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Development of Furnace Lining Bricks for Steel Smelting Using Nasaru, Gada Uku and Gwaram Clays: A Review

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Abstract

Most of the refractory raw materials being used in Nigeria are imported from American, Asia, China, and some other countries. Due to the large deposit of clay available in Bauchi state that are used in the production of locally made pot, there are limited literatures on the study of Bauchi state clays, to examining the mineralogical parameters especially refractoriness for application in steel smelting hence the purpose of this review work. The clays collected from various places had been analyzed based on chemical composition, cold crushing strength, Bulk density, thermal shock resistance, porosity, and Refractoriness from relevant literatures. The result obtained can be compared with the known standard of refractory materials as in table 1. In order to achieve high quality metal, the refractory clay obtain in a single site have to beneficiated with other refractory clays from other site or blended with some other additives, to improve the physical, mechanical and chemical properties of the final products.

Keywords: Clay; Refractoriness; Chemical Composition; Mechanical; Physical.

1. Introduction

Clay is a common name for a number of fine-grained, earthly materials that become plastic when wet. Chemically, clays are hydrous aluminum silicates, ordinarily containing impurities e.g magnesium, sodium, calcium, potassium and iron which are in small quantities (Mohammed and Agbajelela, 2011). The origin of clay may be traced to either of the two geographical processes namely sedimentation and weathering (Ameh and Obasi, 2009). Clay deposits are typically associated with very low energy depositional environment such as marine basins and larger lakes. Primary clays which can be referred to as kaolines, are found at the place of the formation while secondary clay have been moved from their location by erosion and water (Hillier 2003). There are two factors that emphasizes the use of clay. The first one is the increase in the number of metallurgical industries which are in dire need of these refractories and the second is the advent of foreign market (Kipsanai, 2018). Refractory is defined as the quality of materials to retain their strength at high temperature (Adamu et al., 2018). Refractory materials are used in linings for furnaces, reactors, incinerators and kilns. The ability of this material to withstand exposure to heat above 538^0C is the critical distinction separating refractory from other ceramics, fibre and coating application at only lower temperature (Umar et al.,2012). The main objective of a refractory material is to conserved heat and also to resist abrasion and corrosion (Khinyaram, 2014). A refractory material can be classified based on their shape and chemical composition, there are shaped bricks and the monolithic refractories. Monolithic refractories are refractory materials that are single piece casts. The oxides of aluminum, silicon and magnesium are the most important materials used in the manufacturing of refractories (Nwannenna, 2015). The bricks can be made either manually (i.e. using hand) or by machine pressing method. The machine pressing brick is of the highest strength and density. Thus, the most suitable for furnace lining (Khinyaram, 2014). All these works have been centered on the production of refractory bricks from the raw materials. With the revamped of Ajaokuta iron and steel industry, it is estimated to required 36000tons of refractory bricks worth over sixty million naira just for furnace lining purpose only and more than 80% of the refractory bricks to be required are fireclay. As it was estimated by the year 2015, Nigerian steel industries will be consuming about 50,000tons of high alumina bricks and 80,000tons of fired bricks per year (Opeyemi and Samuel, 2012). Some small-scale industries have recently embarked on the production of spare part that needed the application of refractory materials. These spare parts require the use of high temperature furnaces linings (Nwannenna, 2015). In view of above, the review work focusses on furnace lining brick for steel smelting.

2. Materials and equipment

2.1 Materials

The materials used to carry out the experiment are;

- Clay samples and
- Water.

2.2 Equipment

The equipment used in the research include;

- Stop watch
- Steel rule
- Muffle furnace
- Vernier caliper
- Cut-off wheel
- Mercury

- Hydraulic
- Crushing machine
- Star board
- Scriber
- Water manometer
- Metal cylinder
- X-ray fluorescent spectrometer
- Shovel
- Axe
- Bucket and
- Crucible.

3. Material Analysis

The step by step procedure to carry out the material analysis is shown in Figure 1.

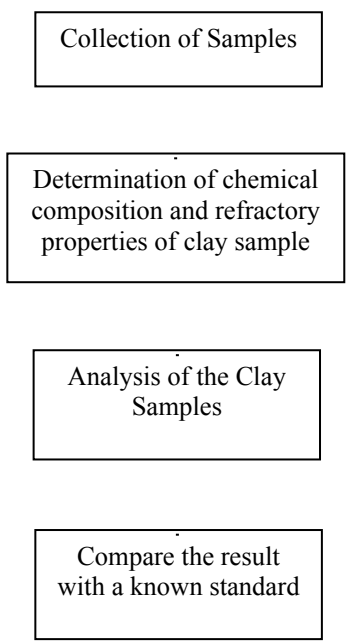

Figure 1: Block Diagram of Material Analysis.

4. Bricks Production

The clay samples were collected from different places. The raw materials (clay) was air dried and grounded to powder with the pestle and mortar to finer particles and then used for chemical tests. The samples will be weighed and dried in the oven at 110^0C for one hour to ensure that all the moisture had been removed. Samples of grounded particles was thoroughly mixed with 8 percent water form a plastic paster (Yami, 2007).

A rectangular wooden box of 8.0 4.0 4.0cm area had been made in a mold and compacted under a hydraulic pressure of 350KN/m^2 (Nnuka and Agbo, 2000). The prepared clay samples were dried in the oven at a temperature of 110^{0}C. The temperature increases by 100^{0}C gradually in interval of ten minutes until the temperature of 1200^{0}C had been attained. The samples were then soak at 1200^{0}C for 8hours and allowed to cool in the furnace for 24hours (Yami, 2007).

Table 1: Typical chemical composition of clay types

	Percentage Composition (%)					
Clay type	Silicon Oxide (SiO_2)	Iron(iii) Oxide (Fe_2O_3)	Calcium Oxide (CaO)	Potassium Oxide (K_2O)	Loss on ignition (LOI)	Aluminium Oxide (Al_2o_3)
Low Melting	35 – 50	3 – 12	0.5 – 3	1 – 5	3 -15	7 – 21
High Melting	53 – 73	1 – 9	0.5 – 2.6	0.7 – 3.5	4 – 12	16 – 29
Refractory	46 – 62	0.4 – 2.7	0.2 – 1	0.3 – 3	8 – 8	25 – 39

Source: (Adamu et al., 2018).

PREVIOUS RESEARCH

The literatures reviewed revealed that most of the clays used within and outside Nigeria have that potential to be used in the metallurgical and non-metallurgical industries.

In western Isles of Scotland, the clays were found to be mainly mullite which can withstand high temperature of many aluminum silicate minerals including Kyanite, kaolinite, pinite and topaz. It was discovered the clays have spalling resistance. They could withstand the shock of heating, cooling and resistant erosion cause by the slag. They could be used in the manufacture of plugs, crucibles for laboratories and saggars (Yami, 2007).

Investigating the refractory property of Jalingo clay deposit. Showed that the bricks have poor crushing strength and can be improved by addition of quartz and other additives. The clays were suitable for

nonferrous metals (Adamu et al.,2018).

A study of the refractory properties of selected clay deposit in Charalaki Kenya. The material has high silica content which makes it withstand high temperature and fairly high iron content which makes it fire terracotta red or brick red on firing. The silica content of the clay satisfies the standard which make it to be used in the manufacture of high melting clay (Kipsanai, 2018).

Research on the characteristics of Dabagi clay are moderately high while the cold crushing strength are low. The result showed that Kaolin clay or rice husk ash and limestone should be added so as to improve the performance of the clay (Abubakar et al., 2014).

Work on the influence of water on silica bricks at elevated temperatures revealed that bars from silica bricks of normal composition and exposed to water vapor for about 5 hours at 1590^0C exhibited of slight surface glaze on bonding. It was also discovered that at 1593^0C water vapor had no effect on American silica of normal composition (Yami, 2007).

A comparative study on the refractory properties of selected clays in North central Nigeria. showed that the clay is highly silicate with moderate alumina content. Low ferrous oxide content and possess very low contents of other metal oxide. The correlation on properties stated that the denser clays are less porous and less likely to shrink (Umar et al.,2012).

Researches on clays from Pennsylvania and Missouri revealed that they were diaspore which is hydrated aluminum oxide of 85% and 15% water content. It was discovered that the clays were hard and very refractory in nature and could be used in making refractory bricks (Yami, 2007).

Characterization of Ibamajo, Maye and Nkwo – Alaiko Fireclays for use as refractory materials in foundry industry. The clays samples are richer in silica and this has contributed to a high compressive strength. The low percentage of apparent porosity enhances the entrapping of gases with material. They could be used with production of bricks for various purposes (Nwannenna et al.,2015).

Work on the effect of coal ash on some refractory properties of alumino-silicate (Kankara) clay for furnace lining. It was reported that the cold crushing strength and thermal shock resistance increases as the percentage of coal ash increases in the clay. The apparent porosity and linear shrinkage of the bricks produced from Kankara clay blended with coal ash decreases with increase percentage of coal ash addition. The addition of coal ash could enhance the refractory properties (Hassan and Aigbodion, 2014).

Studies on the effect of temperature difference on thermal shock behavior of Onibody fireclay material with the addition of alumina. Thermal shock resistance under difference temperatures on the clay sample with the addition of alumina shows that the thermal shock resistance of the material decreases with the increase in temperature. The higher the percentage of alumina in the clay, the higher the refractory result obtained (Apeh et al.,2013).

Studies on the chemical and physical characteristics of selected clay samples. It was discovered that the samples are silicon in nature and of the aluminosilicate refractory which belong to kaolintic fireclay with appreciable values of the refractory properties that are comparable to the standards. The shrinkage value obtained is an indication of its high-water content and plasticity (Sani et al., 2013).

Enhancement of refractory properties of blended clay with groundnut shell and rice husk additives. The presence of useful oxides like P_2O_5 and Al_2O_3 improved the refractory material. The bulk density and modulus of rupture decreased with the increment in the percentage composition of the additives. It was reported that good insulating and refractory properties required for high temperature application could be obtained when the clay material blended with groundnut shell and rice husk additives (Chima, 2017).

Work on the development of refractory bricks from Nigerian Nafuta clay deposit. Established that the porosity and firing shrinkage increases with increase in rice husk. The bulk density decreases with increase rice husk. They, clay could be used as a refractory lining material for furnaces, killing, incinerators etc (Jock et al., 2013).

Studies the effect of cassava peel on insulating properties of Ogugu clay deposit. It was discovered that the addition of cassava peel to the clay was found to have great effect on the insulating properties such as linear shrinkage, bulk density, total shrinkage, modulus of rupture, apparent porosity and water absorption.

The cassava peel was found to be suitable additive both in increasing the strength and refractoriness (Etukudoh, 2016).

Evaluation of refractory properties of selected clay samples from Sokoto state North West Nigeria reveals that the bulk density is affected by number of factors such as particle sizes treatment process and the composition of the sample. The high bulk density might have connection with impurities that were present (Agbajelola et al., 2015).

Studies on the performance of Dioscorea rotundata peel as an environmental waste addition in enhancing the insulating properties of a local clay mineral. It was found that Dioscorea rojundata peel have very good ability in enhancing the insulating properties of the clay minerals. The presence of appreciable amount of K_2O, Na_2O and CaO suggest low or moderate refractoriness (Akpomie et al.,2018).

5. Conclusion

The following conclusion were drawn from the research review above.

- To achieve high quality metal, the refractory clay obtains in a single site have to be blended with other refractory clays from another site to improve their properties.
- Use of suitable additives such as groundnut shell, cassava peel, rice husk, sawdust, etc. to improve their physical, mechanical and thermal properties.
- Improve production method of the bricks using hydraulic pressing machine to make the brick of high strength and density depending on the compression.
- The oxides of aluminium, silicon and magnesium deficiency makes a clay not suitable to refractory industry.

6. Recommendation

- Design expert can be employed to establish a clear fact for collecting the clays.

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