BLENDING OF NSU AND IBEKU CLAYS: A SOLUTION TOWARDS THE REPLACEMENT OF GP 107-3 REFRACTORY BRICK IN THE METALLURGICAL INDUSTRY

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Abstract

This study has compared the thermo-physical properties of local content refractories produced from blends of Ibeku and Nsu Clay deposits of Nigeria with an imported clay product, GP 107-3 aluminosilicate refractories of Germany. The properties considered are apparent porosity, bulk density, linear shrinkage, cold crushing strength, refractoriness, thermal shock resistance. The results revealed that some of the blends of the Ibeku and Nsu refractory bricks produced can suitably substitute for the imported aluminosilicate refractories utilized in metallurgical and allied industries. Ibeku sample enhanced the thermo- physical properties of Nsu sample.

Keywords: Thermo-physical properties, Ibeku-clay, metallurgical industry, aluminosilicate refractories

1. Introduction

Surveys of the requirements of high temperature dependent industries across the globe show that there is an urgent need for reliable data for the thermal and physical properties of the materials needed for high-temperature resistance processes. This is because these properties are extremely useful in improving both process control and product quality [1 - 8]. The economic realities of today, hinged on the aforestated, have compelled Nigerian local researchers and entrepreneurs to look inwards for the sourcing of their industrial inputs with respect to refractories development. Results of these attempts have been quite impressive because Nigeria is well endowed with abundant raw materials, which are of organic as well as inorganic origin, to meet the high temperature cravings of our industries. Proper processing of our local mineral resources would enhance a great deal of sustenance in our metallurgical and allied industries [9-15].

Refractories constitute a key input in high temperature applications in many industries. The bulk of refractory requirement for these industries are at the moment imported. This situation does not favour the development of our national economy.

Refractories are materials which can withstand the action of abrasive or corrosive solids, liquids or gases at high temperatures. The various combinations of operating conditions in which refractories are used make it necessary to manufacture a range of refractory materials with different properties. Refractory materials are made in varying combinations and shapes depending on their applications [2 - 5, 16]. The amount of aluminosilicate refractory required by the major users in Nigeria stands at 67.0×10^3 tons per year. A breakdown shows that Ajaokuta steel complex requires 36.4×10^3 tons per year, Delta Steel Company, 18.0×10^3 tons per year, Mini Steel Rolling Mills 3.0×10^3 tons per year and Cement Industries 4.0×10^3 tons per year [17].

2. Objectives of the Study

The objectives of this work are to assay the thermo-physical properties of various blends of Nsu and Ibeku clays, compare them with those of the imported GP 107-3 aluminosilicate bricks and ascertain the possibility of producing bricks that will replace the imported brick.

3. Materials and Methods

3.1. Materials

The materials employed for this research work comprised Nsu and Ibeku Clay deposits of Imo and Abia States respectively and an aluminosilicate brick imported from Germany tagged GP 107-3 sourced at Delta Steel Company Ltd, Ovwian - Aladja with its specification shown in Table 1. Cone crusher, roll crusher, sieves of different mesh sizes, "Paul Weber" hydraulic press, manual mixer, metal mortar, riffler, "Endecotte" vibrating sieve shaker, oven, kiln, beakers, balance-top weighing balance, "Sartorius" weighing balance, metal mould, "Carbolite" kiln, pair of tongs, hot plate, venier Caliper, suspendable sieve, densometer, thermometer, steel rule, divider, magnifying lens, mallet, asbestos sheet, hand towel and bar magnet were the equipment used for effective research.

Table 1: Materials Specification for GP107-3 Brick

Constituent	**Composition** (%)
Al_2O_3	$\leq 23\%$
SiO_2	$\leq 75.80\%$
Fe_2O_3	$\approx 1.2\%$
Motar (Ox -grade)	Nil
Properties Tested	**Value**
Bulk density	2.15 g/cm^3
Porosity	$\leq 13\%$
CCS	600 kg/cm^2
Thermal shock resistance	8 cycles
Refractoriness	1580℃

Four kilograms (4kg) of each sample were weighed into various head pans, 50ml of water was added and it was then mixed using a manual mixer until consistency was achieved. The mixed samples were then blended in the ratios 1:9, 2:8, 3:7, 4:6 and 5:5 with Ibeku and Nsu clay deposits representing the base material at various points. 150g of mixed sample was weighed and poured into the rectangular metal mould, an accessory of "Paul Weber" hydraulic press. Each brick was moulded by a compressive load of 300kN. Bricks produced were of the dimension 10mm $\times$ 5mm $\times$ 1.5mm. Test bricks produced were air-dried for thirty six hours (36 hrs) at an ambient temperature (T) range of 27℃ $\leq T \geq$ 32℃. The test bricks were then fired from 0℃ to 1200℃ at intervals of 50℃ and allowed for fifteen minutes at each interval to achieve homogeneity. Samples were then subjected to furnace cooling.

The chemical compositions of the samples were obtained using the energy dispersive technique with the aid of the x-ray fluorescence spectrometer. 100 g of the riffled samples were each weighed, ground in the metal mortar and -75 μm particle size was obtained and used. A bar magnet was stuck to a steel rod and rotated within the sieved samples and tiny strips of metal were attracted to aid its removal. 4g of the output was weighed and intimately mixed with 1g of lithium tetraborate ($Li_2B_4O_7$) binder and pressed in a mould to obtain pellets under a pressure of 10-15 tons/in^2. The pellets were dried at 110℃ for 30 minutes in an oven to get rid of absorbed moisture and were finally stored in a dessicator for analysis. The spectrometer was switched on and allowed to stabilize the optics and x-ray tube. The samples were run using the prepared programs (calibrations) and the element concentrations present in the samples were determined and displayed by the spectrometer. Results are shown in Table 3.

The apparent porosity was determined using the boiling point method of (1).

$$P = \frac{(W - D)}{(W - S)} \times 100 \quad (1)$$

where P = apparent porosity, W = saturated Weight, D = dry weight, S = Suspended Weight.

Bulk Density test was carried via the mercury immersion method and the Bulk Density was calculated using equation 2

$$B = \frac{(W_1)}{(W_2)} d_{T^\circ C} \quad (2)$$

where B = bulk density (g/cm^3), W_1 = weight of dry sample (g), W_2 = weight sample in mercury (g) and $d_{T^\circ C}$ is the density at various mercury ambient temperatures.

Linear Shrinkage of samples was obtained using percentage shrinkage method. The linear shrinkage was calculated using equation 3.

$$\text{Linear Shrinkage} = \frac{\text{Final Length}}{\text{Initial Length}} \times 100 \quad (3)$$

Cold Crushing Strength test was done using the compressive load technique, using the "Paul Weber" hydraulic press. The load at which cracks appear on the test specimen was noted and the cold crushing strength was calculated using equation 4.

$$CCS = \frac{\text{Force (kg)}}{\text{Area (cm}^2\text{)}} \times 100 \quad (4)$$

Intermittent heating and cooling technique was used to determine the thermal shock resistance. The surfaces of the fired bricks were observed and detailed information about the bricks was noted. The cycle of intermittent heating and cooling involved bringing out the sample with the aid of a tong into open air within an ambient temperature range of 27℃ $\leq T \geq$ 32℃. Samples were normalized for 10 minutes and observed for crack initiation after which they were returned into the furnace. Samples were further held for 30 minutes in the furnace and normalized for 10 minutes at the tenth cycle. The examination (physical observation) was stopped when cracks were noticed on the surface and the number of cycles was recorded as shown in Tables 4 and 5.

Sintering point, which is a determinant of refractoriness, was determined using the cone comparison technique on triangular base pyramidal samples which were air-dried within an ambient temperature range of 27℃ $\leq T \geq$ 32℃. The dried samples were placed in a refractory material with much higher refractoriness alongside the comparison test cones. Samples were gradually fired from 0℃ to 1000℃ at intervals of 25℃ with soaking for fifteen minutes in the PCE furnace. Close monitoring of the samples followed suit as further firing continued at 5℃ interval and the tilt temperature recorded in comparison with the pyrometric cone equivalence in Tables 4 and 5.

4. Results and Discussions

Results of data obtained are presented in Tables 2 - 5.

The composition of the imported brick shows that alumina Al_2O_3 is $\leq$ 23.00% and SiO_2 is $\leq$ 75%. The values for the apparent porosity, bulk density, cold crushing strength, refractoriness and thermal shock resistance were $\leq$ 13%, $\leq$ 2.15g/cm^3, $\leq$ 600kg/cm^2, $>$ 1580℃ and 8 cycles respectively. For the bricks produced from the blend of Ibeku and Nsu clays the apparent porosity, bulk density, cold crushing strength, refractoriness and thermal shock resistance were in the range 14.96% - 18.24%, 1.97 g/cm^3 - 2.17 g/cm^3,

Table 2: Particle Size Analyses of Ibeku and Nsu Clay Samples

	IBEKU				NSU		
SS (mm)	W (g)	W (%)	CPR	CPP	W (g)	W (%)	CPR
1.000	2.17	2.17	2.17	97.83	3.55	3.55	3.55
0.710	6.96	6.96	9.13	90.87	6.21	6.21	9.76
0.500	11.73	11.73	20.86	79.14	12.73	12.78	22.54
0.355	19.50	19.50	40.36	59.64	14.50	14.51	37.05
0.250	17.03	17.03	57.39	42.61	20.73	20.74	57.79
0.180	21.51	21.52	78.91	21.09	17.45	17.46	75.25
0.125	10.46	10.46	89.37	10.63	13.32	13.33	88.58
0.090	6.18	6.18	95.55	4.45	5.31	5.31	93.89
0.063	2.22	2.22	97.77	2.23	3.93	3.93	97.82
-0.063	2.23	2.23	100.00	0.00	2.23	2.23	100.05
	$\sum = 99.99$				$\sum = 99.96$		

Table 4: Thermo- Physical properties of Ibeku- based blend

COMPOSITION OF BLEND (wt %)		DESIGNATIONS	PROPERTIES					
NSU	IBEKU		AP (%)	BD (g/cm^3)	LS (%)	CCS (kg/cm^2)	R (°C)	TSR (Cycles)
0	100	D	18.60	1.97	0.70	1563	1592	19
10	90	G	18.24	1.99	1.11	1493	1595	19
20	80	S	17.87	2.01	1.52	1424	1601	20
30	70	AE	17.51	2.03	1.93	1355	1610	20
40	60	AQ	17.14	1.25	2.34	1285	1614	20
50	50	BE	16.78	2.05	2.75	1216	1619	21

Table 5: Thermo- Physical properties of Nsu- based blend

COMPOSITION OF BLEND (wt %)		DESIGNATIONS	PROPERTIES					
IBEKU	NSU		AP (%)	BD (g/cm^3)	LS (%)	CCS (kg/cm^2)	R (°C)	TSR (Cycles)
0	100	A	14.96	2.17	4.8	868	1646	22
10	90	N	15.32	2.15	4.39	938	1640	22
20	80	Z	15.69	2.13	3.98	1007	1620	21
30	70	AL	16.03	2.19	5.85	1077	1656	21
40	60	AY	16.42	2.09	5.68	1146	1624	21
50	50	BE	16.78	2.05	2.75	1216	1619	21

Table 3: Chemical Analysis of Ibeku Clay Via X-Ray Fluorescence Technique

Constituents	Composition of Ibeku Clay Deposit (%)	Composition of Nsu Clay Deposit (%)
Al_2O_3	28.20	25.01
SiO_2	55.60	60.70
P_2O_5	0.40	Not applicable
SO_2	Not detectable	Not applicable
K_2O	0.07	0.38
MnO	0.02	0.02
Fe_2O_3	6.76	3.62
NiO	Not detectable	0.01
CuO	0.06	0.06
ZnO	Not detectable	0.08
MgO	0.12	0.15
Na_2O + CaO	0.27	0.28
G_2O_2	0.03	0.06

868 kg/cm^2 - 1216 kg/cm^2, 1592℃ - 1656℃ and 19 cycles - 22 cycles respectively. These indicate that Nigerian made aluminosilicate refractory bricks from Ibeku clay and Nsu clay conveniently replace GP 107 - 3 which is an imported aluminosilicate refractory brick. For the apparent porosity of the developed blends, Tables 4 and 5 show that Ibeku- based blends had lower values than those of the Nsu- based blends; thus indicating that the addition of Ibeku sample to Nsu sample has effectively improved it to achieve a reduced penetration of molten material into the refractory. This concurs with earlier findings [1, 16, 19] on some useful aluminosilicate deposits. The bulk density is a useful property of refractories, which is the amount of refractory material within a volume (g/cm^3). An increase in the bulk density observed of the bricks produce indicates an increase in their volume stability, heat capacity and resistance to slag penetration. These were achieved by the blended refractory bricks produced in this research work. The cold crushing strengths of products were quite appreciable which indicated high abrasion resistance. The refractoriness of the output bricks met the standard of the imported GP 107-3 German brick. Shrinkage behavior gives projection into the service life of the produced bricks [1, 16, 19].

5. Conclusion

This local content based research has proven from results obtained that refractory bricks produced from blends of Ibeku and Nsu clays can suitably substitute for imported aluminosilicate refractories utilized in metallurgical and allied industries especially GP 107-3 German brick. Ibeku sample enhanced the thermo- physical properties of Nsu sample.

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