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Research Article

Assessment of Grey Clay from Iko Town for industrial applications

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Abstract — The aim of this study was to assess the possible industrial applications of grey clay obtained from Iko Town in Eastern Obolo, Akwa Ibom State, Nigeria. Though a number of studies have been reported on clay from various locations, research findings have revealed that clay samples can differ in their properties. The clay, after collection, was sufficiently dried and then crushed. It was subjected to quality assessment to determine its suitability for use. Also, samples were developed from the clay, dried, and tested for durability characteristics, linear shrinkage, and cold crushing strength. The characteristics and chemical composition of the clay material were examined and then compared with the specific requirements to establish its suitability for the intended application. The plasticity index and angle of repose were found to be (32.41 ± 0.01) % and (35.69 ± 0.01) ^{o} respectively. Prominent among the chemical constituents were SiO_2 (54.01 %), Al_2O_3 (16.22 %), Fe_2O_3 (9.08 %), and CaO (1.11 %). The sorptivity and flaking concentration of the clay samples were (4.09 ± 0.02) mm√h and (8.92 ± 0.01) % respectively. The samples' linear shrinkage and cold crushing strength were found to be (6.16 ± 0.02) % and (1.926 ± 0.0020 N/mm^2 respectively. Generally, the clay exhibited acceptable flow characteristic for manufacturing of products. The data indicated that the clay satisfied the requirements for use as a raw material in refractory and brick industries.

Keywords — Chemical composition, Durability, Flaking concentration, Flowability, Plasticity index, Sorptivity

1. Introduction

Aside being a type of fine-grained natural soil containing minerals, clay is the oldest known ceramic material. Though varieties of colors such as red or brown from small amounts of impurities are shown by natural clays, most pure clay minerals are white or light-colored [1], [2]. Clay has been used for making pottery based on the discovery of its useful properties by prehistoric humans. Some of the earliest pottery shards dated around 14,000 BC [3]. Under purview, clay tablets were the first known writing medium. Also, in many modern industrial processes, clay is used for paper making, chemical filtering, and cement production. All these uses of the clay depend on its properties, which of course, can vary depending on certain natural factors. Therefore, investigation of clay properties is imperative for appropriate decisions to be taken concerning its suitability for any intended application(s).

Soil is an important substance for all creatures in the world. It has vast usage in different parts such as civil work, foundation, agriculture, bridges, embankment, buildings, canals, tunnelling. Prominently, applications of clay in buildings and other kinds of construction have been reported. It is observed that one-half to two-thirds of the world's population either work or live in buildings made of clay. This observation resonates with the fact that utilization of clay as a building material is chief evidence showing cyclical dependence of society on technology [4]. Consequently, applications of clay in building construction have been studied extensively. According to Bredenoord [5], homes made with clay bricks have better moisture regulation and are also more comfortable than those built with hollow concrete blocks. Prior to its use as an essential part of building's structure, clay is sometimes modified for improvement of strength and durability properties of the resulting brick [4].

The aim of this study is to assess the grey clay from Iko Town in Eastern Obolo Local Government Area, South-South Nigeria for industrial application. Specifically, the characteristics and chemical composition of the clay material will be examined and then compared with the specific requirements to establish its suitability for the intended application. This paper would be the first to give such report. A related research was reported by Adeola et al. [6] on residual clays from Ijesha-Ijebu and its environs, South-Western Nigeria. However, studies have revealed that clay materials can differ in their properties. For instance, the thermal conductivity values reported for clay from Agbani in Enugu [7], MSila in Algeria [8], and quarry in North of France [9] differ remarkably. Etuk et al. [10] observed that the thermal properties of clay samples from different locations in Akwa Ibom State vary. On their part, Robert et al. [11] found that pink and yellow clay soils existing under the same conditions in a location vary in their properties as well. The findings from this work would benefit researchers and industrialists for their day-to-day development and progress.

2. Related Work

Rondonane et al. [12] performed characterization and application tests for fired bricks manufacturing of kaolinite-based clays with low alkali content obtained from Aboudeia (Southeastern Chad). They based the raw clay characterization on distribution of grain size, Fourier transform infra-red (FT-IR), X-ray diffraction (XRD), chemical analysis employing X-ray Fluorescence (XRF), and thermal analysis (TGA-DSC). Also, the fired products were analyzed at 900, 1000 and 1100 °C using Scanning Electron Microscope (SEM), and physical and mechanical tests (including water absorption, porosity, shrinkage, and flexural strength,). The textural analyses (which included plasticity index, liquid limit, and particle size distribution) revealed that the Aboudeia clays could be used for hollow bricks, dense bricks, and vertically perforate bricks. However, the technological properties (particularly the water absorption) provided evidences suggesting that fluxes amendment is needed for proper used of this clay for structural bricks. Again, they found that relatively low flexural strength and high water absorption were exhibited by the fired products. Santos et al. [13] studied the physical, chemical, mineralogical characteristics of two soil samples in addition to the dosage of mixtures with Portland cement as stabilizer (at 6 %, 9 % and 12 %) for adobe. The results showed compressive strength of up to 5 MPa at 28 days for both type of soils containing 12 % of the Portland cement. it was also observed that 9 % content of cement was enough to reach the minimum compressive strength required by standard.

Safi and Singh [14] surveyed stabilization of clay using waste materials and noted that many such materials are available for stabilizing and strengthening clay soil and are both economical and beneficial for improvement of clay soil. They accurately analyzed and incorporated their research based on indirect methodology (secondary data) and extracted that many waste materials such as nano-silica, white cement, fly ash classes family, lime, copper salt, red mud, Blast furnace slag, and so on are available for stabilization of clay soil and are eco-friendly, economical, and easy-to-find in site and market. Abdullahi et al. [15] examined the engineering suitability of soils for the purposes of making foundation within the southern part of the proposed Faculty of Law in Atere Campus of Al-Hikmah University Ilorin, south-western Nigeria. They carried out geotechnical investigation (based on analyses such as distribution of grain size, specific gravity, Atterberg limits, bulk density, consolidation test, and direct shear box test) on nine samples which were collected from three different locations of the study area by the use of trial pits of about 1.6 - 1.7 m depth at an interval of 0.5 m. From the results of the analyses, it was found that the soil samples could be best classified as sand to gravely sand based on Unified Soil Classification with 0.9 % - 69.73 gravel and 30.27- 99.1% sand. The soil samples were found to be above the activity line of the plasticity chart in the zone of inorganic sand. Above all, it was revealed that the foundation design of the area would be shallow and could support moderately light to heavy structures, thus implying that the soils can be used as a sub-grade materials in high way construction.

Tsega et al. [16] investigated the effects of different firing temperatures on the compressive strength (CS), water absorption (WA), and saturation coefficients (SC) of fired clay bricks produced around Jimma Town. The effects of different heating rates on physical and mechanical properties of firing standard bricks were analyzed during the production process. Also, the effects of different heating rates on physical and mechanical properties of firing standard bricks were analyzed. It was discovered that the CS increased whereas WA and SC decreased with increasing firing temperatures. The researchers noticed that the duration of firing varied directly with the CS but inversely with both the WA and SC of the clay brick. Malebatja et al. [17] conducted an experimental study to examine the chemical composition of clay soil ingested by geophagic women of childbearing age in Tshwane District, Gauteng Province, South Africa. Thirty-nine clay soil samples were collected from study participants attending antenatal care services and family planning at public healthcare facilities of the District and subjected to geochemical analysis. In all the samples, the concentrations of vanadium, manganese, chromium, and barium were detected in quantities exceeding 100 mg/kg but cadmium, mercury, and silver were detected in low concentrations below 1 mg/kg. It was concluded that the chemical composition of clay soil eaten by geophagic women of childbearing age contains potentially harmful substances, thereby making the practise of geophagy toxic and should be discouraged to protect public health.

Ihekweme et al. [18] characterized seven Nigerian clays and clay minerals by multiple means with respect to their potential application in water purification and other industrial areas. Samples were collected using geological bedrock maps provided by the Geological Survey Agency of Nigeria for locating mineral deposits across the federation. Three clay samples were collected from Imo State at strategic locations like Agbaghara Nsu in Ehime Mbano Local Government Area, Onuiyi River in Obowo Local Government Area, and Nkumeato in Ihitte/Uboma Local Government Area. One sample was collected from Isiala Oboro in Abia State. Two samples were collected from Kutigi and Minna in Niger State, while one sample was collected from Afuze in Edo State. The locations covered three out of the six geo-political zones in Nigeria, namely, South-East, North-Central and South-South indicating tremendous deposits in the country. The morphology, chemical mineral compositions, functional groups, stability (in aqueous solution) as well as physical and chemical behaviors of each of the clay samples were investigated. The results revealed that the clays were mostly kaolin and illite while clay minerals were predominantly gibbsite and quartz, although other associated minerals and elements were also observed. Out of the studies clays, two were found to be suitable for application in filter media production for water purification while others possessed potentials for industrial uses like in refractory linings, ceramics, medical, beauty and cosmetic products.

Ghailane et al. [19] studied the particle size distribution, chemical compositions, rheology of clays to understand their behaviors for possible application as construction materials and to enable the prediction of the appropriate amount of water to be added for the fabrication of fired bricks. They deemed such pieces of information fundamental for the fabrication process of fired clay bricks with enhanced physical, thermal, and mechanical properties, which will guarantee the energy efficiency of buildings. They found that the clay-water mixture followed shear thinning properties. Nwokoye et al. [20] performed physiochemical analysis of clay samples collected in some parts of Southeastern Nigeria in order to ascertain the physical and chemical constituents of the samples for possible use in ceramic, cosmetics, pharmaceutical, paper and cement industries and the type that can be used in production of bricks and bleaching clay. The clay samples were picked from three states in the region namely Ozubulu clay from Anambra State, Ngwulangwu clay from Ebonyi State, and Ngwo White clay from Enugu State. The moisture content, ash content, iodine number, p^H, surface area, bulk density/porosity, chemical composition, and loss of ignition of the clay samples were determined and it was found that the clays could be used for industrial and commercial purposes.

Nayak et al. [21] performed characterization and mineralogical study to identify the presence of minerals and compounds for the various soil samples collected from different places along the coastal belt of different places along the coastal belt of Udupi region namely Katapadi, Alevoor, Manipal, Kolalgiri, Brahmavar, Kumbashi, Hemmadi, Valandhur, Nagoor, and Byndoor. The primary minerals observed in majority of the regions were quartz, feldspar such as orthoclase, muscovite, and the secondary minerals formed by the decomposition and chemical alteration of primary minerals include sheet minerals such as kaolinite, halloysite, dickite, gibbsite, and illite in high proportions. The study also showed the presence of iron compounds such as fayalite, goethite, and siderite. The majority of the elements observed were oxygen, silicates, aluminum, potassium, and iron. Armijo et al. [22] designed a study involving mixture of clays with water studied for applications in pelotherapy. They experimentally determined the specific heat capacity and cooling kinetic of pastes prepared by addition of different percentages of water to eight commercially-available clays of varying compositions. It was noticed that that Na-activated magnesium bentonite emerged as the most suitable clay material for preparation of peloids with applications in thermotherapy.

Bekkouche and Boukhatem [23] proposed the use of both PVC and HDPE polymers such as additions in cohesive soils to determine their influence on the physical and mechanical properties of soil-polymer material in function of time, which should insure some optimal period of life. The soil subject of this study was a revised clay from the city of Ramdane Djamel which lies in the northern part of the Wilaya of Skikda (North East of Algeria). Different tests including Atterberg Limits, standard compaction, swelling potential, and swelling pressure were conducted on control and treated soil samples using different percentages (0, 3, and 6 %) of the polymers (PVC and HDPE). Also California Bearing Ratio (CBR) tests were conducted on control and treated samples. The results showed that treatment of the soil with PVC and HDPE resulted in improvement of CBR and maximum dry density but reduction in Atterberg Limits, swelling potential, and swelling pressure.

More so, there have been recent reports on modification/stabilization of clay for certain applications. For instance, Santos et al. [13] characterized two soil samples physically, chemically, and mineralogically and studied the dosage of mixtures for adobe using Portland cement as a stabilizer. The cement contents in the soil were 6 %, 9 %, and 12 %. The results showed compressive strength of up to 5 MPa at 28 days for both types of soils studied with 12 % of Portland cement. Overall, it was found that 9 % of Portland cement was enough to reach the minimum compressive strength required by standard. Reddy et al. [24] collected expansive soil (classified as an A-7-5 soil on the AASHTO classification) from Addis Ababa, Bole sub city and stabilized it using using 3 % lime, 15 % bagasse ash, and 15 % bagasse ash in combination with 3 % lime by dry weight of the soil. They investigated the effect of the additives on the soil was with respect to plasticity, compaction, and California bearing ratio (CBR) tests. The results obtained indicated an increase in optimum moisture content (OMC) and CBR value and a decrease in maximum dry density (MDD) and plasticity of the soil for all the additives. But there was a tremendous improvement in the CBR value was also observed when using a combination of lime and bagasse ash to stabilize the soil.

Sankar et al. [25] investigated the use of agricultural wastes such as corn cob ash, egg shell powder to stabilize the expansive soil. The soil was treated separately at 4 % with the three wastes, 8 % and 12 % with unconfined compressive strength (UCC) test and swell pressure being performed. The investigations revealed improvement in the UCC and swell pressure with the increase in percentage of waste. Emah et al. [26] investigated the effects of Groundnut Shell Ash (GSA) on clay for making sustainable and low-cost building materials. The physical, chemical, thermal, and mechanical properties of the clay-GSA composites were evaluated to assess their suitability for construction purposes. The results revealed that the addition of GSA to the clay matrix had a significant impact on various properties of the samples. The physical characterization showed that GSA was finer and lighter than clay, making the composites more flowable. Chemical analysis indicated that both clay and GSA were rich in SiO_2, Al_2O_3, and Fe_2O_3, with the clay exhibiting high SiO_2 content suitable for brick manufacturing. The composites had lower electrical resistance and higher conductivity with more GSA, which could enable temperature monitoring. Thermophysical testing demonstrated that the composites had better thermal insulation properties with more GSA, as shown by higher specific heat capacity and lower thermal diffusivity. The composites absorbed more water with more GSA, indicating higher porosity due to finer particles. Afolayan et al. [27] reviewed on the reuse of palm oil fuel ash, palm kernel shell ash, rice husk ash, sea-shell powder and sawdust ash for modifying soils with poor engineering properties. The review showed that the modifiers performed effectively on the subgrade soil. All these are like taking steps to preserve soil to ensure sustainable future as posited in [28].

3. Experimental Procedures

3.1 Materials collection and analysis

Grey clay soil was picked from Iko Town in Eastern Obolo Local Government Area, Akwa Ibom State of Nigeria and used in this study. Figure 1 shows the clay soil as collected from the source. The clay was sufficiently dried in the air and then crushed using hammer. Using the standard test method [29], the plasticity index of the clay was determined. Also, the clay was analyzed for flowability in terms of angle of repose using the fixed funnel method [30]. In order to examine the chemical composition of the clay, an X-ray fluorescence analyzer (Spectro X-lab 2000) was employed while loss on ignition was determined as the percentage loss in weight after the clay was heated to about 1000 ^{o}C [6].

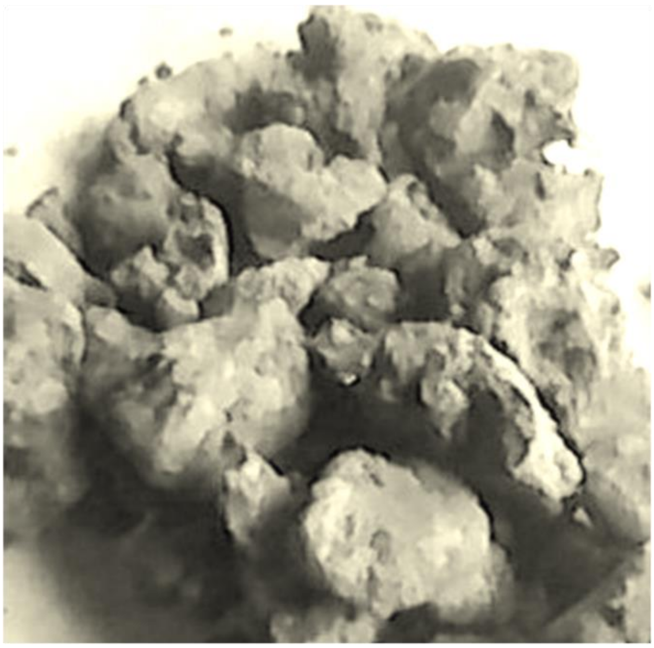

Figure 1. The clay material used in the study

3.2 Samples preparation

Next, the clay was moistened with water and compacted in circular molds using a laboratory-made machine maintained at 2 kN. The molds measured 100 mm 60 mm × 8 mm. The compaction lasted for 6 hours after which the samples were demolded and sun-dried for several weeks until no further change in its mass was noticed. On each day of the drying process, the samples were weighed at certain intervals of time. This approach for drying of the samples has many advantages including preservation of the bonding strength and carbonaceous fractions of the clay material. Three of such samples were prepared and tested for sorptivity, flaking concentration, linear shrinkage, and cold crushing strength.

3.3 Sorptivity test

This test was deemed necessary in order to gain insight into the water infiltration tendency of the product that could be made from the clay. The test was implemented as detailed in [31] but with slight modifications in some aspects. Figure 2 shows the schematic features of the test setup used in this study. Each sample was cut into rectangular shape and weighed to find its initial mass. The sample was then suspended from a point using a strong inextensible string and over a transparent vessel containing some water. The position of the suspended sample was adjusted until the sample's lower end penetrated the water to a depth of about 3 mm. Immediately that happened, the stopwatch was turned ON to measure the time taken by the water to infiltrate the sample. When 30 minutes elapsed, the sample was removed from the water, disengaged from the string, and weighed. The density of water at that temperature was noted and the sorptivity of the sample was computed using the formula

$$S_p = \left[\frac{(M_i - M_d)}{\rho A\sqrt{t}}\right] \quad (1)$$

where S_p = sorptivity of the sample, M_i = mass of the sample at the end of the infiltration process, M_d = mass of the sample prior to infiltration by water, ρ = density of the water, A = area of the sample's surface through which water infiltration occurs, t = infiltration time.

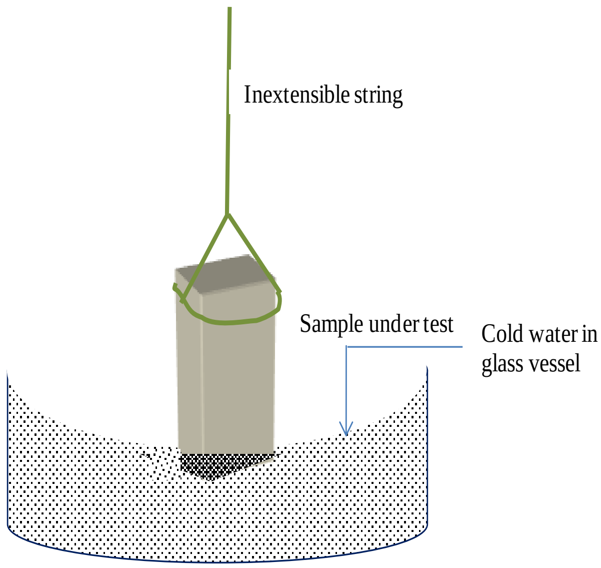

Figure 2. Setup of the sorptivity test

3.4 Flaking concentration test

This test was performed to assess the resistance to abrasion by the sample and it was deemed necessary because it is possible for the sample to undergo tear and wear while in service or being worked on [30], [32]. The technique applied by Robert et al. [33] was adopted in this study. The mass of the sample was determined using a digital weighing balance (S. METTLER – 600/0.1). After that, a very hard shoe brush was rubbed against the two large surfaces of the sample. For the purpose of ensuring that the rubbing was performed with a uniform pressure, a 0.5 kg-mass was firmly attached to the top of the brush. When 70 forward and backward strokes were made by the brush on the sample's surfaces, the flaked sample was weighed. All the samples were assessed similarly for their flaking concentration. The faking concentration in each case was calculated as the ratio of decrease in mass, ΔM to initial mass of the sample, expressed mathematically thus [34]

$$F_c = \left(\frac{\Delta M}{M_i}\right) 100\% \qquad (2)$$

where M_i = mass of the sample before being flaked.

3.5 Linear shrinkage test

Linear shrinkage test is basically a measure to determine the change in the dimensions of the samples. Before drying, the original lengths of the samples (immediately after being demolding) were measured using a pair of vernier callipers and noted. At the completion of the drying process, measurements of the same lengths were made again and the data were noted. The two sets of data were then applied to compute the linear shrinkage of the samples based on the formula

$$L_s = \left(\frac{L_o - L_d}{L_d}\right) 100\ \% \qquad (3)$$

where L_s = linear shrinkage, L_o = original length, and L_d = final length after drying to constant weight.

3.6 Cold crushing strength test

Each of the samples was experimentally assessed for cold crushing strength. In the present study, the sample was placed in a crusher (Amsler Type Crusher). During the test, the pressure adding surface was adequately aligned to the center of the spherical seat of the equipment. Load was applied axially and continuously until the sample fractured. This procedure was repeated for the replicate samples. The respective loads at which each sample fractured were recorded and the cold crushing strength was computed using the formula

$$C_{ss} = \frac{F}{A} \qquad (4)$$

where C_{ss} = cold crushing strength, F = applied load at fracture, and A = area of the sample.

4. Results and Discussion

4.1 Characteristics of the clay

Table 1 shows the values of plasticity index and repose angle obtained for the clay. Characteristically, the plasticity index signifies that the clay material in this case is plastic in nature and it reveals also that the clay has a high affinity for water. It is noteworthy that the more plastic a clay is, the more water it will tolerate without becoming fluid. Typically, the plasticity index shows that the clay material is both organic and inorganic. The plastic nature of the clay is indicative of the fact that it can be molded in any required shape. The index value obtained for the clay falls within the characteristic plasticity range for kaolinites (10 % - 60 %) as observed on the plasticity clay identification chart [35].

Table 1. Characteristics of the clay

Parameters	Value for five determinations
Plasticity index	(32.41 ± 0.01) %
Angle of repose	(35.69 ± 0.01) ^{o}

A group of researchers reported static angle of repose value of (30.01^o) for white clay and noted that Based on the fact that angle of repose is inversely proportional to the size of a material's particle [33]. Comparing with the result in this study, it can be deduced that angle of repose value of the clay is greater by 18.93 %, thus indicating that finer particles in the clay are more than in the case with the white clay. Based on the interpretation of flowability in terms of angles of repose [36], the angle of repose value obtained in this study indicates that the clay has a good flow property for utilization in manufacturing processes. With the index of plasticity and repose angle characteristics obtained in this research, it can be remarked that the clay is likely good for constructional purpose especially bridges when mixed with cement. Alternatively, the clay can be fired to ensure that its capacity is appropriate for load-bearing applications, though such modification process may be expensive.

4.2 Chemical composition of the clay

The knowledge of chemical constituents helps to ascertain the usage of clay. From Table 2, it can be seen that SiO_2 is the most abundant major oxide in the clay followed by Al_2O_3 and then the Fe_2O_3. The amount of Fe_2O_3, though smaller compared to the percentage of SiO_2 or Al_2O_3 indicates that on firing, the clay would change to red color.

Table 2. Chemical composition of the clay

Contents		Percentage (% wt)
Name	Chemical formula	
Silica	SiO_2	54.01
Alumina	Al_2O_3	16.22
Ferric oxide	Fe_2O_3	9.08
Lime	CaO	1.11
Loss on ignition	LOI	12.54

The high content of the Fe_2O_3, as present, renders the clay unsuitable for use by paper and ceramic industries. Just like Attah [37] reported a similar observation for some clay samples from Cross River State, Malu et al. [38] reported for Ndia clay form Takum Local Government Area in Taraba State both in Nigeria. Though the clay examined in this work can be refined to reduce the iron content to a desired level, the process may be too costly for industrial purposes. Owing to the fact that its silica content falls within the range of 51 % to 70 % recommended as the standard requirement [39], the clay could be used in refractory or brick industries. Also, depending on whether the application would be for load-bearing or otherwise, there may be need for modification/stabilization to enhance the strength of the clay bricks. A slightly high amount of CaO present in the clay signifies the presence of carbonates and it gives credence to the high LOI value (12.54 %). The SiO_2 in the clay exists in free form and also as a compound due to the presence of other constituents like Al_2O_3 in mix state. Interestingly, the SiO_2 can make the clay a raw material suitable for bricks production.

The presence of SiO_2 and Al_2O_3 in the clay depicts that the clay could also be used for production of floor tiles.

4.3 Durability Properties

Sorptivity, as an attribute of a particular material, characterizes the tendency of a porous substance to absorb and pass on water and other fluids by capillarity. Since when John Philip coined the term in 1957, it has been utilized extensively for characterising porous composites for constructions, among which are concrete, stones, bricks, and soils. Sorptivity can be confirmed through water infiltration rate into the pores of a porous material whereby the flow of the water is generally influenced by of absorption through capillary action which occurred due to surface tension. Generally, water is involved in every form of deterioration, and in porous solid, thus making sorptivity index an important parameter to evaluate the durability of such material. The lower the water sorptivity index, the better is the potential durability of the porous material. Sorptivity coefficient is an essential parameter for prediction of service life of a structural material as well as improvement of its performance [40]. The knowledge of liquid infiltration helps a great deal for assessment of appearance and durability of porous materials applied for indicates full acceptance of a sample [41]. Thus, the value obtained for the clay in this study, as recorded in Table 3, indicates that the product made from the clay would belong to excellent class in terms of its ability to absorb and transmit water via capillarity suction.

Table 3. Durability properties of the clay

Representative samples	Sorptivity, S_p $(mm\sqrt{h})$	Flaking concentration, F_c (%)
1	4.06	8.92
2	4.11	8.90
3	4.09	8.94
Mean ± Std. error	4.09 ± 0.02	8.92 ± 0.01

The flaking concentration is another durability indicator. It is observed that the flaking concentration of the clay sample is greater than the value (1.016 %) reported for pink clay sample [4]. This means that the grey clay in this case is flakier and would lose its appearance faster if subjected to the same conditions of abrasion in service. It could be that the bonding strength in it is weaker as it contains low amount of CaO given the fact that the structure of a clay material is managed by lime [33]. Still on comparison, it implies that the studied clay is coarser. Based on the limits of flakiness stipulated as 15 % for acceptance of such materials for construction work, the clay can be regarded as a promising raw material.

4.4 Linear shrinkage and Cold crushing strength

Unfired clay has been used in the production of a wide range of earth materials with or without 'reinforcing' strategies such as using straw. If formed in a regular sun-dried (not fired) manner, unfired clay systems comprise mud brick, cob, sod and adobe. However, if used directly without forming into a particular shape, examples include rammed earth. Treatment given to clay aims at strengthening it, though it could be used without such depending its potentials. Clay is a versatile material and the most basic historic clay–based materials capitalize on inherent clay properties, in particular, its cohesive nature. Table 4 shows the linear shrinkage and cold crushing strength values obtained for the clay under consideration in this research.

Table 4. Linear shrinkage and Cold crushing strength of the samples

Representative samples	Linear shrinkage, L_s (%)	Cold crushing strength, C_{ss} (N/mm^2)
1	6.16	1.926
2	6.19	1.924
3	6.14	1.929
Mean ± Std. error	6.16 ± 0.02	1.926 ± 0.002

The shrinkage behavior of the clay is very important because it is one of the factors that determine the suitability of the clay for brick production. The linear shrinkage of the clay is lower compared with the shrinkage (10 % – 13 %) reported for China clays fired at 1280 ^oC [42]. This suggests that the clay is rich in quartz as the presence of such mineral could reduce shrinkage. The value of linear shrinkage obtained in this case is within the acceptable standard values for brick materials, thus implying that the clay could be used for bricks making. For the clod crushing strength, the value is less than the recommended value of 18 MN/m^2 [43]. This low crushing strength, consequently, renders the clay unsuitable for slag and flux transportation.

5. Conclusion and Future Scope

The results of this study have shown that grey clay from Iko Town in Eastern Obolo Local Government Area, Akwa Ibom State, Nigeria possesses acceptable flow property for manufacturing purposes. The iron content of it was found to be 9.08 %, showing that it would be unsuitable for making paper or ceramics. Based on its silica proportion (54.01 %), the clay met the standard requirements for use in refractory and bricks industries though there may be need to modify it to improve the strength of the bricks. The mean value of 4.09 mm/√h and 8.92 % obtained for the sorptivity and flaking concentration, respectively, of the clay samples indicated satisfactory durability for a product desired to be made from the clay. The clay sample recorded acceptable linear shrinkage (6.16 %) with low cold crushing strength (1.926 N/mm^2), indicating possibility for improved performance as on being treated for bricks making. For future study, the heat transfer behavior of the clay could be investigated to determine its suitability as a building material.

Data Availability
All data are available with the corresponding author.

Conflict of Interest
The authors declare that they have no conflict of interests regarding this paper's publication.

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Authors' Contributions

Grace Peter Umoren: Conceptualized the **study, c**reated the methodology for it, analyzed the data, and wrote the first draft of the manuscript.

Itoro Esiet Udo: Gave critical feedback on the structure and contents of the manuscript, contributed to the final version's permission for submission, and served as the lead supervisor.

Usenobong Benjamin Akpan: Assisted in **the** methodology, and approved the submission of the finished version.

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None

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