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COMPOSITE ADDITIVE: ENHANCEMENT OF PORCELAIN INSULATOR PROPERTIES USING AFRICAN GAINT LAND SNAIL (*ARCHACHATINA MARGINATA*) SHELL

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Abstract

The shell of the African giant snail, *Archachatina marginata* was considered as an additive material in the porcelain recipe for electrical support and resistance (insulator) applications. The materials for the recipe: Kaolin, Ball clay, Feldspar and Quartz except the snail shell were sourced commercially. The African Giant Snail Shell (AGSS) was sourced from local food vendors and processed: washed, dried, granulated, demineralized, dried and pulverized; then characterized for chemical composition using X-Ray Fluorescence (XRF). Two samples of porcelain were made (sample A, using the conventional materials; and sample B, using AGSS as additive), and analyzed for physico-electrical properties. Comparison was also made with commercial specifications. Sample B showed low shrinkage and improved modulus of rapture indicative of hardness, mechanical strength, and resilient to shock and stress. The Dielectric constant (<12) of both samples indicating low charge storage, conformed to the requirement that ascertained they are good insulators. The Breakdown voltage of sample B (28.2 kv/mm) indicated higher dielectric strength and better resistance to electric current flow. It can be deduced therefore, the use of AGSS as additive in making porcelain for electrical application will enhance the mechanical strength as well as the viability of the porcelain's electrical insulating potency.

Key words: *Snail Shell, Porcelain, Insulator, physico-electrical properties, porcelain recipe*

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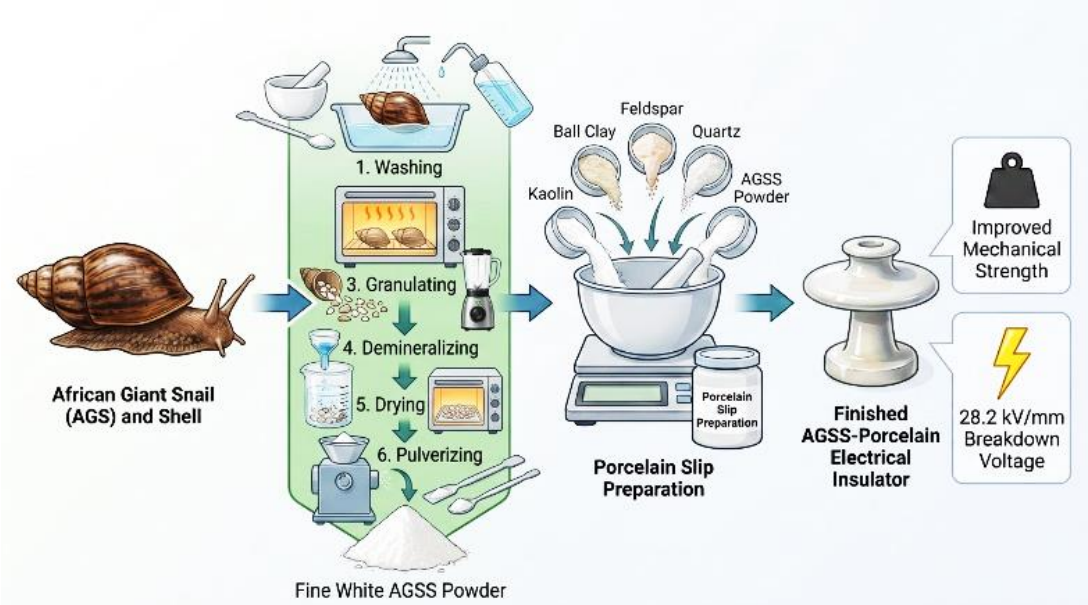

Introduction

The very popular kaolin, feldspar and quartz composition of the ceramic insulator, best referred to as porcelain, have ungrudgingly and substantially met the insulator need in electrical applications. In spite the great advantage of Kaolin-Feldspar-Quartz porcelain: non-sensitive to minor changes in composition, fabrication techniques and firing temperature (Kingery, 1960); no perfect insulator exists. An insulator may be composed for high-strength and high voltage applications, another for low voltage, high frequency and low shaft work, another for highest chemical resistance, and many more; depending on the composite materials and insulation use. Thus, no one porcelain is ideal for every electrical application considering major characteristics of various materials and the porcelain made therefrom: strength, porosity, chemical resistance, and the electrical physiognomies. The use of other materials, either as additives or alternatives, certainly is geared towards improving the plasticity of the mixture, filler and shape upholder during firing, and fluxes; the requisite essence characterizing good porcelain materials. Unquestionably, porcelain insulators have a wide range of application in the safe transmission of electricity.

On the consideration that the electrical application of porcelain is dependent on the electrical need it is intended to meet, the three key mineral compositions: kaolin ($Al_2Si_2O_5(OH)_4$), quartz (SiO_2) and feldspar ($K_2O.Al_2O_3.6SiO_2$) (Oladiji et al, 2010) may not always met all the electrical demand for a good electrical insulator. Besides meeting the intended electrical core for an insulator, the materials may not all be available and easy to come by

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for a producer. Therefore, seeking for other materials as additives; giving equal, improved and/or more desired insulating effect, is essential and very key.

Insulating materials are known to resisting free electron flow very well due to the material having very tightly-bound electrons. Nevertheless, 'with enough voltage applied, any insulating material will eventually succumb to the electrical "pressure" and electron flow will occur' (Csanyi, 2012). When the voltage applied on the insulator exceeds the insulator's threshold, there will be a rush of current through the material resulting in the breakdown of the molecular structure of the insulating material (Csanyi, 2012). The breakdown voltage, otherwise known as dielectric strength of insulating material: the voltage at which the molecular structure of an insulator is altered and allow the flow of current, varies with insulators and materials, their thickness as well as with the material composition of the insulator. The breakdown voltage of some insulating materials are shown in Tab. 1 below:

Table 1: Breakdown voltage comparison between materials (Csanyi, 2012)

Material	Dielectric strength (kV/inch)
Vacuum	20
Air	20 to 75
Porcelain	40 to 200
Paraffin Wax	200 to 300
Transformer Oil	400
Bakelite	300 to 550
Rubber	450 to 700
Shellac	900
Paper	1250
Teflon	1500
Glass	2000 to 3000
Mica	5000

The shells of Marine Mollusca (Oyster and Mussel) have been reported applicable as supplementary additive in animal feed (Houndonougbo et al 2012), composites and agriculture as an alternative liming material to restore soil chemical and microbial properties in upland soil for improved crop productivity. The shells of Oyster and Periwinkle have been used as concrete enforcement and pavement in waterlogged arears in most communities in southern Nigeria; Brass and Ekowe in Bayelsa state. Characterizing the shell of Mussel and Oyster, Hamester et al (2012) reported the presence of CaO, K_2O, SiO_2, SrO, Fe_2O_3, SO_3, MgO, Al_2O_3 as the constituent oxides. Adversely, Yoon et al (cited in Hamester et al, 2012) noted that the decomposition of Mollusca shell can increase the

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atmospheric concentration of acidic and harmful salts such as NH_3, H_2S and amines. African Giant Snail being a very nutritious food for both rural and urban societies. The shells are mostly considered waste for disposal; hence, the indiscriminate disposal of these shells possess a very heavy environment treat. Poor disposal and littery exposes the shells to heavy moving bodies like vehicles that break them; making the ubiquitous broken shells very ready to inflict puncture wounds. Following the indiscriminate disposal of land snail shells, Edokpayi, et al. (2015) noted that several degrees of injuries to children has been attributed to discarded snail shells. Unlike the shell of the marine Mollusca in concrete and pavement, that of the terrestrial snail has virtually no such handy application and the literature, besides in artistic designs, is sparse on its studies. African Giant Snail Shell (AGSS) is a highly neglected waste in the rural and urban settlements in most developing nations. Incorporating the AGSS in composites is a very highly considerable environmentally sustainable waste disposal and environmental protection approach. Nevertheless, in the Vee-Bee time and compaction factor analysis of composite material, attempt has been made in the application of Snail Shell Ash (SSA) as additive for partial replacement of ordinary Portland Cement (OPC). An attempt that gave 13.59% optimal increase in compressive strength and 4.43% tensile strength enhancement (Zaid and Ghorpade, 2014). Also, Snail shell has been applied, merely, in preparing adsorbent (chitosan) for the removal of heavy metal (Popuri, et al. 2009; Chatterjee, et al. 2009) and dye (Li and Ding, 2011). Therefore, within the ambits of present day indigenous technological ingenuity available, the terrestrial snail shell being what it is; a waste with yet no potential economic worth, can be studied as an enhancement or additive material in composites, ceramics and allied products. This work therefore seeks to understudy the snail shell applicability as an additive in the fabrication of porcelain for electrical application.

Literature

Archachatina marginata, ***Achatina achatina*** and ***Lissachatina fulica*** are the **African giant snail species,** the predominant species of land snail reared and consumed in Nigeria as food. As such its farming is one of the booming agricultural practices in Nigeria. There are members of the *Achatinidae* family, the air-breathing tropical land snail classified as a terrestrial pulmonate gastropod mollusc.



Figure 1: The species of African giant snail: (a) *Archachatina marginata*, (b) *Lissachatina fulica* and (c) *Achatina achatina*.

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In the shell of terrestrial snail, like other Mollusca known to contain chiefly Calcium Carbonate; other heavy metal salts and oxides have been identified. Heavy amounts of metals typify the waste materials found in the refuse dumps, backyard soil and garden plants of the Nigerian communities and settings where the African giant snail thrives. This predicts that the habitat of the snail is a presumptive factor for the component salts and/or oxides typical of the shell. Being an omnivorous terrestrial Mollusca that survives in the said heavy metal habitat, *Archachatina spp* is susceptible to containing metal oxides such as Calcia, Alumina, silica, Iron, Magnesia, etc. characteristic in porcelain and significant enough to serve as a compensating additive to improve and/or sustain the mechanical and electrical properties of a good porcelain insulator. This perceived potency of the AGSS has not been given concern irrespective of its abundance in Sub-Saharan Africa: Nigeria (southern), Ghana, and Ivory Coast.



Figure 2: Shell sample of *A. marginata* (Wikipedia); showing the calcia-rich, perfect white porcellaneous interior.

Like pearls, egg shells, shelly marine organisms; AGSS have calcium carbonate ($CaCO_3$) as its main component. Examinations using analytical instrument (XRF and FT-IR) have shown that land snail shell can be composed of up to 95 - 99.9% calcium as the major element (Edokpayi, et al. 2015; White, et al. 2017). Chemical and SEM analysis on Snail shell ash posited an over 60% active calcium oxide and an irregular semi-spherical particulate with porous surfaces (Tobins, Abubakre, Muriana, & Abdulrahman, 2018). In a review study on Portland cement, snail shell was used as source for 60 to 88 percent of the lime (CaO) requirement, served as micro-Filler for nucleation sites, acceleration for setting time and porosity reduction (Alhassan, Aboshio, & Uche, 2023). Calcia have widely been applied in the making of insulating materials like glossy paper, plastics and PVC to improved mechanical and electrical properties (tensile strength and elongation, and volume resistivity respectively). The inner layer in virtually all mollusk shells, like the white inner part in Fig. 2 is porcellaneous which results in the non-iridescent shine and ensuring resistance to cracking. Besides the high calcia content of snail shell; relative to kaolin and characterized by the perfect white of the inner surface, the porcellaneous toughness and crack resistant characteristics of the shell is implicit that it can compensate for the same effect as quartz. Hence, having been tried in cement making; can be studied as additive

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material to enhance the hardness and shock resistant effect attributive to clay and quartz in pottery, glass, enamel, ceramics and porcelain making. This is supported by the equitable abundance of the shell and the thermal glazing attribute of its contained $CaCO_3$ known for its substantial strength, hardness, toughness, brightness and whiteness; characteristic in glaze as oxides. In all sphere in glaze chemistry, CaO is advantageous to the innate features desirous of porcelain for electrical application: hardness, strength, and resistance to scratch, chemical attack and crazing (durability). A study proposal on AGSS noted toughness proclivity in composite: hollow block; and supposing from literature; outstanding viability in bulk density, low porosity and tensile strength. Hollow block with AGSS as additive has been reported to have higher bulk density and low porosity which translate to increased resistance to breakage, enhanced durability (Espada, Caber, Ison, & Franco, 2024), longevity and resistance to wear and tear. Calcium carbonate, the desired mineral in the shell is known to be typical of filling voids hence lowering porosity and ensuring rigidity of the produced material. Hence, the AGSS is considered promising in improving strength and toughness quality in composite materials.

Porcelain Composite

Porcelain is a vitreous clay body made chiefly from Kaolin, feldspar and quartz, and having archetypal attributes such as ceramic hardness, whiteness, semi-transparent and intensive impermeable to liquids. Other attributive features of porcelain is the marked ability to withstand mechanical stress and load as well as its high resistance to electricity and chemical attack. However, according to Al-Bermany (as cited in Al-Bermany et al. 2012), these characters are more affiliated to the hard porcelain. At elevated temperature, above cone 6 (>1200°C), the feldspar in the glaze flows, dissolving the other component particles into a viscous glassy melt that bonds the quartz particles forming the porcelain. Porcelains are typically known to have a smooth and pleasant white surface, though it can be translucent depending on firing temperature. White and translucent porcelains lack iron or impurity that can give it colouration. Hansen (in Digitalfire.com) referred to typical porcelains as a mix of clays (kaolin, ball clay and plasticizers), feldspar (the melter) and quartz (the low expansion filler and framework). Locally made porcelain are known to be much more plastic than industrial made because machines prefer bodies of very low plasticity. High plasticity is favourable for electrical insulator porcelain considering that the higher the plasticity, the lesser the drying shrinkage and the better drying performance that will be created. Ball clay as a glaze material for porcelain, even as low as 5%, is known for plasticity enhancement. Therefore, a glaze mix of low kaolin, increased feldspar above 25% and addition of ball clay drops the glaze maturity for porcelain to about cone 6 (1250°C **at 42°C/hr**) and favours plasticity. The desired features of a porcelain is dependent on its use, the materials available and the quantity applied. Porcelain as

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requisite for electrical application is essential for its inherent hardness, glossy; resistance to stress, leaching, chemical attack and crazing, hence its durability.

As an Insulator

A good porcelain insulator should possess properties such as high tensile and compressive strength, toughness, resistance to shock, scratch and chemical attack; low permeability, translucency etc. making it useful in the various fields of applications such as electrical, mechanical, chemical, structural (Snehesh, 2014), and domestic (dining and home use).

The above demands of a good porcelain for electrical applications follow from it not being limited to the prevention of passage of electricity alone, it also serves as a support to power lines and other power system equipment. Porcelain insulator, in literature, is often interchanged with ceramic insulator, however, irrespective that both are or can be used as insulators for electric fence system; they are not really same and are not terms to be used interchangeably. The difference resides with the clay composite and the firing temperature: while porcelain is made chiefly from kaolin and is fired at a higher temperature than ceramics that is made from variable coloured porous clay. Porcelain is more sustainable; withstanding moisture and harsher weather conditions than ceramics which is more susceptible to chipping and cracking in cold weather (Zareba®). Csanyi (2012) have reported that fundamentally, the materials used in making porcelain insulator include feldspar, Kaolin, flint (quartz), ball clay, and trivially talc.

Physical and Electrical Properties of a good Porcelain

The physical and electrical properties of a porcelain insulator can be estimate either by calculation or via direct measurement using instruments**.** Temperature and Heat resistance, Mechanical strength and Thermal ageing are very common physical attributes of a good porcelain The electrical properties of a porcelain insulator include Resistivity**,** Dielectric Polarization, Dielectric constant, Dielectric strength, Dielectric loses and Power factor**.**

The physical properties of a good porcelain insulator are consisted but not limited to Shrinkage, Porosity, Modulus of Rupture borne from the hardness, strength and durability of the porcelain. **Porosity** of the porcelain insulator determines its compressive, tensile and mechanical strength. The specification of the insulator (comprising Shrinkage, Porosity, Modulus of Rupture, etc) is standardized in the making process; that is, during manufacturing. The physical characteristics of a porcelain insulator can be presumed with its temperature resistance which is related to the thermal aging of the insulator. Thermal ageing, due to prolonged exposure of the insulator to heat resultant of prolonged usage, affects the mechanical properties of the material as a result of heat induced changes in the structure.

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Low temperatures, typical in ceramics making, is typical of making porous porcelain insulators that when exposed to prolonged heat, due to electrical energy, its mechanical properties and structure degradingly change. Due to mechanical defects or material make-up, weak portions/cracks or porosity could result thus encouraging absorption of moisture from air, reacts with it and the surrounding oxygen and enhance the porous and defected points. Consequently, the insulation potency will fall allowing the flow of leaked current and amassing of charges leading to electric energy losses and insulator failure. Weak portions in a porcelain insulator due to porosity or as a result of manufacturing defect, provides the point of breakage of the insulator when mechanical stress in the form of weight load is applied on it by its conductor.

Porcelain being used as an insulator in electrical applications has the tendency of being an insulating and dielectric material; having the capability to block the flow of electric current and to amass electrical energy respectively. Following that porcelain as an insulator, like a capacitor, stores electrical energy for which it is being considered to be destructible at a certain electrical potential. The electrical charge and energy capacity of the porcelain is represented and referred as the relative permittivity of the porcelain. The relative permittivity (Dielectric constant) value is expected to be less for insulating material but high for electric energy storage materials. Dielectric strength and the permittivity of insulators and dielectric materials can be estimated directly using the Megger Insulation Tester (MIT). When electric field is established in an insulator due to the electric potential supply, a dipole displacement occurs in the insulating material's elemental composition and is referred as insulating (dielectric) polarization. The polarization, born from the non-flow of electrical charges in the porcelain, aids in ensuring the absorbance of electric charge sponsored by the non-equipotential interior of the material. The amassing of energy resulting in the electron excitation of porcelain is what predicates the dielectric strength or the **Breakdown Voltage** (BV) of the porcelain. At the breakdown voltage, the accumulated energy become enough to excite the porcelain electrons beyond their electric current resistivity threshold and overcoming the electrical field strength of the porcelain making it to loss its insulating potency and becomes a conductor. The breakdown voltage of an insulating material is dependent and proportional to the age of the material, thickness of material, time of application of electric current, frequency of applied electric field, humidity and temperature. With V being the Breakdown Potential and *d* denoting the Porcelain Thickness, the Breakdown Voltage can be estimated.

$$BV = \frac{V}{d}\ (kV/mm) \quad (1)$$

A good porcelain, as insulator, does not conduct electricity hence carries no electrical load, however; when electric current tries to pass through such high resistance material,

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work is being done hence energy is being dissipated, often observed in the form of heat and referred as **loss power**. The heating effect, centers the assurances of the temperature and heat resistance properties of an insulator or insulating material. This attribute is typical with alternating current application as is the use of most porcelains in electrical works. The power loss of a porcelain can be measured or calculated applying the power factor.

Porcelain recipe

The oxides contained in the conventional porcelain recipe and the composite additives are known to bring durability, mechanical and electrical characteristics to the porcelain product depending on the oxide quantity in the mix. The key porcelain materials which additives can substitute or complement include: kaolin, feldspar, quartz and ball clay. These materials are known to contain characteristic oxides like Al_2O_3, SiO_2, CaO, MgO, Fe_2O_3, K_2O, SrO, Na_2O, etc., responsible for the varied desired and as well debilitating properties of a porcelain based on their quantity. These oxides in any material (including additives) contribute specific properties (favorable or otherwise) to the recipe and mix of the porcelain being made. The quality and properties of the recipe and the desired porcelain produced are inherent of the proportion of the oxide makeup. The presence and proportion of each oxide is responsible for one or more of these properties and character of the porcelain product: Thermal expansion (CaO, K_2O, MgO, Na_2O, SiO_2), Craze (MgO, CaO, SiO_2), Hardness (CaO, SiO_2, and Al_2O_3), Tensile strength, Durability Enhancer, Acid Resistance (Al_2O_3, CaO), Color, etc.

Kaolin and feldspar are known chiefly to providing the whiteness in porcelain, where in also, the kaolin is said to function in strength; holding the vitrifying feldspar and silica upright during firing and cooling. Feldspar is the mother-rock of kaolin and allied materials, and Pegmatite is the most common feldspar and the mother-rock of all feldspars (Hansen: in Digitalfire.com). As the amount of feldspar increases beyond 35%, the melting temperature decreases, however, melt below cone 6 (1200°C) is inherent of devitrification. This is implicit to saying feldspar proportion in cone 6 is the line for vitreous bodies known for significant glossy. Knowing that quartz is known to contain 100% silica, the attributes of silica (SiO_2) is intrinsic to the function of quartz in recipes and mixes. Low silica content to about 15% will favour crazing of the porcelain (Hansen, Digitalfire.com). Though silica as contain in kaolin and feldspar is different from that in quartz, it still exhibits same function irrespective of the containing material. This informed the essence of the reduced feldspar (≤ 25%) to regulate the silica content of the porcelain recipe.

The oxide in the porcelain materials can either enhance the thermal expansion of the porcelain recipe, lower it or be of intermediate effect. K_2O, Na_2O and Quartz (SiO_2) are attributive to high thermal expansion. Intermediate thermal expansion is typical with

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CaO. Increased amount of SiO_2 reduces the expansion of the recipe, but the lowest expansion effect of all oxides is attributive to SiO_2 in the presence of BrO and Al_2O_3 (Alumina). MgO, SrO, PbO and Al_2O_3 are effective expansion lowering oxides with MgO being renowned for its thermal expansion lowering potency. Besides the glossy, colour potency and akin expansion to CaO, SrO is also a typical flux for lowering thermal expansion of the porcelain.

Crazing is a characteristic of porcelain if not consciously averted hence, endeavour is towards ensuring its prevention. The incurrence of crazing in porcelain as well as forestalling it, is typical with certain materials and oxides in the recipe. In non-lead recipes, CaO helps to reduce crazing. MgO is known to be very characteristic with matteness that is resistant to crazing, so high craze resistance can be implicit of matteness due to the high MgO demand. Thus, MgO being the single most effective strategy to reduce crazing. The presence of SiO_2 is known also to prevent crazing, though not in recipes of boracic and feldspathic compositions where the KNaO distinctive with feldspar is typical of dominant crazing enhancement. Besides the outstanding anti-craze attribute of MgO, also; Hansen (Digitalfire.com) have noted that craze reduction in porcelain can be ascribable to iron oxide composition above 2%. High amount of K_2O is also known to contribute to porcelain crazing. This characteristic is often consistent following that K_2O and Na_2O almost always occur together, hence the existence of KNaO in glaze chemistry.

Hardness is one of the core characteristics of a better porcelain, however, this hardness is to a certain degree that supports durability and resistance to shock. Oxides like CaO, SiO_2, and Al_2O_3 are very classic with the attribute of hardness and strength; thus, high amounts are implicit of assured hardness and strength. Alumina is the prime of all the characteristic hardness oxides in porcelain making. Inadequate amount of Al_2O_3 in a porcelain recipe is predicative of porcelain that would lack hardness and strength at any temperature. The three oxides above, besides hardness and strength, are also typical in improving resistance to acids and chemicals.

Durability being a character required in any purpose driven material: lastingness and/or resistance to stress and forces, is a common characteristic required of products like porcelain. Oxides, chiefly SiO_2 and Al_2O_3 are known to effluences the stability and durability of porcelain products. It is noteworthy, the amount of Alumina (Al_2O_3) is significant in virtually all porcelain, next only to SiO_2; nonetheless, Al_2O_3 is the premier in ensuring the durability seconded by SiO_2. The durability effect of SiO_2 is best with high amount. Though Fe_2O_3 behaves as a refractory antiflux oxide and acts like alumina in glaze melts, it is however known to often reduce durability in porcelain glaze (Hansen, Digitalfire.com).

Oxides that heighten **viscosity**, and thus the surface tension, can be attributed to ensuring matteness: MgO is typical in this regard when its amount is high against other fluxes.

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Alumina, known to be refractory, a stiffener and significant in most glaze, likely will enhance viscosity thus, Hansen (Digitalfire.com) noted that addition of CaO in a recipe of ≥ 0.1M Al_2O_3 will help reduce the viscosity of the glaze melt to allow free flow. The prominent alkalis in glaze chemistry, K_2O and Na_2O, are inherent to high melt viscosity of a porcelain glaze: with K_2O being more intrinsic. Beside the lowering potency of CaO in Al_2O_3 mix, PbO is a renounce anti viscosity flux in glaze.

Most porcelain employed in electrical works are often exposed to atmospheric influence like acid rain and chemical aerosol deposits. This contact is conversant with leaching and chemical enhanced degradation of porcelain materials. Porcelain resistance to leaching and chemical attack can be influenced by the proportional presence of oxides like Silica, Alumina and lead. Increased amount of SiO_2, small amount of Al_2O_3 and PbO in combination with Boron oxide are capable of ensuring resistance to leaching and chemical (acid) attack. CaO in combination with lead and potassium daunt leaching. Conversely, irrespective of the high Al_2O_3 in feldspar, high feldspar contents can be responsible to chemically unbalanced recipe that is susceptible to leaching.

Every Porcelain, depending its use, is made in the **colour** borne from the components in the recipes: some oxides and their containing materials are responsible for colouring. CaO have been reported to ensure good colour representation: characteristic for its white colouration but gives yellow colouration in composition with the reddish brown Fe_2O_3. Moreover, the presence of iron is particular with either of these colours: reddish, blackish, pinkish, greenish, yellowish or maroon, grey, brown and deep brown. Iron oxide (Fe_2O_3) is the iron compound most synonymous with glazing and pottery which when alone (sometimes exist with FeO), it produces glossy brown glaze. Iron compounds are the most common coloring agent in porcelain and ceramics such that if not well checked and applied can constitute nuisance in the product, staining an intended white or bright coloured glaze (Hansen, Digitalfire.com). SrO is reported to have an appreciable colour response in glaze than CaO. SrO and K_2O host the brightest colour of all fluxes second only to PbO (Hansen, Digitalfire.com).

Therefore, known for its characteristic calcium content, the AGSS additive is expectantly potent in ensuring decrease and/or control of melt fluidity and viscosity, reduce crazing, improve whiteness, ensure strength and hardness, assure the porcelain's resistance to leaching and chemical attack. These attributes are characteristic of mechanical strength and durability in the porcelain.

Methodology

In accordance with Budnikov's recommendation for electrical porcelain insulator production (Anih, 2005), percentage composition for the composite mixture was made. The processed raw materials in powdered form were carefully weighed out, thoroughly

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mixed in a mortar using stirrer, and adding about 8% water to the mixture until the mixture becomes homogenous. Sample A was composed of Kaolin, Ball clay, Feldspar and Quartz all purchased from bridge head market Onitsha. Processed AGSS was introduced in Sample B as an additive to compensate for quartz. The AGSS used in this study was sourced from snail vendors in Ekowe community in Southern ijaw LGA, Bayelsa state of Nigeria.

The AGSS was washed thoroughly with clean water then twice with distilled water to ensure the removal of dirt and any chemical impurities inherent with normal water. The shell was dried in the oven at 100°C, cooled in a desiccator. A small amount was pulverized to characterize for chemical composition using FTIR. The granulated shell of about 1.0 mm was demineralized using dilute HCl at a mixing ratio of 2:1. The mixture was heated at approximately 70°C for about 1hr in a water bath. The drained granulated shell residual was washed with distilled water till neutrality was observed with litmus paper. Then was dried for 2hrs at 100°C and cooled in a desiccator. The dried demineralized AGSS granule was pulverized by grounding and sieved using sieve sharker. The demineralized and pulverized AGSS referred as the AGSS additive was characterized for chemical composition.

Table 2: Percentage composition of the materials for the porcelain making

Samples	Kaolin (%)	Ball clay(%)	Feldspar(%)	Quartz (%)	Snail shell	Total
A	40	5	25	30	-	100
B	40	5	25	25	5	100

After mixing the component materials, a rectangular porcelain mold was 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 1300 °C, for a soaking period of 6 hours. At the end of the firing, the samples were gradually cooled.

Physical and Chemical Characterization

The calcium content of the processed snail shell powder was verified using Fourier transform infrared (FT-IR) spectrophotometer.

Physical characterization considered on the porcelain samples where total shrinkages and the water absorptivity of the porcelain. The reduction from the original wet dimension of the porcelain to its final fired dimension; defined as the total shrinkage exposes the cracking and distortion resistance of the final porcelain. These properties were computed using the expressions bellow:

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$$Total\ Shrinkage\ (TS) = \frac{Lw-Lf}{Lw} x100\% \quad (2)$$

Where:

L_w = Wet length

L_f = Fired length

Table 3: Physical Characterization of the fired porcecain

Sample	L_w	L_f	TS	w_s (kg)	w_d (kg)	W_{sp} (kg)	W.Abs	P
A	17.50	15.31	12.50	2.0009	2.00	1.74	0.046	0.35
B	17.50	15.40	11.98	2.0008	2.00	1.76	0.038	0.32

Using the soaking weight (w_s) and the dry weight (w_d), the water absorption was computed:

$$Water\ Absorption\ (W.Abs) = \frac{Ws-Wd}{Wd} x100\% \quad (3)$$

As a function of weight difference; the ratio of soaked weight and dry weight to soaked weight and suspended immersed weight, the porosity of the porcelains: A and B were estimated:

$$Porosity\ (P) = \frac{Ws-Wd}{Ws-Wsp} x100\% \quad (4)$$

Where:

w_s = soaked weight

w_d = dry weight

w_{sp} = suspended immersed weight

The strength of the porcelain insulators with regards to withstanding tensile stress was investigated by determining their modulus of rupture. The average values of height, H (cm) and the width, B (cm) of two broken parts were determined and recorded. The modulus of rupture was then calculated:

$$Modulus\ of\ Rupture:\ \sigma_f\ (N/cm^2) = \frac{3PL}{2BH^2} \quad (5)$$

Where:

P = Peak breaking load (N)

L = Span length (cm)

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B = Width of the sample (porcelain)

H = Height of the sample from the fracture

Table 4: Estimation of Flexural breaking of the Porcelain samples

Sample	P (kN)	L (cm)	B (cm)	H (cm)	Modulus of Rupture (σ_f)
A	19.60	15	7	3	70×10^2
B	20.16	15	7	3	72×10^2

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 mega-ohms. The Megger insulation tester is essentially a high-range resistance meter – Ohm meter (Ωm) 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 breakdown voltage which is a destructive test were also carried out. The electrical properties result were recorded, see Tab. 6.

Table 5: Chemical composition of the Pulverized snail shell

Composition	$CaCO_3$	SiO_2	$MgCO_3$	Al_2O_3	$SrSO_4$	Fe_2O_3	PbO	IO
Untreated Shell	95.69	1.12	0.24	1.05	0.37	0.82	0.06	0.03
Demineralized Shell	98.21	1.10		0.10	0.26	0.32		

The ease in leaching of the contained metals in the snail shell can be attributed to their high potency of these metals to form metal-chloride complexes in reaction with hydrochloric acid (HCl).

Table 6: Physical properties

Sample	Total Shrinkage (%)	Water Absorption	Porosity	Modulus of Rupture
A	12.10	0.046	0.35	70×10^2
B	11.95	0.038	0.32	72×10^2

Table 4 illustrated a reduction in shrinkage that could likely be due to the additive, AGSS. The 11.95% total shrinkage of the AGSS additive sample B is approx. equal to the acceptable total range of 12% - 17% for standard electrical porcelain, indicating the porcelain has a very low proclivity to distortion and cracking. The increase in water absorption observed in sample B was slight, implying presence of impurities that permited reaction to form slag. The proximate porosity, though lower in sample B, demonstrates

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the void filling tendency of AGSS enhanced calcite proportion. The modulus of ruptures for sample A and B were above the 69 MPa flexural breaking threshold for safety and sustenance of mechanical loads, line tension, and thermal variations in power transmission line. The high value of sample B indicating improved mechanical strength and capability of withstanding tensile stress is attributive to the high CaO percentage inherent with the AGSS additive. The 72 N/cm^2 for the AGSS additive sample implied the sample is freer of micro-cracks.

Table 7: Capacitance, C (pF) and Dielectric Constant, ε_r at different frequencies (Hz)

Frequency (Hz)	**50**	**100**	**1000**	**5000**	**50**	**100**	**1000**	**5000**
	Sample A				**Sample B**			
C (pF)	7.2	6.8	6.7	6.5	7.1	6.9	6.7	6.4
ε_r	6.4	6.3	6.0	5.0	6.88	6.7	6.35	5.2

The Dielectric Constant values of the snail shell porcelain (sample B) at the considered frequencies correlated very closely with the porcelain from conventional materials (sample A), having values below 12 which conform with the requirement for a good electrical insulator. The low values imply low charge storing capacity characteristic of a good insulator. The electrical test of Table 4 indicated enhanced breakdown voltage; the maximum voltage sample B can withstand was shown to be higher than that of sample A.

Table 6: Electrical Properties

Sample	**Total resistance (MΩ)**	**Total resistivity (MΩcm)**	**Breakdown voltage (kv/mm)**
A	4900	4.0 x10^{10}	27.9
B	4900	4.2 x10^{10}	28.2

Table 4 showed that both samples have very high resistance to electric current flow. The breakdown voltage indicating the amount of current that can destroy the resistive potency of the porcelain insulator has a higher value for sample B implying the porcelain sample can insulate the flow of high amount of current. This is very likely due to the high CaO content of the Snail Shell considering its tendency of improving hardness, strength, and encouraging resistance to chemical attack, mechanical stress/shock and structural collapse (crazing) of the porcelain.

The samples A and B gave significant Total resistivity that explained both porcelains irrespective of size, can insulate electric leakage even in unfavorable environmental condition like during high temperature. The increased resistivity in sample B can be

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attributed to the presence of calcite content inherent in the AGSS. The high resistivity indicated the AGSS additive porcelain can better insulate the flow current from the transmission lines. When compared with the specification of commercial porcelain insulator, the samples showed higher values of breakdown voltages with sample B having the highest value of 28.2 kv/mm. This supports that sample B has a better electrical insulating capacity.

Table 7: Electrical Properties of Commercial Porcelain compared to Samples A and B

Electrical property	Commercial	Sample A	Sample B
Modulus of rupture (N/cm^2)	Not measured	70×10^2	72×10^2
Resistivity (MΩcm)	$2.7x10^4$	$2.66 x10^4$	$2.72 x10^4$
Breakdown voltage (Kv/mm)	25	27.9	28.2
Dielectric constant, ε_r (at 50Hz)	6.35	6.39	6.88

The high Dielectric constant (6.88) suggest the porcelain is suitable for power transmission application rather than electronics where signal transmission is of essence: that is, power transmission where high-voltage, thermal stability and structural strength are key concerns. The high electrical energy storage capability inherent with high dielectric constant allows for built-in surge absorption and indicates the porcelain's excellent stability and high dielectric strength.

Conclusion

Two samples of porcelain insulators were produced: Sample A, produced with the customary materials while the shell of *Archachatina marginata* (African giant snail) was added in sample B as an additive. The lower shrinkage and higher Modulus of rapture of the sample B is illustrative of hardness, significant tensile and/or mechanical strength and resistance to stress and shock. The low porosity reveals that the porcelain as support and insulator can withstand atmospheric pressure; humid conditions. Conforming to standard, being far below 12, the Dielectric constant values for the varied frequencies illustrated that the porcelain was a good electrical insulator. The higher electric current resistance shown by high value of the breakdown voltage supports the postulation that both samples are good insulators with sample B showing a better electrical insulating capacity: having the highest value of 28.2kV/mm. The tabulated results, showing the physico-electrical properties of the porcelain samples, showed that 5% of the 96.5% CaO composed African giant snail shell as additive in a porcelain recipe can significantly improve the physical and electrical properties of the porcelain as electrical support and insulator.

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