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Characterization of Nkalagu Obukpa Clay Deposits for Industrial Uses

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Abstract
Characterization of Nkalagu Obukpa clay deposit has been successfully investigated. The chemical analysis was carried out using Atomic Absorption Spectrometer (AAS) and ultra-violet visible Range spectroscopy (Uv-vis). Particle size analysis and other physical properties tests such as bulk density, water absorptions, moisture content, plasticity, apparent porosity, shrinkage, modulus of rupture, cold crushing strength, thermal shock resistance and refractoriness were carried out using international accepted standard techniques. The result of the chemical analysis shows that the clay has alumina Al_2O_3 (24.63%), calcium oxide CaO (1.15%), silica SiO_2 (50.21%), Iron oxide Fe_2O_3 (1.03%), sodium oxide Na_2O (2.11%), potassium oxide K_2O (2.03%), magnesium oxide MgO (2.32%), manganese oxide MnO (0.31%), Titanium oxide TiO_2 (0.9) and oxide of P, Ni as trace. The results of the physical properties tests conducted at firing temperatures of 900^0C, 1000^0C, 1100^0C and 1200^0C respectively indicated as follows; bulk density (1.670g/cm^3),water absorption (674%),moisture content (4.20%), plasticity (3.20), apparent porosity (33.08%), shrinkage (7.44%) and thermal shock resistance (28cycles), at 1200^0C with an estimated refractoriness of (1647.54^{0}C). The clay deposit therefore can be used for the production of refractory bricks for lining of furnaces for ferrous and non-ferrous metals, low melting point alloys, re-heating furnaces, kilns and other foundry heating equipment that require medium duty refractory bricks. As a result of its low iron oxide and Titania contents, the deposit has whitish colour and can be used by paint, ceramics, and chalk industries.

Keywords: Characterization, Clay Deposits, Industrial Uses

1. Introduction

Clays are refractory materials that are mostly non- metallic materials which have enormous heat capacity that can withstand high temperatures and pressure exerted on them such as thermal shock, impact, chemical attack and high load of elevated temperature [1]. Clay refractories are mainly produced from clay that has alumina, (Al_2O_3) and silica (S_iO_2) contents between 18-44% and 50-70% respectively [2]. Clay is the most widely used raw material in ceramics processing that come directly from nature [3].

Clay minerals are the fine-grained components of geological materials, occurring mostly as particles with a phyllosilicate or sheet structure with diameters ranging from a few microns to a few hundred of a micron. They tend to have large surface areas, often high cation exchange capacities, high absorption capacities and some have swelling properties, all of these characteristics make clays fascinating materials for study and gave them properties which are important from many view points, academic and applied.

Refractory materials are non-metallic, inorganic substances, mainly mixtures of oxides, which are capable of withstanding very high temperature conditions without losing their chemical and mechanical integrity [4].

Stability at high temperatures both physical and chemical is the primary requirements for refractory materials. The ability of a refractory to withstand high temperatures in service is known as refractoriness and its degree in any particular refractory depend on the amount of alumina (Al_2O_3) present which is usually high for alumina content [3].

The percentage of the minerals (Fe_2O_3, MgO, CaO, Na_2O etc) in the clay ultimately determine the areas of application of the clay such as in bricks, floor, tiles and that metal oxides (Na_2O, K_2O, CaO etc) indicate their suitability for making ceramic product [5]. Nuhu and Abdullahi [6], explain that the selected refractory clay will have to be beneficiated with refractory clay material from other sites and be properly blended with other additives to improve their physical, thermal and chemical properties of the final product.

Aremu, Aremu and Ibrahim [7], reported that for Mubi clay to be used as furnace lining material, the percentage composition of impurities such as iron II oxide has to be reduced to traces by

Magnetic sieve. Also clays from Chanchanga, Bida, Suleja and Zungeru all in Niger State have better refractory and physical properties compared with imported ones [8].

1.1 Properties of Clays
These properties are usually taken into consideration in determining the suitability of the clay for a particular application. The physical properties often revealed during the analysis of clay bodies include; plasticity, porosity, water absorption, shrinkage [9].

2. Materials and Method
The clay sample used in this research work was collected from Nkalagu-Obukpa in Igbo-Eze South Local Government Area in Enugu State. The clay sample was collected from four different locations of the deposits and mixed together by pounding process. The mixture was dried, pulverized, sieved and stored in a decicator for various test.

The chemical analysis of the clay was carried out using Atomic Absorption spectrometer (AAS) and ultraviolet visible Range Spectroscopy (Uv-vis). The result is presented in Table 3.1. The physical properties tests carried out include: plasticity moisture content, fired and total shrinkage, bulk density, water absorption, apparent porosity, modulus of rupture, cold crushing strength, thermal shock resistance, loss on ignition and refractoriness (using standard procedures).

3. Results and Discussion

Table 3.1: chemical composition analysis of Nkalagu Obukpa clay deposit

Constituent	Percentage
Al_2O_3	24.63
SiO_2	51.21
K_2O	2.03
CaO	1.15
TiO_2	0.04
MnO	0.31
Fe_2O_3	1.03
Na_2O	2.11
MgO	2.32
LOI	14.09

Table 3.2: Granulometric particle size analysis

Size (mm)	Quantity %
5.0 – 2.0	20
2.0 – 0.5	14
0.5 – 0.1	25
<0.1	33

Table 3.3: Physical properties tests at temperature of 900^0C, 1000^0C, 1100oC and 1200 ^{0}C.

Property/Temperature ^{0}C	900^0C	1000^0C	1100^0C	1200^0 C
Fired shrinkage (%)	3.94	5.42	6.28	7.44
Total shrinkage (%)	9.6	11.0	11.9	12.8
Apparent porosity (%)	43.26	40.22	36.84	33.08
Apparent density (g/cm^3)	2.77	2.67	2.58	2.49
Bulk density (g/cm^3)	1.57	1.60	1.64	1.67
Water absorption (%)	14.24	11.50	8.15	6.74
Cold crushing strength (kg/cm^3	6.25	8.42	10.15	12.54
Modulus of rupture (MOR)	19.37	22.77	24.98	27.14

Table 3.4: Other physical properties

Property	Quality
Modulus of plasticity	3.20
Plasticity ratio	1:26.1
Thermal shock resistance	228
Permeability number	55.23
Green strength (kgf/cm^2)	24.20
Moisture content (%)	4.20
Sintering point ^{0}C	>1400^0C
Estimated Refractoriness	1647.54^0C

Table 3.5: Composition of the chemical properties of international standards

Constituent material	Fired clay (%)	Refractory brick (%)
SiO_2	55 – 75	51 – 70
Al_2O_3	25 – 45	25 – 40
Fe_2O_3	0.5 – 2.0	0.5 – 2.4
K_2O	< 2.0	-
L_2O	12 – 15	-
MgO	< 2.0	-

[7]

Table 3.6: Physical properties of international standard

Constituent	Fire clay
Linear shrinkage (%)	7 – 10%
Cold crushing strength	15000 kg/cm^3
Thermal shock Resistance cycles	25 -30 cycles
Apparent porosity	2.0 – 30%
Bulk density	1.71 – 2.1 g/cm^3

[7]

The result of the chemical composition of Nkalagu Obukpa clay deposit as indicated in Table 3.1 above showed that the clay has 24.63% Al_2O_3, 51.21% S_iO_2, 2.03% K_2O, 1.15% CaO, 0.04% T_iO_2, 0.31% MnO, 1.03% Fe_2O_3, 2.11% Na_2O, 2.32%MgO, and 14.09% loss on ignition (LOI) as it constituents matter. The results of the chemical composition analysis shows that the alumina (Al_2O_3) content of the sample shown in Table 1 is 24.63% which is of approximately within the range of 25% – 40% for refractory bricks and25%– 45% required for fire clay as shown in Table 3.5. Alumina content of clay determines its refractoriness [10] and the higher the amount of alumina in clay, the higher the refractoriness of the clay and according to Mohammed [11], high value of silica content and other particles such as Fe_2O_3 contribute to low refractoriness. Therefore, in this study, the relative increase in value of refractoriness of Nkalagu Obukpa may be due to the relatively increase in the alumina contents of this sample.

Silica (SiO_2) content as shown in Table 3.1 is 51.21% which satisfies the range for refractory bricks.

This means that the clay could be used for important applications such as lining of heat treatment furnace, melting furnace for low melting point metals, roofs of electric steel making furnaces, liquid metal ladles and portions of blast furnaces.

The iron oxide (Fe_2O_3) content of 1.03% fall within the standard specification of 0.5-24 for refractory bricks and that of fire clay (see table 3.5).

This category of clay is suitable for structural engineering.

The estimated refractoriness of the clay was 1647.54 ^{0}C using Shuen's formular [12]. The estimated refractoriness of Obukpa clay fell with the pyrametric seger cone of 31. Also the sintering point of above 1400 ^{0}C is a good indication that the clay is of high refractory class and can be used where medium and high temperatures are required for melting of non-ferrous metals and their alloys, treatment of steels and their alloys, melting of cast irons and alloyed cast irons etc [2].

Physical properties

Fired shrinkage – The fired shrinkage of Obukpa clay deposit is 7.44%, which falls within 7 – 10% as shown in Table 3.6. The shrinkage was seen to increase with the increase in firing temperature. The higher a clay material is fired, the more it looses it absorbed moisture and constitutional water thereby leading to increase in shrinkage and reduces porosity and also the more a clay body shrinks, the less porous it becomes hence the denser.

Apparent porosity:- The apparent porosity of Nkalagu Obukpa is 33.08%, which is within the standard indication in Table 3.6, It is noted that thermal conductivity increases with the pores acting as non-heat conducting media. Other factors affecting porosity include size and shapes of particles, ramming pressure and the reaction occurring on firing.

Bulk Density:- The result of bulk density is shown in Table 3.3 as 1.67g/cm^3 which is little below the standard range of 1.71 – 2.1g/cm^3 (see Table 3.6) and can be accepted that Nkalagu Obukpa clay satisfied the condition for fire bricks in Table 3.6.

This property has been shown to be important in the transportation or handling of refractory materials and is also responsible for the overall weight coming upon the foundation of a refractory structure in furnace. According to Omotoyinbo [13], some of the factors known to affect this properties include treatment during manufacturing, nature of materials in the clay sample and the proportion of the clay mixture with their size affected the bulk density.

Cold crushing strength:- The cold crushing strength of Nkalagu Obukpa clay is 12.54kg/cm^3 which is little below the standard value of 22.9 – 59N/mm^2 [14]. This result shows the effect of firing on ceramic bound and this may be affected by firing sintering characteristics and pressing pressure.

Thermal shock resistance:- The result of the thermal shock resistance of the sample is 28cycles which is within the acceptance values of 25 – 30cycles (see Table 3.6). The refractoriness value obtained is 1647.54^{0}C which is within the standard range of 1500 – 1700^{0}C for the fireclay according to De Bussy [15].

Loss on Ignition:- The result of loss on ignition of the sample presented in Table 3.5 is 14.9% and it is within the range of 12% – 15% for refractory clay. This suggested that Nkalagu Obukpa clay is of fine grain and compacted.

Moisture content (MC) :- The moisture content of the clay collected from Nkalagu Obukpa is 4.20% which is higher than the range for standard according to Chester [16] which is within 2.6-2.7%.

The plasticity and strength of clay depend on the amount of water present in the clay

Water absorption: The water absorption of Nkalagu Obukpa clay deposit is 6.74%, this value is found to be higher than the recommended value of 2.6-2.7% according to Chester [16].

Conclusion

In this study, Nkalagu Obukpa clay has been characterize to ascertain their potentials for refractory and industrial uses. From the result obtained, it was confirmed that the clay contained 24.63% Alumina content which is within the range of the required standard for refractory brick (20- 40%) and approximately within the standard for fire clay which lies within the range of 25 – 45% as shown in Table 3.5.

The silica content (S_iO_2) which satisfies the range for refractory bricks and fall below the required range for fire clay, means that the clay could therefore be used in the production of alumina-silicate refractory for lining of furnaces for non-ferrous metals, production of heat – treatment furnaces for steel and its alloys, liquid metal ladles and portions of blast furnaces. The refractoriness of the clay is 1647.54^{0}C which is within the standard range of 1500^{0}C-1700^{0}C for fire clay. This means that, there is sufficient refractoriness of the clay content. The iron oxide content of 1.03% fall within the required range for both the fire clay and refractory bricks.

The clay deposit if exploited, harnessed and utilized can help in the nation's quest for rapid industrial, technological and economic development. This will go a long way in achieving the aims and objectives of vision 20, 20, 20.

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