Enhancement of Ceramic Insulator Properties with Periwinkle Shell as An Additive

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Abstract -- The raw materials for the production of Electrical porcelain insulator were characterized, a sample used as a test piece were produced using universal composition of kaolin, Feldspar and Quartz. A second sample was produced using periwinkle shell as additive to make up the composition of quartz in the mixture. The physico-electrical properties of the two samples were investigated and compared with the imported porcelain insulator obtainable from the market. The result obtained shows that the periwinkle shell and other similar shells can be added to ceramic insulator to improve its properties.

Indexed Terms: kaolin, feldspar, quartz, periwinkle

I. INTRODUCTION

Insulators are materials that inhibit the flow of electrical current. The opposite of conductors, which allow electric particles to flow freely, insulators are implemented in household items and electrical circuits as protection. Insulators possess a high resistivity and low conductivity. Their atoms have tightly bound electrons that do not move throughout the material. Because the electrons are static and not freely roaming, a current cannot easily pass

A ceramic is an inorganic non-metallic solid made up of either metal or non-metal compounds that have been shaped and then hardened by heating to high temperatures. In general, they are hard, corrosion-resistant and brittle. 'Ceramic' comes from the Greek word meaning ‘pottery’. The clay-based domestic wares, art objects and building products are familiar to us, but pottery is just one part of the ceramic world. Nowadays the term ‘ceramic’ has a more expansive meaning and includes materials like glass, advanced ceramics and some cement systems as well.

According to [1] Ceramics are defined as solids composed of compounds that contain metallic and non metallic elements and the atoms in the compound are held together with strong atomic forces either ionic or covalent bonds.

The word ceramic is derived from a Greek word ‘keramos’ meaning pottery. It is related to an old Sanskrit root meaning ‘to burn’ but primarily, the Greeks used the term to mean "burnt stuff" or "burned earth". Thus the word was used to refer to a product obtained through the action of fire upon earthy materials [2].
Ceramics are essential to our daily lifestyle and their applications of products are widely used. Ceramics materials include things like tile, bricks, plates, glass, porcelain etc.

Ceramic insulator, commonly referred to as porcelain are primarily composed of kaolin, feldspar and a filler material, usually quartz or alumina. The clay material, gives plasticity to the ceramic mixture; quartz maintains the shape of the formed article during firing; and feldspar serves as flux. The clay content is a combination of ball clay and kaolin contents.
Porcelain is a ceramic material made by heating raw materials (which generally include clay in the form of kaolin) in a kiln to temperatures between 1,200 °C and 1,400 °C [3]. 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 had been found to be veritable stoneware due to its very high density, industrial fast firing cycles, tangible mechanical strength and wear resistance [4]. Unquestionably porcelain insulators have a wide range of application in the safe transmission of electricity.

II. AIM OF THE STUDY

Porcelain bodies vary among manufactures, depending on quality control and/or application for which the product is intended. Thus, one manufacturer may compound a body designed for high-strength, high voltage applications, another for low voltage, high frequency (low loss) work, another for highest chemical resistance. No one porcelain body is ideal for every job, considering the varying requirements of strengths, non-porosity, chemical resistance, and electrical characteristics. The three principal raw materials sometimes do not satisfy most application, hence the need to introduce other materials as additive to meet the necessary requirement(s).

III. COMPOSITION OF CERAMICS INSULATOR

Porcelain is primarily composed of clay, feldspar and filler material, usually quartz or alumina. The clay [$(Al_2Si_2O5(OH)_4$] gives plasticity to the ceramic mixture, quartz [SiO_2] maintains the shape of the formed article during firing and feldspar [$K_2O.Al_2O_3.6SIO_2$] serves as flux [3]. These three constituents place electrical porcelain in the phase system in terms of oxide constituents, hence the term triaxial porcelain [5]. One great advantage of Kaolin-Feldspar-Quartz bodies is the fact that they are not sensitive to minor changes in composition, fabrication techniques and firing temperature [6].

IV. METHODOLOGY

The processed raw materials in powdered form were carefully weighed out, thoroughly mixed in a motor using s stirrer, and adding about 8% water to the mixture until the mixture becomes homogenous. This is tagged sample A. the percentage composition of the mixture chosen in the study was in accordance with Budnikov's recommendation for electrical porcelain insulator production [7]. Processed periwinkle shell were introduced in the second sample tagged sample B

Table 1: Percentage composition of sample A

Kaolin(%)	Ball clay(%)	Feldspar(%)	Quartz (%)	Total
40	5	25	30	100

Table 2: Percentage composition of sample B

Kaolin (%)	Ball clay(%)	Feldspar(%)	Quartz (%)	Periwinkle shell	Total
40	5	25	25	5	100

After mixing the raw materials, a rectangular mould fabricated from hardened steel were used to shape the samples followed by drying, done under free natural circulating air for a period of 24 hours. The samples were fired in an electric furnace with a gradually rising temperature up to 1200 °C, for a soaking period of 6 hours. At the end of the firing, the samples were gradually cooled.

V. DETERMINATION OF PHYSICAL PROPERTIES

The dry linear shrinkage and fired linear shrinkage were calculated using Equations (1) and (2). Then total shrinkage was computed with equation (3).

$$\textit{Drying Shrinkage} = \frac{Lw-Ld}{Ld}\text{x}100\% \quad (1)$$

$$\textit{Fired Shrinkage} = \frac{Ld-Lf}{Ld}\text{x}100\% \quad (2)$$

$$\textit{Total Shrinkage} = \frac{Lw-Lf}{Lw}\text{x}100\% \quad (3)$$

where Ld = Dry length, Lw = Wet length, Lf = Fired length

The water absorption was computed using equation (4).

$$\textit{Water Absorption} = \frac{Ws-Wd}{Wd}\text{x}100\% \quad (4)$$

Where Ws = soaked weight and Wd = dry weight

While Porosity was calculated as a function of the specimen's weight difference between soaked weight and dry weight to specimen's weight difference between soaked weight and suspended immersed weight . The results were obtained by equation (5).

$$\textit{Porosity (P)} = \frac{Ws-Wd}{Ws-Wsp}\text{x}100\% \quad (5)$$

Where ws = soaked weight, wd = dry weight, *wsp* = suspended immersed weight

The strength of the porcelain insulators was investigated by determining their modulus of rupture. The Height, H (cm) and the width, B (cm) of the broken pieces were determined and the average value obtained from two broken parts was recorded. The modulus of rupture was then calculated as given by the equation 6.

$$\text{Modulus of Rupture } (kg/cm^2) = \frac{3PL}{2BH^2} \qquad (6)$$

VI. DETERMINATION OF ELECTRICAL PROPERTIES

Megger insulation Tester was used for the electrical measurement. This is a small portable instrument that gives a direct reading of insulation resistance in megaohms. The Megger insulation tester is essentially a high-range resistance meter (ohmeter) with a built in direct current generator. The meter was used to carryout electrical properties test on the samples to determine capacitance, the direct constant. The break down voltage which is a destructive test were also carried out. The electrical properties result were recorded in Table 4

VII. RESULTS AND DISCUSSION

Table 3 Result of the Physical properties Test

Sample	Total Shrinkage (%)	Water Absorption	Porosity	Modulus of Rupture
A	12.10	0.8	2.4	10.4
B	11.9	1.0	2.4	12.4

Table 4 The result of capacitance and dielectric constant measurement at different frequencies

Frequency	Capacitance(pF) Sample A	Capacitance(pF) Sample B	Dielectric Constant Sample A	Dielectric Constant Sample B
50	7.3	7.4	8.0	8.2
100	6.8	6.9	7.9	7.9
1000	6.6	6.7	7.6	7.5
5000	6.5	6.3	6.4	6.3

Table 5: Result of Electrical Properties Test

Sample	Total resistance (MΩ)	Total resistivity (MΩcm)	Break down voltage (kv/mm)
A	4920	$1.9x10^4$	26.9
B	4920	$1.9x10^4$	27.3

The shrinkage in percentage was found to reduce at the introduction of additive, periwinkle shell, as shown in table 3. The slight increase in water absorption observed at the introduction of the additive was small, which shows that feldspar as a flux permits reaction from impurities to form slag. The porosity was observed to be the same, because at elevated temperature slag are burnt off, hence creation of pores. It was observed that the mechanical strength of the insulator increases at the introduction of the additive.

The result of electrical properties test indicates the maximum breakdown voltage and dielectric constant the samples can withstand. Insulators that have their value of dielectric constant below 12 are good for electrical insulation, since it implies that they have low charge storing capacity, but those above 12 are considered good for capacitors.

Table 6 comparison between the samples and the commercial available one

Electrical property	commercial porcelain	Sample A	Sample B
Modules of rupture	Not measured	10.4	12.4
Resistivity (MΩcm)	$3.7x10^{10}$	$1.9x10^4$	$1.9x10^4$
Breakdown voltage (Kv/mm)	25	26.9	27.2
Dielectric constant	6.35 at 50Hz	7.9	8.1

VIII. CONCLUSION

Two samples of ceramic insulator were produced, Sample A was produced with the traditional raw materials, while periwinkle shell was added in sample B as an additive. when compared with the commercial ceramic insulator, the sample with additive had a break down voltage of 27.2 kv/mm, against the commercial insulator and sample A (without additive) with 25kv/mm and 28.9 kv/mm respectivey. The result of physico-electrical properties showed that the physical and electrical properties of a ceramic insulator can be improved with addition of periwinkle shell in the percentage composition of the ceramic mixture.

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