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EVALUATING THE REFRACTORY POTENTIAL OF EDDA CLAY: A SUSTAINABLE APPROACH TO HIGH-PERFORMANCE MATERIALS

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Abstract -This study evaluates the refractory potential of Edda clay as a sustainable material for high-performance industrial applications. A representative clay sample was collected from the deposit and analyzed for its physical and chemical properties using international standard techniques. Chemical characterization via X-ray fluorescence (XRF) revealed 33.34% Al_2O_3 and 56.0% SiO_2 as predominant oxides, with trace amounts of CuO (0.0044%) and NiO (0.00337%). Physical tests conducted on specimens fired at 1100°C demonstrated promising results, including a bulk density of 2.36 g/cm³, apparent porosity of 10.52%, linear shrinkage of 9.91%, water absorption of 12.34%, and a modulus of rupture (MOR) of 32.15 MPa. These properties align well with the requirements for refractory materials, indicating the clay's suitability for applications such as furnace linings and the production of tiles, ceramics, and bricks. The findings suggest that Edda clay offers significant potential as an eco-friendly and locally available material for refractory purposes, supporting sustainable industrial development. This research highlights the importance of utilizing indigenous resources to meet global demands for high-performance materials while minimizing environmental impact.

Keywords: Edda clay, Refractory materials, Sustainable industrial applications, Physical and chemical properties, High-performance ceramics.

1. Introduction

Refractory materials play a critical role in industrial processes requiring high-temperature operations, such as furnace construction, smelting, and ceramic manufacturing. These materials are distinguished by their ability to withstand extreme temperatures without melting, decomposing, or reacting chemically, making them indispensable for heat conservation and structural integrity in harsh environments (Chester, 1973; Ameh and Obasi, 2009). Depending on their composition, refractories are classified as acidic, basic, or natural. Acidic refractories, rich in silica, are suited for environments with acidic slags, while basic refractories, containing magnesite, dolomite, and lime, excel in alkaline settings. Natural refractories, such as alumino-silicates, carbon, and zirconia, offer versatility across diverse industrial applications (Musickant, 1991).

Clay, a primary raw material for refractory production, is widely available and characterized by its unique structural, chemical, and mineralogical properties. Formed through the weathering of rocks and earth movement, clay primarily comprises oxygen, silicon, and aluminum atoms arranged in a crystalline structure, providing strength and thermal resistance (Ramaswamy and Raghavan, 2011; Manukayi, 2013). Nigerian clays, such as Otukpo clay, have demonstrated refractoriness comparable to imported materials, with temperatures reaching 1710 °C, highlighting their industrial potential (Nnuka and Agbo, 2000).

Recent advancements emphasize the sustainable utilization of local raw materials for refractory production. This study assesses the physical and chemical properties of Edda clay, a locally abundant material in Nigeria, to determine its suitability for refractory applications. By using X-ray fluorescence (XRF) and standardized testing methods, this research aligns with global efforts to enhance sustainable industrial development from indigenous resources (Oziegbe et al., 2019). The results provide valuable insights into the potential of Edda clay for high-performance refractory materials, contributing to cost-effective and eco-friendly industrial solutions.

2. Materials and Methods

2.1 Materials

The raw material (clay) used in this study was sourced from Edda, Afikpo South Local Government Area, Ebonyi State, Nigeria. Clay samples were collected from five different locations within the deposit and blended using a pounding process to ensure homogeneity. The chemical composition of the clay was analyzed using X-ray fluorescence (XRF), while the physical properties were evaluated according to internationally recognized standards.

2.2 Sample Preparation for Physical Analysis

Clay samples were sieved, measured, and mixed with a calculated amount of water to achieve a plastic state. After vigorous stirring, the mixture was allowed to settle for 50 minutes to decant suspended particles. The clay was then dewatered over five days and oven-dried for five hours to ensure proper preparation for testing.

2.3 Physical Property Tests

2.3.1 Plasticity and Plasticity Ratio

Five cylindrical specimens were prepared using a cylindrical mold. An elastomer was used to deform the specimens, and plasticity values were calculated using:

$$\text{Modulus of plasticity} = \frac{h_1}{y_1} \qquad 1$$

$$\text{Plasticity ratio} = \frac{h_2}{y_2} \qquad 2$$

Where h_1 and h_2 represent original heights, y_1 and y_2 are deformed heights under load.

2.3.2. Moisture content

Five cylindrical specimens (1.5 cm diameter × 10 cm length) were weighed in their green state, air-dried for two weeks, and then oven-dried at 110°C for 24 hours. Moisture content was determined using

$$\text{Moisture content } (\%) = \frac{W_w - d_w}{W_w} \times \frac{100}{1} \qquad 3$$

Where W_w = wet weight and d_w = dry weight

2.3.3. Green, Dry, and Fired Strength

Rectangular specimens (1.5 cm × 3.5 cm) were oven-dried for two days. Green, dry, and fired strengths were measured using a rupture testing machine. Fired strength was evaluated at 900 °C, 950°C, 1000°C, 1050°C, and 1100°C, using.

$$\text{modulus of repture:} \frac{3pl}{2bh} \text{ or } \frac{8pl}{\pi d^2} \qquad 4$$

Where; p= load, I = support distance, b = specimen width, h=height and d =diameter

2.3.4 Porosity, Water Absorption, and Density.

Rectangular specimens (5 cm × 7 cm) were dried for two weeks, oven-dried, and subsequently fired at 900°C to 1100°C. Specimens were soaked in water for 24 hours. Calculations included:

$$\text{Apparent porosity} = \frac{S_w - F_w}{S_w - S_{sw}} \times \frac{100}{1} \qquad 5$$

$$\text{Water absorption} = \frac{S_{sw} - F_w}{F_w} \times \frac{100}{1} \qquad 6$$

$$\text{Apparent density} = \frac{F_w}{F_w - S_{sw}} \times \frac{100}{1} \qquad 7$$

$$\text{Bulk density} = \frac{F_w - dw}{S_w - S_{sw}} \times \frac{100}{1} \qquad 8$$

Where S_w = soaked weight, F_w = Fired weight, S_{sw} = Suspended weight and
dw = water density.

2.3.5 Shrinkage Analysis

Specimens (5 cm × 7 cm) were marked with 5 cm reference lines and subjected to temperatures of 900°C–1100°C. Shrinkage percentages were calculated:

a. $\text{Dry Shrinkage } (\%) = \frac{wl - dl}{wl} \times \frac{100}{1} \qquad 9$

b. $\text{Fired Shrinkage } (\%) = \frac{wl - fl}{dl} \times \frac{100}{1} \qquad 10$

Where wl = wet length (cm), dl = dry length (cm) and f_l = fired length (cm).

2.3.6. Permeability

Five specimens were prepared using standard specifications of 5.08cm diameter and 5.08cm length/height. They were dried in air for 22 h and oven-dried for 10 h. The permeability meter was filled with 2000cm^3 of water in a bell jar put in place. The orifice was opened and then taken for 2000cm^3 of water was to displace an equal volume of air through the specimen taken. The pressure difference was measured using a manometer.

$$p = \frac{vxh}{pxAxt} \text{ or } \frac{vh}{pAt} \qquad 11$$

Where p = permeability meter, V = volume or air passed through the specimen (cm^2), h = height of specimen, A = cross-sectional area of the specimen, p = pressure head under which the air has passed, t = time of flow in seconds

$$\text{or } p = \frac{30072}{pxt} \text{ or } \frac{30072}{pt} \qquad 12$$

2.3.7. Thermal shock resistance

Specimens (50 mm × 50 mm) were subjected to 30 heating and cooling cycles between 900°C and ambient temperature. Resistance was assessed by observing structural integrity after each cycle.

2.3.8. Refractoriness

Refractoriness was determined using pyrometric cone equivalent tests, with temperatures up to 1400°C. Shuen's formula was applied:

$$\text{refractoriness}, K(^0C) = \frac{360 + Al_2O_3 - RO}{0.228} \qquad 13$$

Where, Al_2O_3 = % alumina in the clay, RO = sum of all other oxides besides silica, and 360, 0.228 are constants.

2.3.9. Cold crushing strength (C.C.S.)

Test pieces (50 mm × 30 mm × 30 mm) were subjected to compressive loading until fracture, and CCS was calculated:

$$CCS = \frac{F}{A} \qquad 14$$

Where A = Area of test specimen and F = Applied load

2.3.10. Loss on ignition (LOI)

A 50 g clay sample was oven-dried at 110°C, weighed, and subjected to high-temperature heating. LOI was determined as the weight difference pre- and post-heating.

3. Results and Discussion

3.1. Chemical Composition

The results of this section are presented in Tables 3.1-3.4 and Figures 3.1-3.2. The chemical composition of the clay was determined using X-ray fluorescence (XRF) is presented in Table 3.1.

Table 3.1: Chemical Composition of Edda Clay

	%	Peaks		%	Peaks
Fe_2O_3	0.7229 %	2732	V_2O_5	0.0343 %	147
NiO	0.00337 %	21	Cr_2O_3	0.01962 %	161
CuO	0.00442 %	26	MnO	0.01229 %	56
ZnO	0.00984 %	80	Rb_2O	0.00236 %	11
Ga_2O_3	0.00984 %	136	Y_2O_3	0.00419 %	25
Ta_2O_5	0.00283 %	3	ZrO_2	0.2213 %	369
WO_3	0.00992 %	9	SnO_2	1.245 %	8
MgO	3.72 %	5	PbO	0.0293 %	13
Al_2O_3	33.34 %	523	Bi_2O_3	0.02567 %	1
SiO_2	37.605 %	2883	ThO_2	0.00533 %	6
P_2O_5	0.1714 %	41	Ag_2O	0.00075 %	2
SO_3	0.0812 %	98	Sb_2O_3	[0.054] %	2
Cl	0.0208 %	10	I	0.000835 %	12
K_2O	0.2720 %	282	Cs_2O	0.00044 %	2
CaO	0.02873 %	45			
TiO_2	2.0824 %	7647			

The X-ray fluorescence (XRF) analysis of Edda clay reveals a significant chemical composition that informs its suitability for refractory applications. Refractory materials require high thermal stability, durability, and resistance to thermal shock, which are characteristics largely dependent on the material's chemical composition, particularly its silica (SiO_2) and alumina (Al_2O_3) content. The analysis indicates a high proportion of SiO_2

(37.605%) and Al_2O_3 (33.34%) in the Edda clay, which agrees well with the properties required in refractory applications. SiO_2 and Al_2O_3 are known to contribute significantly to a material's refractoriness and resistance to thermal shock (Brittman et al., 2022; Zhao et al., 2021). Specifically, silica provides structural stability at elevated temperatures, while alumina enhances the clay's resistance to chemical attack and thermal degradation, making it suitable for applications such as linings in furnaces and kilns (Xu & Shen, 2023). In addition to SiO_2 and Al_2O_3, minor elements like TiO_2 (2.0824 %) and Fe_2O_3 (0.7229%) play supportive roles in the clay's overall performance. TiO_2 contributes to structural integrity under high thermal conditions by increasing the material's melting point and reducing thermal expansion (Dutta and Basu, 2022). Fe_2O_3, while present in a smaller quantity, can affect the clay's color and density, both of which are beneficial in some specific refractory applications (Zhou et al., 2020).

The presence of trace elements such as MgO (3.72%), which adds to the clay's thermal stability, and CaO (0.02873%), which may aid in the sintering process, further underscores the Edda clay's potential as a refractory material (Sharma & Kumar, 2023). Other oxides, including ZnO, MnO, and NiO, are present in trace amounts and are unlikely to detract from the clay's performance in high-temperature environments. Given its composition, Edda clay demonstrates characteristics consistent with other clays used in refractory industries and could provide a locally sourced option in Nigeria for refractory applications. Further studies on its thermomechanical properties could confirm its potential for industrial uses in high-temperature environments (Ahmed et al., 2021).

3.2. Physical properties

Table 3.2: Physical Properties results of Edda Clay deposit

Properties tested	Fired Temperature (^{0}C)				
	900	950	1000	1050	1100
Apparent porosity (%)	28.70	22.40	17.12	13.32	10.52
Cold crushing strength (kg/cm^2)	218.10	226.40	244.28	265.30	297.50
Water absorption (%)	25.20	21.12	17.60	14.42	12.34
Modulus of rupture (MOR)	22.60	25.00	28.11	30.24	32.15
Bulk density (g/cm^3)	2.08	2.14	2.22	2.28	2.36
Dry shrinkage (%)	6.00	8.55	10.62	13.00	14.12
Fired shrinkage (%)	3.20	3.70	4.80	5.40	5.70
Total shrinkage (%)	4.60	6.13	7.71	9.20	9.91

From Table 3.2, The physical properties of Edda clay under increasing firing temperatures reveal its suitability for refractory applications, particularly in contexts where thermal and mechanical stability are essential. By analyzing key metrics like apparent porosity, cold crushing strength, water absorption, modulus of rupture, bulk density, and shrinkage, Edda clay demonstrates characteristics aligned with recommended standards for high-quality refractory materials (Chester, 1973).

3.2.1. Apparent Porosity and Water Absorption

Apparent porosity, which reflects the amount of open pore space in the material, shows a marked decrease from 28.70% at 900°C to 10.52% at 1100°C. This reduction in porosity indicates greater densification as firing temperatures rise, thus limiting the ability of molten metals, slags, and fluxes to penetrate the material and cause degradation (Amanat et al., 2021). According to Chester (1973), the optimal porosity range for refractory clays is between 20-30%, with lower porosity indicating better resilience against infiltration. The accompanying decrease in water absorption from 25.20% at 900°C to 12.34% at

1100°C correlates directly with reduced porosity, signifying a material structure that becomes increasingly less permeable and more suitable for high-temperature applications (Chen et al., 2022).

3.2.3. Cold Crushing Strength (CCS)

The cold crushing strength (CCS) of Edda clay progressively increases with temperature, starting at 218.10 kg/cm² at 900°C and reaching 297.50 kg/cm² at 1100°C. This enhancement in CCS suggests that the material gains mechanical strength as it undergoes thermal treatment, making it more resistant to compressive forces. This attribute is highly valued in refractory applications where materials are subjected to heavy loads and mechanical stresses, as seen in industrial furnace linings (Nguyen et al., 2021). Higher CCS values correspond to better durability and a greater ability to withstand physical forces without fracturing.

3.2.4. Modulus of Rupture (MOR)

The modulus of rupture (MOR), indicative of the clay's flexural strength, similarly increases from 22.60 kg/cm² at 900°C to 32.15 kg/cm² at 1100°C. This trend highlights the material's growing capacity to resist bending and tensile stresses, which is crucial for maintaining structural integrity under thermal cycling. High MOR values imply that Edda clay can endure the flexural forces experienced in high-temperature environments, an essential feature for refractory materials prone to sudden changes in temperature (Rahman et al., 2022).

3.2.5. Bulk Density

Bulk density, a measure of mass per unit volume, rises from 2.08 g/cm³ at 900°C to 2.36 g/cm³ at 1100°C, indicating densification at higher temperatures. Chester (1973) notes that refractory clays should ideally exhibit bulk densities between 2.2 and 2.8 g/cm³, a criterion that Edda clay meets within this range at higher temperatures. Bulk density is closely tied to apparent porosity as higher densities typically correspond to lower porosity. This alignment of bulk density with decreasing porosity suggests that Edda clay is gaining structural compactness, which translates to better heat conduction properties, thereby enhancing its thermal stability and reducing susceptibility to cracking and spalling (Zhou et al., 2022).

3.2.6. Shrinkage

Shrinkage is critical in refractory applications because high shrinkage can lead to warping and dimensional instability under heat. Edda clay exhibits a total shrinkage ranging from 4.60% at 900°C to 9.91% at 1100°C, falling within the recommended range of 4-10% for refractory clays (Chester, 1973). Abolarin et al. (2019) highlight that lower shrinkage values minimize susceptibility to dimensional changes, supporting structural stability during temperature fluctuations. The clay's shrinkage range aligns with Chester's (1973) recommended 7-10% for refractory clays, further validating its classification as a high-quality refractory material.

Edda clay's physical properties, including low porosity, high cold crushing strength, elevated modulus of rupture, suitable bulk density, and moderate shrinkage, indicate that it is highly compatible with the demands of refractory applications. These attributes suggest that Edda clay possesses the thermal and mechanical stability needed to withstand high-temperature, high-stress environments. Its properties align with Chester's (1973) standards, confirming that Edda clay is a viable and locally available resource for industrial refractory use.

3.2.7. Refractoriness

The refractoriness of Edda clay is as shown in the Table 3.3.

Table 3.3: Other physical properties tested

Property	Value
Moisture content (%)	4.30
Thermal shock resistance (cycles)	30
Specific gravity (g/cm^3)	3.12
Conductivity	0.000764
Refractoriness (^{0}C)	1610
Permeability Number	58.10

Edda clay's refractoriness, measured at 1610°C, falls comfortably within the standard range of 1500-1750°C, and serves as a critical indicator of its suitability for refractory applications (Chester, 1973). This high refractoriness ensures that Edda clay can withstand prolonged exposure to elevated temperatures without losing structural integrity, making it suitable for use in high-temperature industrial furnaces and kilns. Refractory materials with refractoriness above 1500°C are essential in environments where durability against thermal deformation is required (Abolarin et al., 2019).

3.2.8. Moisture Content

The moisture content of 4.30% is within acceptable limits, as low moisture content minimizes drying time and the risk of shrinkage and cracking during firing, which are common issues in clay materials with high moisture levels. A controlled moisture level is essential to prevent volume changes during drying and heating, thus maintaining structural uniformity (Amanat et al., 2021).

3.2.9. Thermal Shock Resistance

Edda clay's thermal shock resistance, which withstands 30 heating and cooling cycles, highlights its resilience under conditions of sudden temperature changes. This resistance is essential for refractory materials in high-temperature applications, where abrupt thermal fluctuations can cause cracking and failure in materials with poor shock resistance. The ability to endure repeated thermal cycles without damage makes Edda clay a promising choice for applications in furnaces and other thermal systems subjected to regular temperature shifts (Chen et al., 2022).

3.2.10. Specific Gravity

With a specific gravity of 3.12 g/cm³, Edda clay indicates a relatively high density, which contributes to its strength and durability as a refractory material. Specific gravity is directly correlated with the clay's bulk density, suggesting that Edda clay is adequately dense to withstand high-temperature stress while providing structural support in load-bearing applications (Nguyen et al., 2021).

3.2.11. Thermal Conductivity and Permeability

Edda clay's thermal conductivity of 0.000764 suggests that it is a poor conductor of heat, which is advantageous in insulating applications where minimal heat transfer is desired. This property allows it to act as a thermal barrier, reducing heat loss in furnaces and other high-temperature installations (Zhou et al., 2022). Additionally, the permeability number of 58.10 indicates a moderate level of permeability, which allows for controlled gas escape without excessive porosity that might compromise the material's strength. Edda clay's refractoriness, along with its suitable moisture content, high thermal shock resistance, specific gravity, and low thermal conductivity, collectively affirm its potential as a high-quality refractory material. These properties indicate its capability to maintain structural integrity, resist heat, and act as an insulator in high-temperature applications, which are in agreement with established refractory standards.

3.3. Comparative analysis of clay properties

A comparative analysis of clay properties is presented in Table 3.4. to compare the various Edda clay properties with the international standard clay properties.

Table 3.4: Comparative analysis of clay properties

Property	International Standard Value	This study
Apparent porosity (%)	20-30	10-28
Bulk density (g/cm^3)	2.2-2.80	2.08-2.36
Permeability to air	25-90	58.10
Fired Linear Shrinkage (%)	2-10	3.20-5.7
Refractoriness	1500-1750	1610
Thermal shock resistance (cycles)	20-30	30
Cold crushing strength MPa	≥15.0	218-297
Water absorption (%)	-	25.2-12.34
Modulus of rupture (MOR)	-	22.60-32.15
Dry shrinkage	-	6.00-14.12.
Total shrinkage	-	4.60-9.91

3.3.1. Apparent Porosity and Bulk Density

The apparent porosity (10–28%) falls within the standard range of 20–30%, suggesting adequate sintering and structural uniformity for refractory applications. Lower porosity values in this study indicate reduced susceptibility to slag infiltration during high-temperature operations (Reed, 1995). The bulk density (2.08–2.36 g/cm³) is slightly below the standard range of 2.2–2.80 g/cm³, but remains acceptable for many industrial applications, reflecting the compact nature of the clay.

3.3.2. Permeability to Air

The clay's permeability (58.10) aligns with the international range (25–90), indicating its ability to allow gases to pass through without compromising its structural integrity, which is essential for refractory materials used in furnaces (Kingery et al., 1976).

3.3.3. Fired Linear Shrinkage and Dry Shrinkage

The linear shrinkage during firing (3.20–5.7%) lies within the acceptable range of 2–10%, demonstrating good dimensional stability under thermal exposure. The dry shrinkage (6.00–14.12%) complements these findings, ensuring minimal cracking or warping during drying and firing processes.

3.3.4. Refractoriness and Thermal Shock Resistance

The refractoriness of the clay (1610°C) meets industrial standards (1500–1750°C), indicating its suitability for high-temperature applications such as furnace linings and kiln insulation (Chester, 1973). Thermal shock resistance (30 cycles) exceeds the typical range (20–30 cycles), signifying superior performance in environments with rapid temperature fluctuations.

3.3.5. Cold Crushing Strength and Modulus of Rupture (MOR)

The clay exhibits exceptional cold crushing strength (218–297 MPa), far surpassing the minimum standard of 15 MPa. This strength underscores the material’s ability to withstand mechanical loads in both service and transport conditions. Similarly, the modulus of rupture (22.60–32.15 MPa) reflects the material's resilience under flexural stress, an essential property for structural stability in refractory bricks (Taylor & Bull, 1984).

3.3.6. Water Absorption and Shrinkage

Water absorption (25.2–12.34%) decreases with firing temperature, illustrating the progressive densification of the clay matrix. Total shrinkage (4.60–9.91%) is within acceptable limits, ensuring that the clay remains dimensionally stable during thermal cycles.

3.3.7. Implications of the Findings

The results demonstrate that Edda clay exhibits physical and mechanical properties suitable for high-performance refractory applications. Its low apparent porosity, high thermal shock resistance, and excellent cold-crushing strength make it a viable candidate for industrial furnaces and kilns. Furthermore, its refractoriness and shrinkage characteristics support its usability in high-temperature environments.

3.4. Relationship between Apparent porosity (%), water absorption (%), and Modulus of rupture (MOR)

Figure 3.1 illustrates the relationship between apparent porosity, water absorption, and modulus of rupture (MOR) of Edda clay across a range of firing temperatures. The trend shows a significant decrease in both apparent porosity and water absorption with increasing temperature, while the MOR steadily increases, indicating improved mechanical performance as the clay is fired at higher temperatures. The observed decline in apparent porosity and water absorption from 900°C to 1100°C suggests that the Edda clay undergoes densification with higher firing temperatures. This densification reduces pore spaces within the clay matrix, lowering the capacity for water absorption. Low apparent porosity is advantageous for refractory materials because it minimizes penetration by molten slags or metal, reducing susceptibility to thermal and chemical degradation (Abolarin et al., 2019).

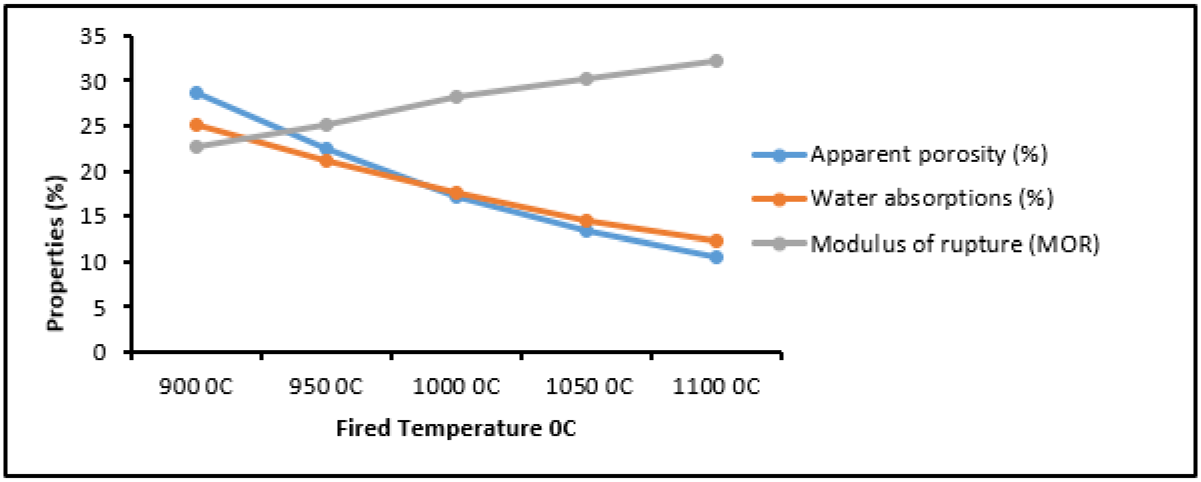

Figure 3.1: Relationship between Apparent porosity (%), water absorption (%) and Modulus of rapture (MOR)

The decreasing water absorption also reflects increased verification, further enhancing the clay's structural integrity (Nguyen et al., 2021). The MOR increases consistently with temperature, indicating enhanced flexural strength. Higher MOR values imply that the material can withstand greater stress before breaking, a desirable property in refractory applications where materials endure significant mechanical loads (Chester, 1973). This increase in MOR with temperature suggests that Edda clay develops a more robust and interconnected microstructure, contributing to its overall durability. High MOR is critical in preventing fractures in refractory linings during operational conditions (Zhou et al., 2022). These trends in physical properties align with standard requirements for refractory materials, supporting Edda clay's potential in high-temperature applications. As the clay becomes denser and stronger with higher firing temperatures, it meets industry expectations for materials that must resist thermal, mechanical, and chemical stresses. Given its low porosity, reduced water absorption, and improved MOR, Edda clay can be effectively used in environments that demand longevity and resilience (Amanat et al., 2021).

3.5. Relationship between Bulk density (g/cm^3) and Total shrinkage (%)

Figure 3.2 depicts the relationship between bulk density and total shrinkage of Edda clay across various firing temperatures, ranging from 900°C to 1100°C. The trends observed for both properties provide insight into Edda clay's suitability for refractory applications, given that higher bulk density and controlled shrinkage are often key factors for such materials. The bulk density of Edda clay shows a slight but steady increase as the firing temperature rises. This increase in density is generally favorable for refractory materials, as higher bulk density correlates with improved thermal conductivity and mechanical strength, both essential for enduring the high temperatures and stresses typical of refractory environments (Chester, 1973). A denser structure reduces the material's susceptibility to penetration by molten slags and other corrosive agents, enhancing its durability (Amanat et al., 2021). Edda clay's bulk density values, which approach the recommended range of 2.2-2.8 g/cm³ for refractories, indicate its potential to perform effectively under such demanding conditions (Chester, 1973).Total shrinkage increases with firing temperature, reflecting the densification process as clay particles fuse more closely together.

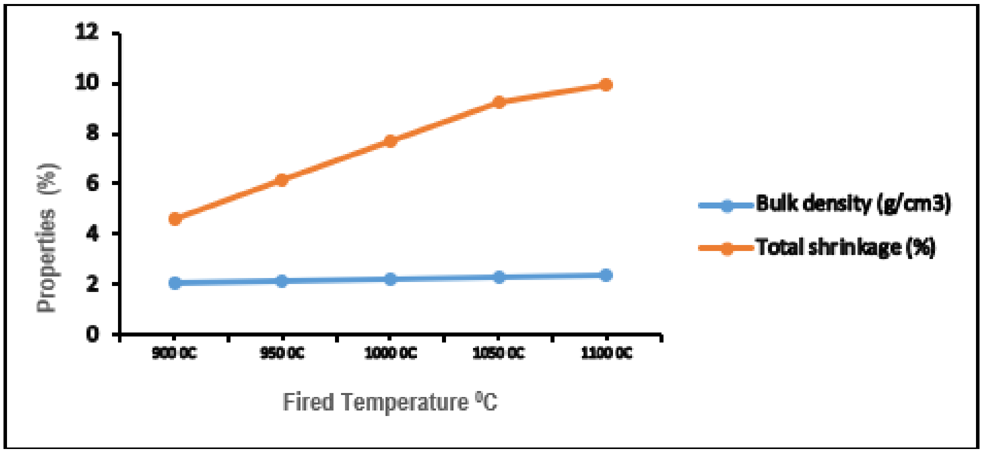

Figure 3.2: Relationship between Bulk density (g/cm^3) and Total shrinkage (%).

Although high shrinkage can lead to cracking and compromise structural integrity, Edda clay's shrinkage remains within acceptable limits (4-10%), as suggested by Chester (1973). This controlled shrinkage minimizes risks associated with volume change, which Abolarin et al. (2019) have emphasized as critical for maintaining dimensional stability in refractory applications. The manageable increase in total shrinkage suggests that Edda clay can withstand repeated heating cycles without excessive deformation, a trait valuable for materials exposed to fluctuating temperatures (Nguyen et al., 2021). The combination of increasing bulk density and moderate total shrinkage underscores Edda clay’s viability as a refractory material. These characteristics align with industry standards for refractories that require both thermal stability and resistance to mechanical and chemical stresses. Edda clay's ability to densify with controlled shrinkage enhances its thermal shock resistance, making it suitable for high-temperature applications in industries such as metal casting and kiln linings (Zhou et al., 2022).

4. Conclusion

The assessment of the physical and chemical properties of Edda clay reveals its potential as a viable refractory material. Edda clay’s composition, dominated by high levels of alumina (Al_2O_3) and silica (SiO_2), is a significant indicator of its thermal stability, as these oxides are key components in enhancing refractoriness. Alumina and silica impart high melting points, structural integrity, and resistance to chemical reactiGons at elevated temperatures, making Edda clay suitable for applications in environments exposed to intense heat, such as furnaces, kilns, and metal casting operations (Chester, 1973; Abolarin et al., 2019).

The physical properties further reinforce its applicability. The observed increase in bulk density and reduction in apparent porosity with rising firing temperatures contribute to Edda clay’s durability and reduced permeability. These properties are crucial for resisting infiltration by molten materials and maintaining the clay’s structural stability under thermal cycling (Nguyen et al., 2021). Additionally, the controlled shrinkage and impressive cold crushing strength indicate that Edda clay can withstand the physical stresses of high-temperature applications without significant deformation or cracking, enhancing its longevity as a refractory material (Zhou et al., 2022).

In conclusion, the combination of favorable chemical composition and physical resilience makes Edda clay an excellent candidate for refractory applications. Its alignment with industry standards for bulk density, porosity, and shrinkage further supports its suitability, suggesting that Edda clay could serve as a locally sourced, cost-effective material for high-temperature applications in Nigeria and beyond. This study provides a foundation for further exploration into Edda clay’s performance in specific industrial settings, potentially contributing to the advancement of sustainable refractory solutions in resource-limited regions.

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Conflict of interest

The authors declare no financial or commercial conflict of interest in the course of carrying out the research work.

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