistency which enabled working and shaping.

2.3.1. Chemical composition of clay.

The chemical analysis was carried out at the Centre for Energy Research and Training. (CERT) Zaria. Using a mini Pal Energy dispersive X-ray spectrometer. (PW 4030) which detects and measures elements from sodium to Uranium. The sample was crushed and mixed with a binder and compressed into pellets and used for the analysis.

2.3.2 Brick production

The dried sample of clay was crushed and mixed with water and kneaded to achieve consistent plasticity and covered in a polyethylene bag and allowed to age for three days. The clay mass was then formed into bricks using a wooden mould. The resulting semi-dry brick was air dried for 14 days under normal temperature and pressure and then dried inside a drying cabinet for 7days at 110^{0}C.

2.3.3. Firing of Bricks

Ten samples were made. Efforts were also made at compacting the bricks by ramming. After the processes of drying using the ceramic drying cabinet, the bricks were then loaded into an electric Kiln and fired to a temperature of 1250^{o}c for 8 hours then allowed to cool to room temperature inside the kiln for 24hours before they were removed.

2.4. Refractory Properties Evaluation

The bricks were tested for linear shrinkage, apparent porosity, cold crushing strength, thermal shock resistance, specific gravity and the Refractoriness was estimated using the Shuen's formula which estimates the refractoriness of a particular clay from its chemical composition.

2.4.1. Linear Shrinkage

The standard procedure for determining shrinkages of bricks according to Griffiths and

Radford (1965), the measurement of the brick was taken before and after firing. The percentage of the resulting difference or change in dimensions gives the value of the linear shrinkage using the expression;

$$\% \text{ shrinkage} = \frac{Dl - Fl}{Dl} \text{x } 100$$

Where Dl = dry length (mm)

Fl = Fired length (mm)

2.4.2. Apparent Porosity

This refers to the percentage of total volume of pores relative to the total volume of the refractory material (brick). Three bricks were weighed, in air and then heated in a pot. The brick was wrapped inside a wire gauze and heating lasted for three hours. The brick had been dried in an oven for four hours before subsequent boiling in water. The rationale behind using a wire gauze was to ensure that the brick does not have contact with absorption of the brick. After three hours of boiling, cooling was allowed to take place and then the brick was wiped off dripping water and then weighed. With the following expression below, the percentage apparent porosity was then determined.

$$\frac{S-D}{S-I} \, x \, \frac{100}{1} = \%\text{P}$$

Where D = weight ofdry test piece.

S = weight of wet test piece after soaking in water.

I = weight of test piece immersed in water.

2.4.3. Specific Gravity

Following the Archimedes principle, the specific gravity the brick was then determined. The brick was weighed in air and also weighed when suspended in water

With this relationship; $S_G = \frac{D}{D-I}$

Where D = the weight of the brick in air.

I = the suspended weight of brick in water.

D-I = the weight of water having the same volume as the brick.

2.4.4. Flexural Strength (MOR)

This is a mechanical parameter which quantifies the ability of a brick material to resist deformation under load. The ASTM C133 – 97 (2008) is the standard test method for the determination of cold crushing strength and MOR of Refractories but not a measure of performance at elevated temperature. In this test a 3-point loading or bending jig was used where a known dimension of brick was tested. loading continued until the brick failed. The pressure at which the brick failed was recorded and the M.O.R was evaluated using the expression below;

$$\text{M.O.R} = \frac{3FL}{2bh^2}$$

Where F=force

L=length between knife edges.

B=breadth of brick.

H=height of brick.

2.4.5 Refractoriness.

The refractoriness of the clay was estimated using Shuen's formulas stated below;

$$K = \frac{360 + Al_2O_3 - RO}{0.228}$$

Where K = Refractoriness

RO = the sum of all other oxides except SiO_2 in the clay

Al_2O_3 =Alumina content in the clay

360 and 0.228 are constants

2.4.6 Thermal shock resistance

In this test, a brick with a dimension of 14cm x 6cm x 5cm was placed inside a locally made blacksmith's wheel which was spun by an electric motor. The wheel attained a temperature of 1280^{0}C as recorded by a Vici VC99 digital multi meter with K-type thermocouple wire.

3.0 RESULTS AND DISCUSSION

The results of the tests and experiments are given below in tables1-3.

Clay	Colour	Physical form
Makurdi	Brown	Soft, smooth lumps
Vandeikya	White	Moderately hard lumps
Enugu	Dark	Very hard lumps
Nsu	Gray	Moderately hard lumps

Table 1 **compares the physical characteristics with some other Nigerian clays.**

Elements	Al_2O_3	TiO_2	SiO_2	CaO	K_2O	MnO	Fe_2O_3
Conc. Unit%	23.8	2.16	57.6	1.69	4.67	0.213	8.85

Table 2 shows the chemical composition of Makurdi clay.

Oxide%	Makurdi Clay	Ceramics	Refractories	Brick clay	Kaolin
Al_2O_3	**23.8**	26.5	**25-44**	9-45	25-45
SiO_2	**57.6**	67.5	**51-70**	38-67	40-60
CaO	**1.69**	0.18-0.3	**0.1-0.2**	1-5	<2.5
K_2O	**4.67**	0.1-3.1	-------	2-7	-----
Fe_2O_3	**8.85**	0.5-1.2	**0.5-2.4**	2-7	1-5
MnO	**0.213**	ND	-------	-----	-----
TiO_2	**2.16**	ND	-------	-----	-------

Table 3 showing composition of Makurdi clay in comparison with oxide ranges for industrial applications

Details	Makurdi Clay (cm)
Linear dried sample A	9.4
Linear dried sample B	9.2
Linear fired sample A	9.1
Linear fired sample B	8.8

Table 4shows the Dried and fired shrinkages of the clay.

Sample Details	Weight (g)
D	*230.54*
S	*256.23*
I	*147.67*

Table 5showing the apparent porosity of the clay brick

$$\%P = \frac{S-D}{S-I} \, x \, \frac{100}{1}$$

Details	*Sample 1*	*Sample 2*
Force	*37KN*	*33KN*
Length	*11.8*	*11.5*
Height	*4.3*	*4.15*
Breadth	*5.5*	*5.2*
M.O.R	*6.44MPa*	*7.5Mpa*

Table 6showing results for flexural strength

$$M.O.R = \frac{3FL}{2bh^2}$$

3.1 Chemical composition

The chemical analysis showed an oxide composition given in table 2.Iron and titanium oxides are high which is likely to reduce its fusing temperature coupled with lime potassium oxide.

3.2 Linear shrinkages (Dry and Fired)

The results in table 4, upon mathematical evaluation showed a percentage dry shrinkage of 7% and a percentage fired shrinkage of 10.5%. Chester (1973), recommends a shrinkage range of between 7-10 % for clays of refractory properties. The results in this work almost fell short of the recommended range due to the high iron content and the low alumina content. This can be made up through an increase in the percentage of alumina or an inclusion of grog and reduction of the iron content.

3.3 Apparent Porosity

The result of the apparent porosityof the brick sample was determined and found to be 23.62 as shown in table 5 and evaluated using the expression. The result falls within the acceptable range of between 10-30% as suggested by Chester (1973).

3.4 Modulus of Rupture

The brick failed at a force of 37 kN the modulus of rupture was then evaluated and the value 6.44 MPa. This also is within the acceptable limits recommended by Chester (1973) which states the minimum value for a refractory clay material to be 5 MPa. Also as stated by ASTM C-27.

3.5 Refractoriness.

The refractoriness of the clay was estimated using Shuen's formula and was found to be 1606.215^{O}C. The results show good prospects of use as a good low-medium duty refractory brick in ovens and driers.

3.6 Thermal Shock Resistance

During the test, firing utilized coal to reach the temperature within the shortest possible time. At 1280^{0}C the brick was allowed to soak for ten minutes. It was then first removed at 1280^{0}C and cooled in water using metal thongs and this was repeated at 850^{0}C until it failed. Failure was first recorded at 8 cycles of heating and quenching and finally at 13cycles the brick disintegrated.

CONCLUSION

This work shows that the vast deposits of the Makurdi clay can be processed with little adjustments to enhance its refractoriness and thermal shock by adding a little amount of grog and mixing with Vandeikya clay which has a high amount of kaolin. On the whole, it is suitable for use as a medium duty refractory brick. Almost all the properties evaluated had results that were within the acceptable values for medium duty refractory applications. It is recommended that the processing of this clay as refractory should be done with the aim of first reducing the iron content as much as possible.

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