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A COMPARATIVE STUDY ON REFRACTORY PROPERTIES OF DOLOMITE USING CLAY AS ADDITIVES

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ABSTRACT

The progress in the metallurgical field in Nigeria has called for an increase in demand for refractory materials in recent times. A large proportion of these materials are currently being imported to meet its increasing demand. Therefore, this stirs up the need to investigate the properties of suitable locally made refractory.

This study presents the results of comparative analysis and evaluation of the refractory properties of some prepared dolomite purchased at Ilorin using clay deposit in OrileIgbon, Ogbomosho, Nigeria as an additive with a view of improving the suitability of dolomite uses as a refractory material.

The test carried out, revealed that the dolomite and water has a bulk density between 1.27 – 2.05g/cm^3, linear shrinkage between 0 - 0.73%, 12-17 cycles for thermal resistance and a value between 0.21 and 0.34KN/cm^2 for cold crushing strength, dolomite, water and honey has a bulk density between 1.61 – 3.03g/cm^3, linear shrinkage between 0 - 0.74%, 12-35 cycles for thermal resistance and a value between 1.11 - 2.51KN/cm^2 for cold crushing strength. Dolomite, clay, water, and honey has a bulk density between 1.72 – 2.56g/cm^3, linear shrinkage between 0 - 0.76%, 19-42 cycles for thermal resistance and a value between 1.41 and 2.57KN/cm^2 for cold crushing strength and clay and water has a bulk density between 1.93 – 2.44g/cm^3, linear shrinkage between 0 - 8.70%, 22-42 cycles for thermal resistance and a value between 2.90-3.95KN/cm^2 for cold crushing strength which shows that the investigated properties, the mixture (clay and dolomite) and clay alone are better refractory materials and suitable for lining of furnace where the materials melted requires basic environmental and operating temperature above 1100^{o}C than dolomite alone.

KEYWORDS: *Clay, Dolomite, Refractory Materials*

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INTRODUCTION

Dolomite mineral is a double carbonate of calcium and magnesium having the formula CaMg $(CO_3)_2$[8]. It is slightly hard, transparent, and forms rhombohedron as its typical crystal habit. Dolomite used for refractory purpose should be hard and compact with uniform texture containing very low percentages of iron, silica, alumina etc. This is because these impurities adversely affect the refractoriness of dolomite refractories [9]. Under actual conditions of operation, refractories are subjected to mechanical loads. For this reason, refractory materials are assessed by their ability to withstand loads at high temperatures [10]. Each refractory composition has optimal conditions of heating and roasting which should be adhered to in order to prevent cracking, glass phase formations etc [11].

The chemical composition of refractories depends on the composition of the starting materials. The composition of refractories determines their activity in steelmaking slags. Refractories that are of silica composition (an acid oxide), should not be in contact with basic slags' while those prepared from basic oxides (MgO, CaO), should be protected from having contact with the acid slags; otherwise, their particles in the lining will be slagged vigorously, resulting in quick failure of the lining [10]. The stability of refractories determines not only their consumption but also the productivity of steel making. The refractory material for steel making should have low porosity i.e high density so as to avoid the erosion by the moving metal and slag [11].

In the last few years, there have been tremendous works towards developing refractory products from local clay deposits. Various research works have found that our local refractory clays are suitable for use in furnace lining and steel industries.

Agha (1998) showed that some local clay has better refractory and physical properties than imported ones. Nnuka and Agbo (2000) studied the characteristics of Nigerian clays and discovered that the Otukpo clay has refractoriness of $1710^{o}C$, which compares well with imported refractories. Omowumi (2001) also discovered the close relationship of the clays studied with properties of known refractory materials. Another recent research by John (2003) has indicated the suitability of producing refractory materials for base plates of stoves, bricks for furnace lining and other industrial uses from Nigerian clay deposits. [12]

In this work, various properties of two local refractory materials (dolomite and mixture of dolomite and clay) were investigated to determine their suitability for producing refractory bricks for furnace lining.

METHODOLOGY

The samples investigated were: clay, dolomite and the mixture of both. The clay was collected from OrileIgbon, in Ogbomoso of Oyo State, Nigeria and the dolomite was purchased from Ilorin. The sample was crushed and sieved through three different meshes: 90um, 180um, and 250um. The binder was added in order to impart green strength and act as a plastifier and hydration protection. The raw purchased dolomite was introduced into the furnace for burning (calcination), the carbonates decomposed between $780^{o}C$ and $1100^{o}C$ and are transformed into calcium oxide and magnesium oxide while carbon (iv) oxide was given off. The calcined dolomite were crushed, partially washed and then mixed with water and other binders, pressed and molded into the desired shape and fired in a furnace.

Chemical Analysis

The chemical analysis of the samples was carried out using atomic absorption spectrophotometry (AAS) method at the International Institute of Tropical Agriculture (IITA), Oyo Road, Ibadan, Nigeria. The percentage composition of the various constituents is recorded in Table1 and 2.

Figure 1

Bulk Density

The weights of sintered samples were determined by using an electrical weighing balance and the volume was calculated taking the measurement of the dried length, breadth, and height. Thus; the bulk density is calculated using the weight over the volume.

Thermal Shock Resistance

Test pieces were placed in a furnace which has been maintained at 1000°C. This temperature was maintained for 10 minutes. The specimen was removed with a pair of tong from the furnace one after the other and then cooled for 10minutes on a platform. The specimens were returned to the furnace for a further 10 minutes. This process was continued until the test piece cracked and fell into pieces. The number of heating and cooling cycles for each specimen was recorded.

Linear Shrinkage

The rectangular test pieces were marked along a line in order to maintain the same position after heat treatment. The distance between the two ends of the slab was measured with vernier calliper. The samples were air dried for 24 hours and oven dried at 110°C for another 24 hours. They were then fired for 6 hours. The test pieces were cooled to room temperature and measurements taken. The linear shrinkage was calculated from the equation below

$$LS = \frac{LD - LF}{LD} \text{ X } 100$$

Where; LS = Linear shrinkage

LD = Dried length, and

LF = Fired length

Dry Compressive Strength

The dry compressive and dry shear strengths of dolomite were determined by using the compressive testing Machine. Specimens of different size were sintered at the designated temperature. The test specimens were inserted into the compression and shear heads. The readings at which the specimens failed were recorded as the dry compressive strength.

RESULTS AND DISCUSSIONS

Results

The result were summarized and compared with standard value in the table below

Table 1: Chemical Composition of the Orile-Igbon Clay Sample (%)

Types of Oxides	Al_2O_3	SiO_2	Fe_2O_3	MgO	CaO
Orile-Igbon clay	20.40	26.55	18.30	0.35	1,98
*Gur	21.25	59.20	15.70	0.98	1.92
*Yamarkumi	19.68	41.80	8.89	0.98	1.51
**Refractory Clay	25-39	46-62	0.4-2.7	0.2-1.0	0.2-1.0
**High Melting Clay	16-29	53-73	1-9	0.5-2.6	0.5-2.6
**Ceramics	26.50	67.50	0.5-1.2	0.18-0.3	0.1-0.19

*Yami and Umaru (2007) ** Nnuka and Agbo (2000)

Table 2: Chemical Composition of the Purchased Dolomite Sample (%)

Types of Oxides	Al_2O_3	SiO_2	Fe_2O_3	MgO	CaO
Composition (%)	0.11	1.5	2.5	42.0	22.80
^{o}Composition (%)	-	1.8	-	19.76	32.65
^{o}ASTM standard Value	Below 1.5	Above 1.0	Below 1.5	Above 20.0	Above 30.0

^{o}Olaiya K.A. et al (2014)

Table 3: Result of Bulk Density, Linear Shrinkage, Thermal Shock Resistance and Compressive Strength Test for Dolomite, Water and Honey Compared with ASTM Standard for Dolomite

Quantity of Dolomite	Sample 1	Sample 2	Sample 3	Mean	Standard Value
Bulk Density	3.03	2.25	1.69	2.32	2.40– 3.20
Linear Shrinkage	0	0.37	0.37	0.25	0 – 0.2
Thermal Shock Resistance	30	20	16	22	23 – 28
Compressive strength Test	1.81	1.92	1.99	1.91	1.5 – 16

Table 4: Result of Bulk Density, Linear Shrinkage, Thermal Shock Resistance and Compressive Strength Test for Dolomite, Water, Honey and Clay Compared with Fired Clay Bricks

Quantity of Dolomite	Sample 1	Sample 2	Sample 3	Mean	Fired Clay
Bulk Density	2.49	2.14	1.91	2.18	2.3
Linear Shrinkage	0.75	1.0	0.37	0.71	4-10
Thermal Shock Resistance	27	24	22	24	20-30
Compressive strength Test	2.57	2.18	1.78	2.18	1-15

DISCUSSIONS

Bulk Density

The acceptable range of B.D value according to ASTM (1982) for refractory grade Dolomite is 2.40g/cm3 and 3.20g/cm3. The B.D value obtained for the first three set of samples falls outside this range except for few and that of clay samples, In comparison to clays from other regions of Nigeria, these are quite dense when compared with values obtained for Gur and Yamarkumi clays (2.06-2.11 g/cm3), Plateau and Bauchi clays (1.94-2.04 g/cm3) as respectively reported by Yami & Umaru (2007) and Abolarin*et al* (2004). As Bukuru clay is Plateau clay, this is in agreement with the value obtained in the present study. Onyeji (2010) noted the correlation between bulk density, linear shrinkage, and apparent porosity and stated that the denser clays are less porous and less likely to shrink [2].

Linear Shrinkage Value

Linear Shrinkage Value obtained is within the acceptable range of 0 - 0.2% specified for refractory grade Dolomite according to ASTM (1982) standard. Also, the average linear shrinkage for the clay is within the recommended range of 4-10% for fireclay as reported by Omowumi (2001). This is more desirable. Higher shrinkage values may result in warping and cracking of the brick and this may cause loss of heat in the furnace.

Thermal Shock Resistance

The thermal shock resistance value between the range of 13-26 cycles for dolomite and/or additives (clay or honey) was obtained. According to Gupta (2008), the acceptable value for refractory grade Dolomite is 25 to 30 cycles. Most of the value obtained falls out of this range. This implies that the sample has to be worked upon by blending with suitable additives to improve its TSR Value, and that of clay the thermal shock of the acceptable values i.e 25-30 cycles as compared in Table above

Compressive Strength Test

Compressive Strength Test increases as the quantity of clay increases. The essence of undertaking this test is to determine the ability of bricks to withstand stresses in service. The values obtained for the samples were between 1.37 and 3.95KN/cm^2 respectively. These values are higher than the standard which is very satisfactory.

CONCLUSIONS

The investigations on the properties of the samples show that their values compare favorably with imported fireclay bricks and ASTM standard for refractory grade dolomite.

The Following Can Also be Inferred

- The melting temperature of the mixture of clay and dolomite reached is above 1100^{o}C. This implies that they can only be used to melt metals not exceeding these temperatures.
- Both the mixture (clay and dolomite) and clays have a good cold crushing strength of 1.91 KN/cm^2 and 2.18KN/cm^2 respectively which are higher than the standard of 1.5 KN/cm^2.

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