



Research Article

Characterization of Oleh Clay Deposit for Industrial Application

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Received: 25 July, 2025
Accepted: 18 August, 2025
Published: 19 August, 2025

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Keywords: Oleh; Clay deposits; Refractoriness; linear shrinkage

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Abstract

The potential of a clay deposit in Delta State, Nigeria, specifically in Oleh Town, Isoko South Local Government Area, as an industrial raw material was investigated. The physicochemical properties were determined using standard methods. X-Ray Diffraction (XRD) was used for the analysis of mineralogical/chemical composition. Physical properties such as linear shrinkage, porosity, crushing strength, bulk density, as well as its thermal shock resistance, refractoriness, and Loss on Ignition Test (L.O.I) were also studied. The XRD studies showed that the clay contains silica (SiO_2) 46.85%, alumina (Al_2O_3) 28.59%, magnesia (MgO) 0.053%, chromium oxide (Cr_2O_3) 0.03%, titanium oxide (TiO_2) 0.053%, calcium oxide (CaO) 2.70%, iron oxide (Fe_2O_3) 2.00%, sodium oxide (Na_2O) 0.58%, potassium oxide 0.50%. It was observed that the physical properties changed with a change in temperature between 9000 and 12000 °C. At a maximum temperature of 1200 °C, it was observed that the clay has a bulk density; 1.91 g/cm³, an apparent porosity; 9.20%, linear shrinkage; 5.70%, cold crushing strength; 252.06 kg/cm² respectively, hence the refractoriness of 1400 °C. The thermal shock resistance of 26 cycles, water absorption of 4.82%, and modulus of rupture of 44.11 kg/cm³ were also obtained at a firing temperature of 12000. Maximum apparent porosity and apparent density of 26.00% and 2.35g/cm³ respectively, were observed at a firing temperature of 900 °C. The clay is hence classified as belonging to the aluminosilicate family, hence its use for refractories production.

Introduction

Clays are complex alumina-silicate compounds with the main formula $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot \text{H}_2\text{O}$ that have water molecules bound to them [1], which have different characteristics from other elements that were dissolved in them during production or by other ways [1]. Clays are mostly non-metallic; they have a huge heat capacity that allows them to endure high temperatures and pressures, including impact, chemical attack, thermal shock, and heavy loads at high temperatures [1]. Velde [2] stated that the majority of clays found in natural environments possess a sheet-like or phyllosilicate structure, which suggests that the proportion of particle sizes is relatively similar to that of a sheet of paper. It was reported [2-4] that zeolites, quartz, and oxide minerals, among the many minerals of different grain shapes that are present in the clay fraction, and trace amounts of other minerals that can be found in the geological environment. According to [5,6], reported that

fireclay's chemical composition is well within the typically broad percentage ranges: silica 40% – 60%, alumina 10–40%, iron oxide 1% – 5%, alkalis < 3%, lime and magnesia <5%, and loss on ignition 5% – 14%. [5,6] also noted that as the amount of alumina grows and the amount of impurities like iron oxide and alkalis decreases, its refractoriness rises. According to Chester [7], industrial finished goods like ceramics, electrical porcelain insulators, and refractories are made from clay. According to Hongai [8], materials classified as refractory are inorganic non-metallic substances with a refractoriness of at least 1500 °C. Hongai [8] stated that these refractories are used in the construction of cement production kilns, rotary furnaces for reducing iron ore, smelting ore furnaces, storing molten metals and slags, heat treatment procedures, and casts. These refractory materials are used in heat exchangers, melting glass, iron, and nonferrous metals, and other applications.

Nonetheless, several researchers have conducted numerous studies aimed at assessing and developing Nigerian clay reserves

for industrial uses [9–13]. To evaluate the Oleh clay deposits' potential in Oleh town, Delta State, Nigeria, as raw materials and determine their appropriateness for industrial use, this research will contribute to the study of their mineralogical and physicochemical features.

Experimental procedure

Materials collection and preparation

The clay sample utilized in this study was gathered from Oleh in Delta State, Nigeria's Oleh Town, Isoko South Local Government Area. Samples were taken at a depth of 150 cm from ten different locations throughout the 100m² area. The samples were taken at random within the radius. 100 kg of the samples were gathered after they were combined and crushed in a hammer mill. For uniformity, the sample was further ground (Figure 1).

Chemical analysis

A PANalytical X'Pert PRO was used to perform X-ray diffraction (XRD) analysis with K radiation to determine the elemental composition of the clay sample. The diffraction 2 θ angles ranged from 0° to 90°. Table 1 displays the sample's chemical constituents.

Physical analysis

The mixed clay was sampled for a variety of mechanical and physical testing. Permeability, green strength, shock resistance, moisture content, sintering point, refractoriness, wet-dry shrinkage, dry-fired shrinkage, bulk density, total shrinkage, e.t.c were all tested. The standard test procedures outlined in BS 1902: part 1A, these experiments were conducted using the methods described by Chester [7].

Results and discussion

Colour

At room temperature, the dried clay sample had a faint brown tint that turned dark brown when fired because iron

oxides were present. A colour chart was utilized to ascertain this.

Chemical composition

The clay's chemical makeup was ascertained using XRD and is shown below (Figure 2).

The chemical composition of the Oleh clay deposit is presented in Table 1. In terms of composition, the clay contains 46.85% SiO₂, 28.59% Al₂O₃, 2.70% CaO, 2.00% Fe₂O₃, 0.58% Na₂O₃, 0.50% K₂O, 0.053% MgO, 0.03% Cr₂O₃, and 0.014% TiO₂. The outcome demonstrates that the percentages of silica and alumina, which are 46.85 and 28.59, respectively, satisfy the requirements for refractory bricks as stated by Ruh [5]. The amount of aluminium oxide (Al₂O₃) in clay has a direct impact on its refractory properties; the more alumina there is in the clay, the more refractoriness there is. However, clays' refractoriness is decreased by their high silica, iron oxide, Na₂O₃, and K₂O concentrations. According to Ruh [5], these oxides are in the range for Burnt clay and refractory bricks.

Physical properties

Shrinkage: The results on firing the clay samples at

Table 1: Chemical composition of the clay sample (%).

S/N	Constituent	Percentage
1	SiO ₂	46.85
2	Al ₂ O ₃	28.59
3	CaO	2.70
4	Fe ₂ O ₃	2.00
5	Na ₂ O ₃	0.58
6	K ₂ O	0.50
7	MgO	0.053
8	Cr ₂ O ₃	0.03
9	TiO ₂	0.014
10	Moisture	2.00
11	Loss of Ignition	12.00

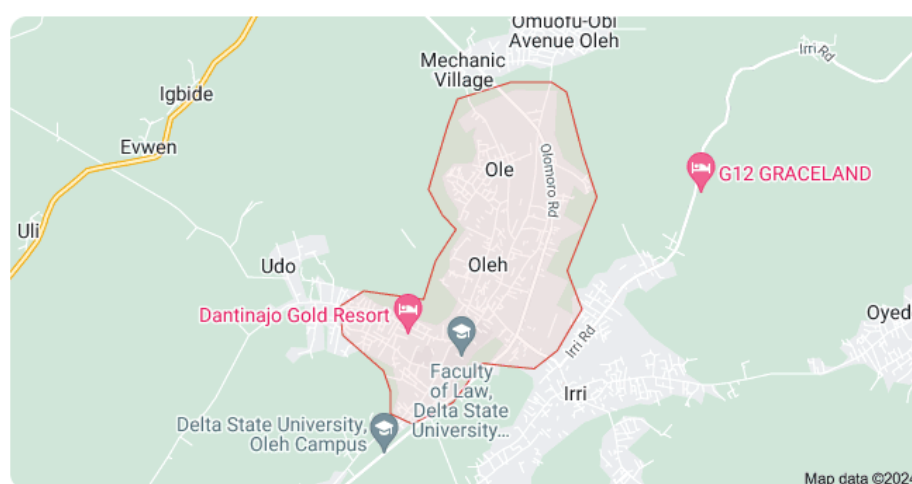


Figure 1: Localisation of Oleh [14].

temperatures between 900 and 1,200 degrees Celsius are displayed in Table 2, Figures 3a and 3b. In contrast to Abolarin et al.'s recommendation [15] that lower values were preferable to make the clay less vulnerable to volume change, the results indicate that the clay sample had higher shrinkage values. According to Omowumi [11], it is within the recommended range of 4% – 10% (Table 3).

Apparent porosity: The apparent porosity of Ole clay is displayed in Table 2 and Figure 3c-3h. At 100%, the porosity ranges from 26.0% to 9.2%, representing a reduction at 900, 1000, 1100, and 1,200. The outcome demonstrates that perceived porosity reduces with increasing temperature. According to Chester's study [7], the apparent porosity result displays values above the minimal limit of 20% that is recommended for the suitability of samples used as refractory material. Higher temperatures of 1,100 and 1,200 degrees Celsius, however, showed reduced apparent porosity; according to Gupta [16], this low apparent porosity can harm the refractory by trapping gas.

Bulky density: At 900, 1000, 1,100, and 12000, the bulk density was 1.74, 1.75, 1.90, and 1.91g/cm³, respectively, according to the results of the bulk density calculations, which are displayed in Table 2. Within the recognized range of 1.7–2.1g/cm³, the bulk density values for the clay were found. Bulk

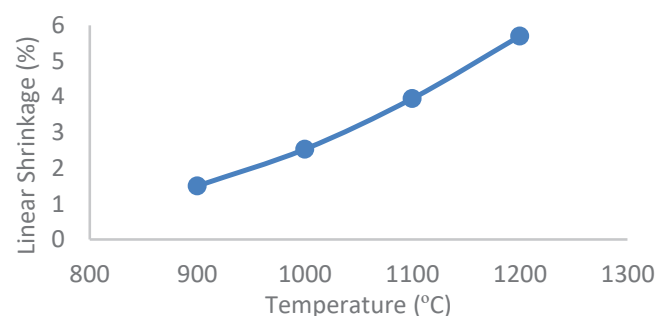


Figure 3a: Plot of Linear shrinkage against Temp.

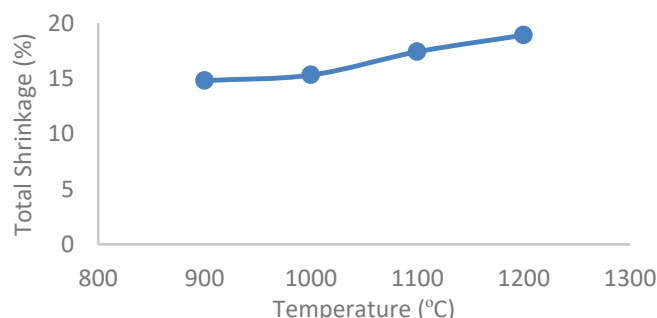


Figure 3b: Plot of Total shrinkage against Temp.

Table 3: Other properties of Oleh clay.

Water of Plasticity (%)	38.33
Thermal shock resistance, cycle	26
Refractoriness. (°C)	1500

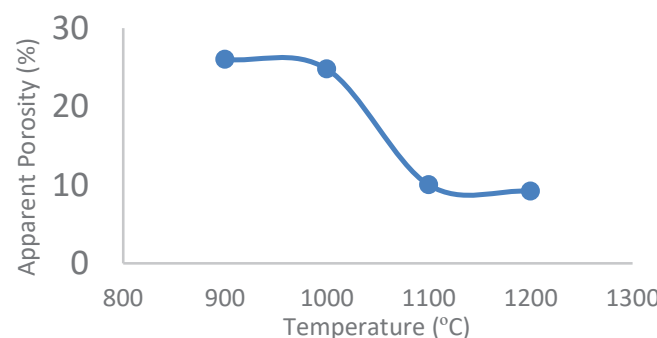


Figure 3c: Plot of Apparent Porosity against Temp.

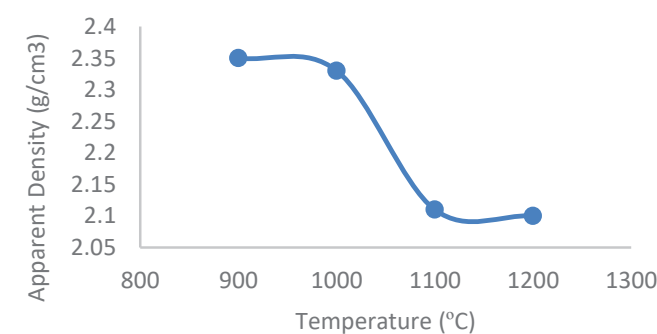


Figure 3d: Plot of Apparent density against Temp.

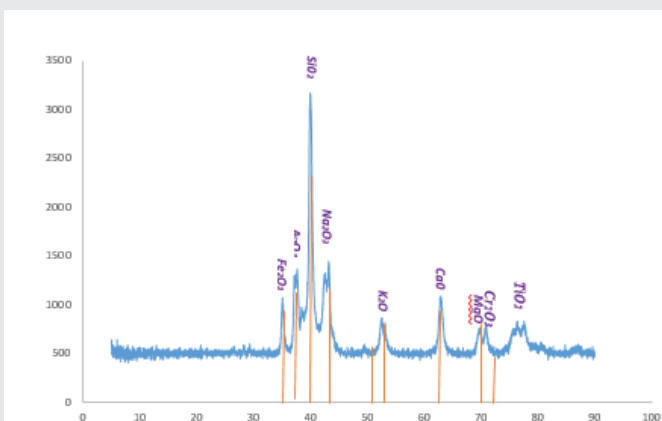


Figure 2: X-Ray diffraction spectrum of the clay sample.

Table 2: Summary of the clay physical analysis results.

Parameter/Temperature	900 °C	1000 °C	1100 °C	1200 °C
Linear Shrinkage (%)	1.50	2.53	3.95	5.70
Total Shrinkage (%)	14.80	15.30	17.40	18.90
Apparent Porosity (%)	26.00	24.77	10.00	9.20
Apparent Density (g/cm³)	2.35	2.33	2.11	2.10
Bulk Density (g/cm³)	1.74	1.75	1.90	1.91
Water Absorption (%)	14.94	14.13	5.26	4.82
Modulus of Rupture (kg/cm²)	31.81	37.00	40.00	44.11
Cold crushing strength (kg/cm²)	190.20	204.60	221.44	252.06
Firing colour	White brown	White brown	White brown	Yellow brown
Crack formation	No crack	No crack	No crack	No crack

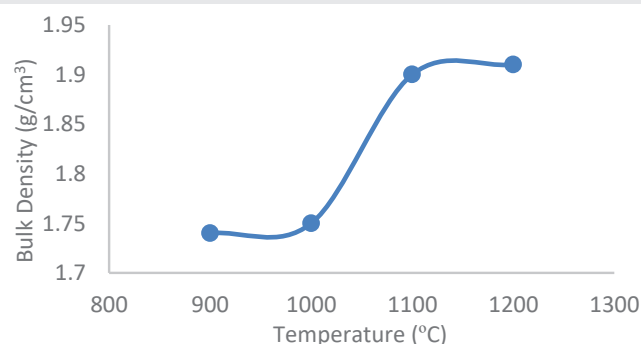


Figure 3e: Plot of Bulk density against Temp.

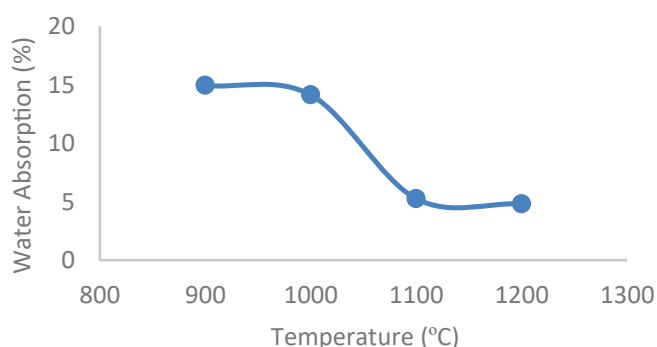


Figure 3f: Plot of Water absorption against Temp.

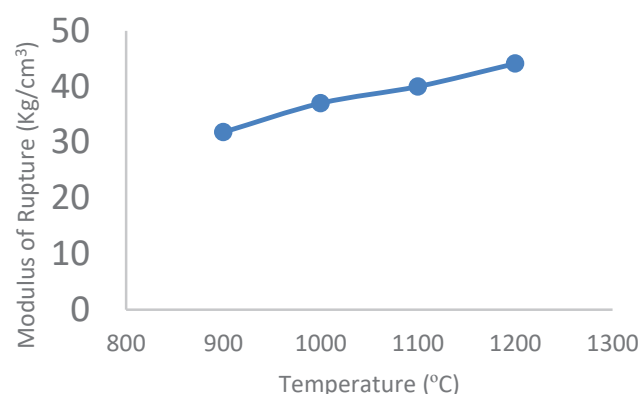


Figure 3g: Plot of Modulus of Rupture against Temp.

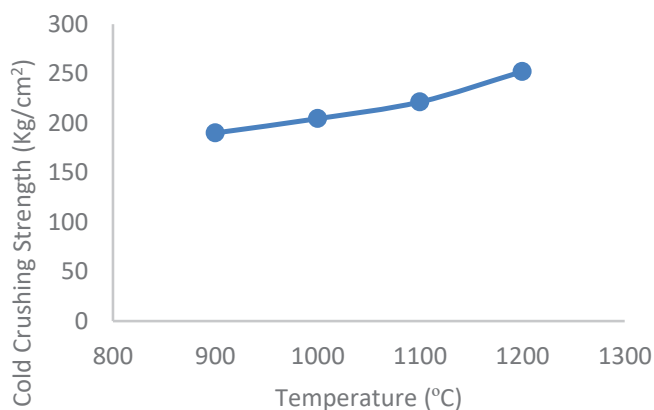


Figure 3h: Plot of Cold Crush strength against Temp.

density, which gives information on the product's quality, is defined as the weight of a specific volume of refractory.

Modulus of Rupture (MOR): The maximum rupture strength of 44.11 kg/cm³ was attained at 12000, as indicated in Table 2. The modulus of rupture of Ole clay rose as the firing temperature increased. The outcome falls between 35 and 44 kg/cm², which is the International Standard (NIS).

Cold crushing strength: As indicated in Table 2, the cold crushing strength attained on Ole clay samples tested at room temperature ranges between 190.20 kg/cm² and 252.06 kg/cm², which is significantly more than the minimal requirement of 15 MPa as stated by Chester [7].

Thermal shock resistance: According to Chester [6], Ole clay exhibits good 26-cycle thermal shock resistance, well within the allowed 20–30 cycle range.

Refractoriness: The ability of a material to tolerate exposure to extremely high temperatures without experiencing a degradation in its physical and chemical properties is known as refractoriness. Ole clay was burnt up to 1,200 degrees Celsius, at which point it turned white and brown, but it can withstand temperatures as high as 1,400 degrees Celsius without cracking. Because of its high alumina concentration (28.59%; Table 1), it has a high refractoriness. Oleh clay belongs to the group of medium-duty fireclay (pyrometric cone equivalent or PCE 29–31) due to its refractoriness [15].

Conclusion

The investigation of the properties of the Oleh clay deposit for industrial applications has been conducted and documented. The chemical analysis carried out showed that the clay has silica and alumina at 46.85% and 28.29% respectively, as its major constituents. The clay is hence classified as belonging to the aluminosilicate family (Table 1). The clay physical and thermal properties at temperatures of 900 °C, 1000 °C, 1100 °C and 1200 °C were investigated, the measured linear shrinkage is within 1.50% and 5.70%, water absorption is within 14.94% and 4.82% whereas the apparent density is within 2.35 g/cm³ and 2.10 g/cm³ at temperatures between 900 °C and 1200 °C, these are within the permissible range for refractories production according to international standards. It is recommended that a geological survey of the sampled area be carried out to ascertain the extent of the deposit for industrial use.

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