

**DEVELOPMENT OF ELECTRO PORCELAIN COMPOSITE FROM LOCAL RAW
MATERIALS (*ISAN-EKITI CLAY*)**

BY

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MME/11/0423

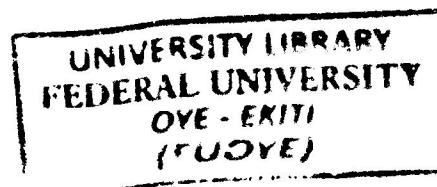
**A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF MATERIALS
AND METALLURGICAL ENGINEERING**

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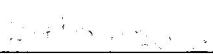
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CERTIFICATION

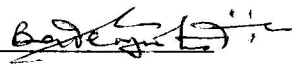
I hereby certify that this project was carried out by **ARIYO, OMOKEHINDE ABISOLA** with matriculation number **MME/11/0423** of the Department of Materials and Metallurgical Engineering, Federal University, Oye-Ekiti, Ekiti State, Nigeria and that this project has not been submitted elsewhere for a degree programme.



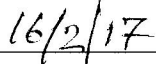
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DEDICATION

I dedicate this research work to God Almighty for his immeasurable grace and mercy throughout the period of my Degree programme, and also to my parents and wonderful siblings for their encouragement, moral and financial support towards the success of the project.

ACKNOWLEDGEMENTS

My first gratitude goes to the Almighty God, the giver of wisdom for His grace, love and for keeping me alive and healthy since the beginning of my programme and made this project a thing of reality.

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ABSTRACT

In this study, production of electro porcelain, for insulator applications by using inexpensive natural raw materials was undertaken. The principal raw materials of porcelain, such as kaolin, feldspar, and quartz, are relatively inexpensive and readily available. The raw materials used in this study were collected from Nigerian source (Isan-Ekiti). The basic raw materials were separately prepared using a 150microns sieve.

The samples synthesized were characterized by X-ray fluorescence (XRF) technique.

The investigation had shown that high quality electrical porcelain insulators could be achieved from locally sourced materials.

Keywords: *Electrical Porcelain, Insulators, Isan-Ekiti,*

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Study

The electric power industry tends to develop extra high voltage, large capacity and long distance transmission, the electric porcelain is required. An advantage of electric porcelain over other insulating ceramic materials is the fact that it enables one to make large size high-voltage insulators of a complex configuration. Electro porcelain can be classified as follows based on its purpose and properties: normal high voltage porcelain used in the production of high-voltage line and apparatus insulators; high-voltage porcelain with an increased quartz content used to make high-voltage apparatus insulators with improved electromechanical properties; high voltage alumina porcelain for high-voltage apparatus insulators with elevated mechanical strength; low-voltage porcelain used in the production of insulators and insulating parts for plants up to 500V generating direct and alternating current and weak current plants (Kolpashchikova et. al., 2003). It has been estimated that more than 20% of the total outlay for a typical transmission and/or distribution system of electric energy is spent on insulation alone and prominent among them is porcelain (Anih, 2005).

The utilization of ceramic materials as electrical insulators goes back until 1850 when Werner von Siemens introduced in the construction of electrical air lines the use of electro technical porcelains. During this long period of time it has been realized that several characteristic properties of porcelain (e.g. mechanical strength, high-power dielectric strength and corrosion resistance) as a ceramic product cannot be obtained in other materials. Today, the growing demand for porcelain in the field of electrical engineering, caused by the importance of electric energy in modern society, motivates many research projects in order to obtain the best properties for the requirements and

applications of porcelain insulators (Amigo et. al., 2004. Basically porcelain is an insulator but the rise of temperature as example may damage its insulation property due to decrease in its resistivity and the porcelain body may be employed as conductor (Chaudhuri et. al., 1999).

Electro technical porcelain is a clever compromise between electrical, thermal and mechanical resistances. Improving performance characteristics of the electrical porcelain involves the updating of its production technology. The characteristics of porcelain insulators depend to a marked degree on the percentage composition of the mixture, sources of the mixture and method of manufacture. The production of electrotechnical porcelain is based predominately on natural raw materials. To this end, kaolin-feldspar-quartz triaxial porcelain was prepared from locally available raw materials and characterized. The characterisation is aimed at comparing the electrical properties of the triaxial porcelain with those of others works and hence explores the possibility of local substitution of the imported variety which is the subject of a future research.

Clay minerals are the most important industrial minerals. Millions of tons are utilized yearly in various applications. These applications include uses in geology, the process industries, agriculture, environmental remediation and construction. The reason for utilization of certain clay minerals in specific application is that the physical and chemical properties of a particular clay mineral are dependent on its structure and composition. The structure and composition of kaolins, smectites, and palygorskite and sepiolite are very different even though they each have octahedral and tetrahedral sheets as their basic building blocks. However, the arrangement and composition of these octahedral and tetrahedral sheets account for major and minor differences in the physical and chemical properties of kaolin, smectites and palygorskite (Kolpashchikova et. al., 2003). Clays have received considerable attention especially as potential adsorbents for environmental research. Many researchers around the world, have beamed their search lights on the phase developments

that occurred by sintering clay in the presence of some oxides (Amigo et al., 2004). Deposits of clay raw material are widely distributed in Nigeria (Demirkiran et al., 2010). In order to determine the profitability of utilizing clay from a particular deposit for any application, it is of paramount importance to examine the microstructural morphology, determine the mineralogical composition and analyse the various available phases in such clay deposit.

1.2 Aim of Research

The aim of research is to develop electro porcelain composite using local raw material (Isan-Ekiti Clay).

1.3 Objectives of the research

Specific objectives of the research are to;

- a) To procure from Isan-Ekiti two types of monolithic clay
- b) Sun-dry the clays, then mill into powder and sieve into various meshed sizes.
- c) Carry out chemical composition analysis of the clays.
- d) Conduct leaching processes on the clays to remove electron conductivity substances
- e) Determine the electrical conductivity and resistivity of the leached samples and:
- f) Form electro porcelain composite from the clays.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Electro porcelain

Porcelain is a ceramic material made by heating raw materials, generally including clay in the form of kaolin, in a kiln to temperatures between 1,200 °C (2,192 °F) and 1,400 °C (2,552 °F). The toughness, strength, and translucence of porcelain arise mainly from the formation of glass and the mineral mullite within the fired body at these high temperatures (Porcelain, 2009). Porcelain had been found to be a veritable stoneware due to its very high density, industrial fast firing cycles, tangible mechanical strength and wear resistance (Tucci et al., 2007).

Unquestionably porcelain insulators have a wide range of application in the safe transmission of electricity. Porcelain is primarily composed of clay, feldspar and filler material, usually quartz or alumina. The clay $[(Al_2Si_2O_5(OH)_4)]$ gives plasticity to the ceramic mixture, flint or quartz $[SiO_2]$ maintains the shape of the formed article during firing and feldspar $[K_xNa_{1-x}(AlSi_3)O_8]$ serves as flux (CRMPI, 2006). These three constituents place electrical porcelain in the phase system in terms of oxide constituents, hence the term triaxial porcelain (Buchanan, 1991).

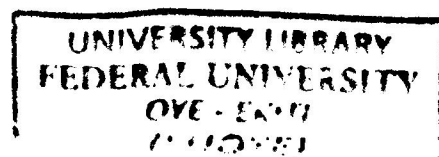
Most existing literatures on body compositions and processing conditions for porcelains of all kinds such as (Norton, 1980) and (Olupot, 2006) applies mainly to foreign raw materials, which can be quite different from the local ones in terms of chemical, mineralogical and physical characteristics. Therefore, more efforts should be channeled to establish data and procedures on the development of electrical porcelain with local raw materials.

2.1.1 Strength Considerations for Porcelain

The great interest in high strength of porcelain and the wide research on the porcelain system have resulted in three major hypotheses describing the mechanical strength properties of porcelain formulations. These were described by (Carty and Senapati, 1998) as the mullite hypothesis, the matrix reinforcement hypothesis and the dispersion strengthening hypothesis, respectively.

The mullite hypothesis suggests that porcelain strength depends on the felt-like interlocking of fine mullite needles. Specifically, the higher the mullite content and the higher the interlocking of the mullite needles, the higher is the strength. Hence the strength of porcelain depends on the factors that affect the amount and size of mullite needles, like the firing temperature and composition of alumina and silica in the raw materials.

The matrix reinforcement hypothesis concerns the development of compressive stresses in the vitreous phase as a result of the different thermal expansion coefficients of dispersed particles, or crystalline phases, and the surrounding vitreous phase. The larger these stresses are, the higher is the strength of the porcelain body. The phenomenon is known as the pre-stressing effect. The dispersion strengthening hypothesis, on the other hand, states that dispersed particles in the vitreous phase of a porcelain body, such as quartz and mullite crystals in the glassy phase, limit the size of Griffith flaws resulting in increased strength. There is evidence of studies supporting each of the above hypotheses (Maity and Sarkar 1996, Stathis et al 2004, Islam et al. 2004). (Carty and Senapati, 1998) concluded that the typical strength controlling factors in multiphase polycrystalline ceramics are thermal expansion coefficients of the phases, elastic properties of the phases, volume fraction of different phases, particle size of the crystalline phases and phase transformations. (Islam et al., 2004) conclude that the best mechanical and dielectric properties can be achieved by high mullite and quartz content with low amount of the glassy phase and in



absence of micro cracks. Adherents of the matrix reinforcement theory suggest that the composition of porcelain should be such that the batch should contain as little clay as conformable with the workability of the body, as little feldspar as conformable with the impermeability of the fired porcelain, and as much quartz of uniform grain size as possible (Mattyasovszkyzsolnay, 1957. Stathis et al, 2004). Indeed, (Mattyasovszky-zsolnay. 1957) reported maximum strength for a body having quartz content of 39% while (Stathis et al., 2004) kept the filler content to 29%.

2.1.2 The role of quartz in porcelain formulations

Quartz is added to ceramic bodies as a filler. Its main purpose is to reduce the tendency of the body to warp, distort or shrink when it is fired to temperatures that result in substantial quantities of viscous glass. Silica phases cause detrimental or favourable effect on mechanical strength, depending on the quantity present in the final body. Thus, strength depends on the quantity of quartz in the batch and on its dissolution during firing which in turn depends on fineness, on the system under consideration and on the firing conditions (Schüller, 1997). Quartz grains embedded in the porcelain glassy matrix have a deleterious effect on the mechanical strength mainly because of the occurrence of micro cracks caused by the quartz inversion during cooling (Schroeder, 1978). Because of this, several investigators have carried out studies and reported significant improvements in the mechanical properties of porcelain by reducing/eliminating the use of quartz. These include replacement of quartz with kyanite (Schroeder, 1978), replacement of quartz with alumina (Kobayashi, et al, 1987; Das and Dana, 2003), replacement of quartz with rice husk ash (Prasad, et al, 2001), replacement of quartz and feldspar by sillimanite sand and alumina/ cordierite glass ceramic, respectively (Maity and Sarkar, 1996), replacement of quartz with fly ash (Dana, et al. 2004), partial replacement of feldspar and quartz by fly ash and blast furnace slag (Dana, et al. 2005), replacement of quartz with silica fume (Prasad, et al, 2002), substitution of quartz by a

mixture of rice husk ash and silica fume (Prasad, et al, 2003). However, an effort to substitute part of quartz with fired porcelain by (Stathis et al.,2004) did not result in a positive effect on the bending strength.

On the other hand, there is abundant evidence that under certain conditions, quartz has a beneficial effect on the strength of porcelain. Such evidence includes the use of fine particle quartz in the range of 5-30mm. Different views have also been expressed regarding optimum firing temperature, particle size range and quantity when working with quartz in improving strength (Ece and Nakagawa 2002, Bragança and Bergmann 2003, Stathis et al 2004). These modifications and the low cost of quartz compared to the substitutes above, are responsible for the continued utilization of quartz in electrical porcelains.

2.1.3 Other Modifications on Porcelain Body

Other modifications on the traditional porcelain body, which have proven successful include: replacement of clay with aluminous cement (Tai et al, 2002), substitution of feldspar with nepheline syenite (Esposito, et al, 2005), use of soda feldspar in preference to potash feldspar (Das and Dana, 2003), partial substitution of feldspar by blast furnace slag (Dana and Das, 2004), use of recycled glass powder to replace feldspar to reduce firing temperature (Bragança and Bergmann, 2004). Strength aside, the other limiting factors are the forming/shaping process adopted and the particle size of the starting powders. For an extrusion process, quartz content is limited by the need to have a more plastic body.

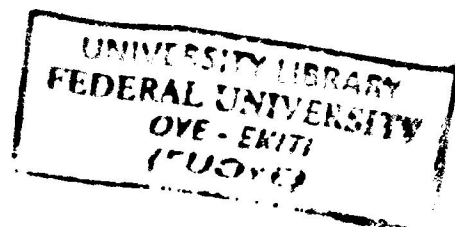
2.2 CLAY

Clays are anhydrous complex compounds of aluminum (Al_2O_3) and silica (SiO_2) that exist in various proportions and contain varied amount of impurities of iron, organic matters and residual minerals (Sanni 2005). Nigeria as a developing economy houses a lot of industries that utilize refractory material in abundance. Nigeria also has abundant mineral resources including clay. Despite the large deposits of clay in many parts of the country, local manufacturing of refractory materials for local use had been very low. Refractories are used in metal melting and heat treatment industries because of their high temperature operating conditions. It is also used in industries both as lagging and insulating material. They degenerate with time and therefore need replacement (Abifarin 1999). If the industries that use them are to remain in business, replacement must not only be produced but also must be locally sourced. Clay minerals are of secondary geologic origin i.e. they were formed as alteration products of alumino-silicate rocks in an environment in which water is present (Olusola 1998). Clay minerals are produced mainly from the weathering of feldspars and micas. They form part of a group of complex alumino-silicates of potassium, magnesium and iron, known as layer-lattice minerals. They are very small in size and very flaky in shape, and so have considerable surface area (Thring 1962). The clays used for furnace linings in metallurgical industries are classified as refractory clays. However, the degree of refractoriness and plasticity of any clay material is often influenced by the amount of the impurities contained in them. Moreover, the ability of selecting refractory clay to withstand high temperature and resist physical and chemical corrosion determines the quality.

2.2.1 ELECTRICAL RESISTIVITY OF CLAY

The effects of clay on the frequency-dependent electrical impedance of rocks has not been investigated with the same intensity as have the effects of conductive minerals, such as sulfides. Investigators in the mining geophysical community who have examined clay effects have been primarily concerned with polarization phenomena. Most notable is the work of Vacquier et al (1957) and Madden and Marshall (1959) who describe, respectively, time-domain IP measurements on artificial clay-sand mixtures and a theoretical model for membrane (clay) polarization. Olgilvy and Kuzmina (1972) described additional time-domain measurements on artificial mixtures, while Roy and Elliott (1980) used horizontal layers of varying clay-sand composition to model negative apparent chargeabilities due to geometric effects. The theoretical model of Madden and Marshall (1959) was simplified and compared to measurements made on natural samples of dirty sandstone by Sill (1964). It is generally accepted that membrane polarization is a result of differences in mobility between anions and cations in adjacent zones in pore passages. Polarization is then due to concentration gradients that develop at zone boundaries in response to current flow. This implies that electrical properties differ from place-to place within the rock, and that the clay distribution is not uniform when examined on a fine enough scale.

The dependence of resistivity on clay type and content has been examined in some detail by individuals interested in predicting porosity and hydrocarbon saturation from well logs of resistivity. Waxman and Smits (1972) and Waxman and Thomas (1976) present a semi-empirical model for describing the dependence of resistivity on clay content, expressed as cation exchange capacity (CEC) per unit pore volume. They assume that resistivity is frequency independent and that all of the clay in their samples contributed to the observed decrease in resistivity. This implies that the clay is uniformly distributed throughout the rock and that paths of conduction along clay



surfaces are continuous. It is unclear how the Waxman-Smits model would apply for estimating the CEC per unit pore volume for polarizable samples. Unfortunately, there does not exist presently a sufficiently quantitative model for predicting clay content for such polarizable material. It is evident that a systematic and thorough laboratory study is needed in order to completely understand the effects of clay. A more complete data base is needed in order to test various rock models. To this end we have undertaken a laboratory investigation of the electrical properties of natural clay-bearing rocks and mixtures of clay and glass beads. Our main objective was to measure the spectral characteristics of these materials, and to compare results to various rock models. A secondary objective was to compare the nonlinear response of clay-bearing materials to observations presented by Olhoeft (1977a, 1977b, 1978, 1979) and Olhoeft and Scott (1980), who have observed unusual nonlinear properties for various ion exchange materials.

Clay is a natural earthy fine grained material, which is powdery when dry, plastic when wet and stone-like when baked Mohammed et al (2011). Most clays are crystalline, with a definite repeating arrangement of atoms in them. The majority of them are made up of planes of oxygen atoms, with silicon and aluminum atoms holding the oxygen together by ionic bonding. Brady et al (1999) Clay minerals have the ability to exchange ions. This mineral property of clays that causes ion in solution to be fixed on the clay surface or within internal sites applies to all types of ions, including organic molecules. Hans (1994) Depending on the source, there are four main groups of clays namely montmorillonite-smectite, illite, and chlorite. Montmorillonite often results from the further degradation of illite, but the weathering of plagioclase feldspar in volcanic ash deposits also forms it. Essentially, the structure consists of three layer arrangements in which the middle octahedral layer is mainly gibbsite but with some substitution of aluminum by magnesium. Manukaji (2004). A variety of metallic ions (other than k^+) provide weak linkage between sheets.

As a result of this weak linkage water molecules are easily admitted between sheets, resulting in a high shrinkage swelling potential. Agha (1998). The degradation of micas (e.g. muscovite and sericite) under marine conditions results in a group of structurally similar minerals called illites. These, feature as predominant minerals in marine clays and shells, such as London clay and Oxford clay (Mahmoud et al., 2003). Some illites are also produced when in the weathering of orthoclase not all of the potassium ions are removed. The structures consist of three layer gibbsite sheets with k^+ ions providing a bond between adjacent silica layers. The linkage is weaker than that in kaolinite, resulting in thinner and smaller particles (Li Zaigeng et al., 2001)

2.2.2 INSULATING PROPERTY OF CLAY

Clay minerals have an electrically 'active' surface layer. This active surface not only affects the electrical resistivity of clay water mixtures but it also affects the degree to which water is held within the clay structure and so ultimately influences the mechanical strength and density of soils containing clay. The latter properties are beyond the scope of this course and are very well described in a classic text by Mitchell (1993). To better understand the role of clay in influencing the electrical resistivity we need to review some basic clay properties. The following summary is taken from Mitchell.

The basic structure of a typical clay particle consists of alternating layers of two sheet-like crystalline lattices. The first is a planar structure of silica tetrahedra, silicon atoms surrounded by oxygen atoms on the vertices of an enclosing tetrahedra. The second is a planar structure of octahedral units consisting of either magnesium or aluminum atoms surrounded by hydroxyls or oxygen atoms on the vertices of the enclosing octahedra. The typical clay mineral is a sandwich consisting of one sheet of the octahedral lattice between two tetrahedral sheets. At the time of formation other ions can be substituted for the basic silicon, magnesium or aluminum in the lattice.

In the tetrahedral layer aluminum can replace silicon and in the octahedral layer magnesium replaces aluminum or iron replaces magnesium. If the original or ideal structure was electrically neutral, then substituting Mg^{++} for Al^{+++} **leaves a net negative charge**. To maintain electrical neutrality the clay particle attracts cations to its surface from its surroundings.

These cations are not part of the crystalline structure of the clay, they are simply drawn from the aqueous solution that surrounds the clay at its formation. They may be replaced by other ions when the clay formation evolves and the aqueous environment changes. They are said to be exchangeable and the quantity that is available for exchange, which in turn depends on the number of negative charges present in the actual clay lattice, is called the Cation Exchange Capacity (CEC).

Ions held adjacent to the exposed lattice structure of the surface can be released into solution and ions in the solution can be drawn to sites on the surface. Clays can thus take ions from the solution and replace them with different ions from their structure.

An important net effect is that when water is added to clay the concentration of ions is increased in the solution in the vicinity of the clay surface. While some of these released ions and polar water molecules held tightly to the surface, the fixed layer (or Stern layer), others are held less strongly in a diffuse but mobile layer extending into the solution. These ions diffuse into solution as a result of the concentration gradient but are also held by the voltage gradient (the electric field) of the negatively charged clay surface. The charged surface and its associated zone of decreasing ion concentration is called the diffuse double layer. This diffuse layer has a higher conductivity than the normal pore fluid and represents a parallel low resistivity path for current conduction along the mineral surfaces. Clay particles have an enormous surface area per unit weight and consequently a relatively small amount of clay can dramatically increase the bulk conductivity.

The effect is most dramatic when the pore fluid is of high resistivity and is insignificant for highly concentrated pore fluids, which carry the current easily without the benefit of the surface conduction paths.

Waxman and Smits (1968) derived relatively simple expression that specifically ties the apparent formation factor F_a to the true formation factor F (the formation factor measured at high pore solution concentration) and the cation exchange capacity via:

$$F_a = \frac{\rho_b}{\rho_w} = \frac{F}{1 + \rho_w BQ} \dots\dots\dots(1)$$

where Q is the cation exchange capacity per unit volume of the clay and B is a factor which accounts for the variation of the ion mobility with solution concentration.

2.3 ISAN-EKITI CLAY

2.3.1 Kaolin

Kaolin is an industrial clay mineral with the chemical composition, $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$. this kind of clay can be found in Isan-Ekiti, Ekiti state. Due to its whiteness, fine particle size and plate-like structure, it holds importance as a major raw material in refractory applications and ceramic production. Kaolin is also suitable as a coating, functional filler, extender, pigment, catalyst, concrete and fiber glass. Current applications of Kaolin include:

- **Refractory Bricks:** Refractory bricks (fire bricks) are used to line high temperature furnaces and kilns, hence must be able to resist high temperature. User industries are all heat using industries such as iron and steel, ceramics, glass, cement, galvanizing and petroleum.

Despite having huge deposits of kaolinite clay mineral in Nigeria, Nigeria continues to depend on

external sources of refractory clays for its industries (Aliyu, 1996). In 1987 alone, Nigeria imported about 27 million metric tons of refractory materials (Obadinma, 2003).

- **Ceramic Wares:** Kaolin stands out as the major raw material in almost all ceramic products. These include structural ceramics (drain pipes, sewage pipes, tiles, etc.), white wares (household utensils, sanitary wares, etc.), and porcelain, e.g. high and low tension electrical insulators and dental ceramics.
- **Paper Making:** The largest use of kaolin is in the production of paper where it serves both as a coating pigment and as a filler to replace fibre. Kaolin is suited in this aspect because it possesses desirable optical properties, chemically inert and relatively inexpensive when compared to other minerals.
- **Concrete:** Kaolin when added to concrete helps to improve strength and durability of concrete and mortars. It reacts with free lime during hydration to produce additional cementitious material, resulting in an improved high performance concrete.
- **Plastics and Rubber:** Kaolin is widely used as a functional filler in the plastic and rubber industry because of its inert chemical nature, unique size, shape and structure. Its presence results to improved overall performance of the plastics and rubber.
- **Paint:** In the production of paint, kaolin is used as an extender pigment. Primarily, kaolin in paint reduces the amount of expensive pigments e.g. titanium dioxide, assists the desired rheological properties that help maintain proper dispersion, and provides bulk to the product.
- **Pharmaceuticals and Cosmetics:** Kaolin is used in pharmaceuticals for treating different stomach irritations such as diarrhea. In cosmetics, it is used in various skin care products in removing blackheads and dirt from the skin/skin pores (Franklin, 2010).

CHAPTER THREE

3.0 METHODOLOGY

3.1 Materials and Equipment

- a. Isan-Ekiti clay
- b. Pulverizer
- c. Ball mill
- d. Sieve (150 microns)
- e. Leaching apparatus
- f. Oxalic acid
- g. Distilled water
- h. Measuring cylinder
- i. Filter paper
- j. Beaker
- k. Electronic weighing balance
- l. Oven dryer

3.2 CLAY PREPARATION

The preparation of the clay was carried out in the metallurgical minerals and mining laboratory. The first stage in the clay preparation is the comminution process (i.e crushing and grinding).

3.2.1. Comminution process: This stage involves the crushing and grinding of clay samples by making use of the pulverizer and ball mill. Two different clay samples were gotten from Isan-Ekiti. The pulverizer reduced the particle size of the clay samples into smaller lumps

and then it was put in the ball mill which grounded the smaller lumps of the clay samples into finer particles.

3.2.2. Sieving process: The sieving process was carried out manually by making use of a sieve with 150microns aperture size. The clay samples produced after sieving was of a much finer particle size than the one gotten from the ball mill.



Figure 1. Sieving of clay samples



Figure 2. Sieved clay sample

3.2.3. Mixing process: The clay samples were then mixed together in equal proportions in order to form a homogenous mixture of the required raw mix.

3.2.4. Leaching process: The leaching process was carried by making use of the leaching set-up in the laboratory. This process basically involves removal of the metallic contents and electrical conducting elements. Distilled water of 600ml was poured in a measuring cylinder and then oxalic acid of 126.7g was added to the distilled water. It was then stirred until it dissolved and then 400ml of distilled water was added, after which it was stirred again.

The mixed clay sample was put in a beaker, and then the distilled water was added to it. The beaker has a magnet equipped in it which serves as a stirrer. The beaker was then placed on the leaching set-up. The leaching equipment was switched on and the leaching process took a total period of 60 minutes. Afterwards, the metallic particles in the sand settled in the lower part of the beaker, and the sand in the upper part was collected by making use of a filter paper.



Figure 3. Leaching set-up



Figure 4. Leaching process

3.2.5. Drying process: After the leaching process has been successfully carried out, the sample was dried in an oven for five (5) minutes so as to reduce its moisture content.

3.2.6. Moulding process: The moulding process was carried out manually i.e. by hand moulding. The clay sample was moulded to take the desired shape of an electrical insulator, and followed by the surface finish.

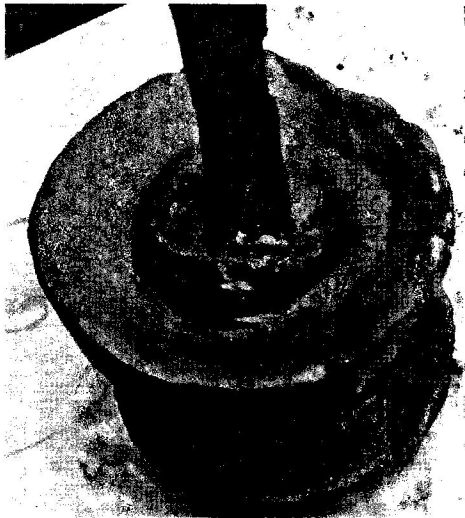


Figure 5. Hand moulding process



Figure 5b. Hand moulding

3.2.7. Drying Process: After the hand moulding process, the clay sample was placed in an ambient atmosphere with little or no access to direct sunlight in order to harden it and make it suitable for use as an insulator. The moulded sample was not placed in an environment with direct access to sunlight so as to avoid cracking.

3.2.8. Glazing Process: The moulded sample was dipped in the glazing oil (gloss) in order to give it a smooth, shiny surface. After dipping it in the oil, the sample was then allowed to dry thereby giving the sample the desired colour.



Figure 6: Glazing process

3.3 TEST FOR ELECTRICAL CONDUCTIVITY AND RESISTIVITY

The leached clay sample was taken to the laboratory where continuity test was carried out on it to determine its level of electrical conductivity. The test was carried out with the use of digital multi-meter and it was found out that the clay sample possessed zero electrical conductivity which therefore makes it suitable for use as an insulator.



Figure 7. Electrical conductivity test

3.4 CHEMICAL COMPOSITION TEST

The chemical composition of the clay samples was found out by carrying out X-ray Fluorescence (XRF) test in the laboratory. This test influenced the kind of leaching process to be carried out on the clay samples.



Figure 8. EDX 3600B X-ray Fluorimeter (XRF)



CHAPTER FOUR

4.0. EXPERIMENTAL RESULT AND DISCUSSION

4.1. CHEMICAL COMPOSITION

The chemical composition of the Isan-Ekiti clay sample was determined using the X-ray Fluorimeter (XRF). The composition of the compounds, elements present in the clay can be found in the table below

<i>Al₂O₃</i>	<i>SiO₂</i>	<i>K₂O</i>	<i>CaO</i>	<i>Ti₂O</i>
13	41	3	1.1	2.7
<i>MnO</i>	<i>Fe₂O₃</i>	<i>MgO</i>	<i>Na₂O</i>	<i>Cr₂O</i>
0.15	25.5	0.10	0.02	0.06
<i>LOI</i>				
10.7				

Table 1. Chemical composition of Isan-Ekiti clay

4.2. DISCUSSION ON CHEMICAL COMPOSITION

From the table above, it can be determined that Isan-Ekiti clay has a fairly high percentage of quartz (SiO₂) present in it, which therefore makes it suitable for use as an insulator.

Also, Isan-Ekiti clay contains about 25.5% of Fe₂O₃, which is a metallic element that conducts electricity so therefore there is need to carry out leaching test on it in order to rid the clay sample of its electrical conducting element.

4.3. ELECTRICAL CONDUCTIVITY AND RESISTIVITY

The clay samples were tested to determine whether or not it still possessed some electrical conducting elements, and the test was carried out with the use of a digital multi-meter in the laboratory. The results gotten from the clay sample can be found in the table below.

Electrical Conductivity	0 ohms
Electrical Resistivity	> 200,000 ohms

Table 2. Electrical conductivity and resistivity of leached Isan-Ekiti clay sample

4.4. DISCUSSION ON ELECTRICAL CONDUCTIVITY AND RESISTIVITY

From the table above, it can be determined that the leached Isan-Ekiti clay sample has zero (0) conductivity and a very high resistivity of about 200,000 ohms. Therefore, we can accurately conclude that the leached Isan-Ekiti clay sample is very suitable for use as electro-porcelain insulator since it possesses no electrical conducting element.

CHAPTER FIVE

5.0. CONCLUSION AND RECOMMENDATIONS

5.1. CONCLUSION

This chapter presents conclusions arrived at based on the results obtained and observations made in this study. The abundant ceramic resources in Nigeria when exploited and utilized, will in the long term, result to economic empowerment, job creation and technological advancement. Transforming the challenges to opportunities will strengthen the nation and bring her close to the economically and technologically developed nations of the world.

The conclusions drawn from this study are listed below

1. Isan-Ekiti clay has two types of monolithic clays which are suitable for use in production of insulators.

Characterisation results suggest that Isan-Ekiti clay contains about 41% quartz (SiO_2). This deposit also has a relatively high amount of Fe_2O_3 .

2. Its use in the production of porcelain insulators requires the removal of Fe_2O_3 , and other electrical conducting elements.
3. The analysis has revealed Isan-Ekiti clay to show strong kaolinitic characteristics.

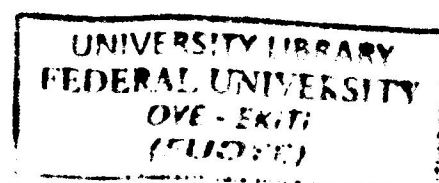
5.2. RECOMMENDATIONS

The following recommendations were suggested during the course of this project:

1. More facilities for research should be procured and installed in the departmental laboratory.
2. Deep investigations should be carried out in order to know the necessary steps to take to achieve the aim of the study.
3. More focus should be placed on exploiting and utilizing Nigeria's raw materials for production of pottery, refractories, chemical stoneware, electrical porcelain(insulators), bricks, tiles, Portland cement, filters, sanitary wares, drilling mud, sculptural ceramics, etc.

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