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Recyclination of Waste Sanitary Ware Product for Production of Ceramic Socket

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The study explores the use of recycled sanitary ware waste products as raw materials in the production of ceramic sockets. The waste is typically discarded in construction and renovation environments, offering a sustainable approach to solving melting issues on wall sockets. The research involves collecting raw materials like kaolin, ball clay, and feldspar from discarded ceramic toilets, sinks, and bathtubs, and processing them into suitable ceramic powders. The aim of the research involves using the processed ceramic materials to solve the melting issue on wall sockets. It also employs an experimental methods in which various techniques, including powder form processing, mixing, pressing, drying, and firing, to produce ceramic sockets using recycled sanitary ware waste products. Sanitary ware waste product was varied with kaolin by 5% increase interval. The results shown from the tests carried out that incorporating recycled sanitary ware waste improves the physical, mechanical, and dielectric strength properties of ceramic sockets The results provide insights into the feasibility and potential of using recycled sanitary ware waste products in ceramic socket production. The study shows that the more sanitary ware waste is added, the more

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it increases its strength, it also indicated that the reuse of sanitary ware waste having more dielectric strength than kaolin and potential as a good electrical insulator. The study also reveals that the reuse of sanitary ware waste products can be varied with kaolin or used without kaolin.

Keywords: Sanitary ware waste; clay material; insulating test; physical test.

1. INTRODUCTION

Production is the process of mixing a variety of material and immaterial inputs to create a consumable product. It is the act of producing output, such as a good or service that has value and adds to people's utility.

Scientific exploration and application of ceramic materials can be considered a crucial step in the development of well-finished local ceramic products with high marketing value. Especially, an expansion of scientific knowledge in the area of porcelain body and processing can further help the small and medium-scale ceramic industry embarking on the production of ceramic wares for domestic and international markets. Ceramics is an attractive and excellent product for a wide range of applications. Unfortunately, the ceramic industry involves high energy consumption, resource waste, serious pollution, and high-quality products [1].

According to Kitouni [2], domestic electrical appliances such as home entertainment systems, vacuum cleaners, irons, washing machines, electric cookers, microwave ovens, water heaters/boilers, refrigerators/freezers, and air conditioners are steadily being added to our daily living spaces to improve our quality of life. The above-mentioned domestic electrical gadgets are typically powered by a wall socket and require a significant amount of electricity. As a result, the demand for power from the house power distribution box increases at the residential level. These electrical appliances are installed without regard for the wall socket power capacity at the specific point in the house, and the overload protection is provided by the power distribution box circuit breaker [2].

With the advancement of human material living standards, people are beginning to place a greater emphasis on a product's worth and psychological experience, rather than only its functions and low price. The ceramic socket is an industrial product, industrial design intervention is required if the ceramic socket is to be integrated into the area and environment. Ceramic sockets are one of the most basic electrical installations in our home, and they must be installed in every room. It was previously overlooked in the residential environment, but now since plugs are used so frequently in our daily lives, people demand higher-quality sockets. Consumers want a socket that is not only secure and trustworthy but also attractive and trendy, allowing them to blend into their home surroundings more readily.

According to Nwachukwu and Lawal [1], the chemical composition of ceramic products is determined not only by the overall chemical composition of the raw materials, but also by the individual compositions, crystalline structures, and particle sizes. Minor impurities can also have a big impact, making it difficult to make quantitative predictions about the best composition that could be used for the production of ceramic sockets. It has also been discovered that the proper particle size of the materials used, as well as their crystalline formation, are required to produce high strength in any electrical home appliance.

According to Kashim,(2004), porcelain insulator 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 insulators arise mainly from the formation of glass and the mineral mullite within the fired body at these high temperatures [3]. Porcelain was a veritable stoneware due to its very high density, industrial fast firing cycles, tangible mechanical strength, and wear resistance [4].

Recycling has been used as one of the major sources of raw materials in industries; it helps to reduce the importation of raw materials. It is believed that the recycling of sanitary ware waste is beneficial as it allows the preservation of resources and improves public health and safety, According to Lee and Igbal [5] possibility of recycling ceramic waste for raw materials should be encouraged as an alternative to material development to the success of ceramics sub-sector of the nation’s economic and industrial growth. Ceramic raw materials, whether recycled from ceramic waste or sourced naturally, remain viable provided it possesses the chemical properties of the raw material needed for production. Ceramic raw materials have special chemical characteristics; their properties are dictated by the type of atoms and bonds present between them.

Specifically, this study looked into the re-use of recycled sanitary ware waste products in the manufacture of a ceramic socket to reduce the amount of used sanitary ware products discarded in the industry and as well as solving the melting issue on wall sockets by replacing them with a ceramic body. It is well clear that sanitary ware products contain more of the mullite phase of high percentage of kaolin according to Akinbogun, [6]. Sanitary ware product forms mullite from kaolin when it is fired at 1200°C, making the change formation that occurs during firing irreversible; due to its composition and lack of electron movement compared to the glassy phase.

The sanitary ware products are mixed with other materials like quartz, kaolin, and feldspar to make a porcelain insulator equipment composition. Furthermore, these possess several distinct characteristics, such as increased durability and resistance to degradation; decrease heat as well as electrical employment.

2. MATERIALS AND METHODS

Material: The materials involved in this investigation are sanitary ware waste, ball clay, kaolin, feldspar, and Quartz. Feldspar, quartz, and kaolin were sourced from Auchi in Edo state Nigeria. Meanwhile, sanitary ware waste was gotten within the Federal University of Technology, Akure Nigeria.

Methods: The raw materials dug from the research area which were packed, bagged, and transported to the laboratory for experimental analysis. The ball clay material was first sun-dried for two weeks to remove moisture content in order to ease the pounding and grinding of the materials. The dried samples were then crushed to break the lumps using mortar and pestle and further pulverized using a grinding machine to achieve a very fine particle size. While the sanitary ware materials were broken down into smaller sizes for easy access for pulverization it was then sieved with the mesh of 150mm; all the materials were measured and poured into the balling to the mill at the dried start for more particle size and the homogenous mixture then use to compose the test sample.

The materials were thoroughly mixed together with water and were molded into a wooden cubic mold of 50 × 50 × 50mm in accordance with the standard precision of an Automatic Digital Readable machine (ADR). Using Olupot composition [7], kaolin was varied with sanitary ware waste and five replicates of each sample composition were also made in order to have enough samples for the tests that were carried out. The samples produced were sundried for some weeks to remove moisture from it before it was fired in an electric kiln to 1150º C.

Table 1. Olupot Composition Table

Kaolin	Ball Clay	Feldspar	Quartz
30	15	30	25

Source Olupot [7]

Table 2. Body Composition of Sample Test

Samples	Sanitary ware waste (S.W.W)	Kaolin	Feldspar	Ball clay	Quartz
A	5	25	30	15	25
B	10	20	30	15	25
C	15	15	30	15	25
D	20	10	30	15	25
E	25	5	30	15	25
F	30	0	30	15	25

Tests Procedure: The following tests were carried out on the samples produced to ascertain the suitability of the materials and compositions for ceramic socket production; the procedures are as well explained:

Water Absorption: The percentage of the relationship between the weight of the water absorbed to the weight of the dry samples was determined using the below formula:

$$\text{Water absorption (A\%)} = \frac{\text{W} - \text{D}}{D} \times \frac{100}{1}$$

Where,
W = weight of the water absorbed specimen
D = weight of the Dry specimen.

This test was carried out after the firing of the test samples; in which the test samples were boiled for two hours and soaked in the water for 14 hours immediately after offloading them from the kiln just to make absorb enough water. The weight of the dry test samples was subtracted from the weight of the soaked test tiles, divided by the weight of dried test samples, and the result obtained was multiplied by 100.

Mechanical analysis: The mechanical properties of samples produced were conducted at the Department of Civil Engineering, School of Engineering and Engineering Technology, FUTA, using Automatic Digital Readout Machine. The sample was loaded into the machine each after the other and force were applied to the sample to determine the peak load at which the sample failed. The compressive strength of the sample was measured from the force applied and the cross-sectional area of the samples as shown

$$\text{Compressive Strength} = \frac{\text{Force Applied (N)}}{\text{Cross} - \text{Sectional Area (mm)}}$$

Electrical analysis: The dielectric property test was conducted on the samples produced at the National Electrical Management and Service Agency (Akure Area) under the Ministry of Power and Mines, Federal Secretariat, Igbatoro Road, Akure. The electric property of the samples produced was done in two ways to determine the:

i resistivity of the samples; and
ii dielectric strength of each sample.

These two aims were done using a meggar tronic, which has two terminal points with the cathode and anode, the cathode and anode were placed on two ends of the copper wire that was tied around the sample so as to determine their resistivity and their strength according to each sample.

Two samples were each tested using the meggar tronic so as to determine an accurate result, each sample was placed on both 500 mega ohms and 1000 mega ohms to determine their strength and resistivity. The records of all the samples tested were collected around their time frame which was 30 seconds each.

Apparent Porosity: This is expressed as a percentage of the relationship of the volume of the open pores in the specimen to its exterior volume. The apparent porosity values were measured using ASTMC20-00 by:

1. Determine the dry weight (D) in grams
2. Placing the test specimen in water, boil it for about 3 hours and then keep them Entirely covered with water for a minimum of 12 hours before weighing it
3. Determine the weight of each sample
4. Mopping up each test specimen lightly with a moistened smooth linen or cloth to remove all drops of water from the surface and determine the saturated weight by weighing in air. The apparent porosity is then calculated using this equation:

$$\text{AP}(\%) = \frac{\text{W}-\text{D}}{V} X \frac{100}{1} \quad (3)$$

Where,
W-D = Actual Volume of the pores of the specimen
V = Exterior Volume of the specimen (V is equivalent to W-S).

The test was carried out by measuring the dried-fired test sample’s weight (D). Records of samples boiled for two hours and later soaked for fourteen hours were also measured by weighing the samples (S). The immersed weight i.e. the suspended weight of the fired test samples in water was taken also.

3. RESULTS AND DISCUSSION

Objective 1: Analyze the Phase Chemical Composition of the collected Raw Material using X-ray Fluorescence: Each sample material was sent to Engineering Material Development Institute (EMDI) in order to carry out the Elementary Composition of each sample, the sample that was sent included, Sanitary ware waste (S.W.W), Kaolin, Ball clay, Quartz, and Feldspar.

Chemical Composition of Ball Clay from Ishan Ekiti: Fig 1, Alumina (Al_2O_3), Silica (SiO_2), and iron oxide (Fe_2O_3) had the highest content present from the result of the materials. Alumina which is present in the materials helps them become more plastic and it also increases the bonding strength of the materials, Silica which had the highest content helps the materials increase in hardness and strength while iron oxide helps the samples to be reddish in color. The result gotten agreed with Motta, Zanardo, and Cabral, [8] principle which indicates a high percentage of impurity (Fe_2O_3) resulting in reddish color after it has been fired.

Chemical Composition of Feldspar from Auchi: It was observed that this study agreed with Mostafa, El-Fadaly, and Abo Breka, [9], the result gotten from the X-ray fluorescence test indicates a high percentage of silica (SiO_2), Alumina (Al_2O_3), and also high percentage of potassium oxide (K_2O) as followed in decreasing order from Fig 2. The result gotten gave more reddish color, and the temperature gotten was reduced by the presence of flux ($K_2O. Al_2O_3.6SiO_2$). The feldspar used for this study resulted to be a potash feldspar with a chemical formula of ($K_2O. Al_2O_3.6SiO_2$).

Chemical Composition of Kaolin from Auchi:

Observation: The X-ray Fluorescence result agreed with Idowu, [10] from Fig 4, kaolin contains the highest percentage of silica and alumina, it also shows that potassium and iron oxide was present in the composition. The silica helps in the shrinkage and firing behaviour, alumina that was present help in the strength, and thermal stability meanwhile the iron oxide added to the reddish colour resulted in the sample. It was also observed that the kaolin contains impurities.

Chemical Composition of Quartz from Auchi:

Observation: Fig shows that SiO_2 was abundant more than other elements, the quartz used for this study contains little iron oxide Fe_2O_3 which indicates a sign of impurity. It also resists thermal shock, improve the thermal stability of the samples, and help withstand high temperature at 500 – 1000 (MΩ). The result of the X-ray Fluorescence agreed with (Ferreira, Correia, & Gonçalves 2010) that quartz (SiO_2) containing iron oxide (Fe_2O_3), lithium oxide, sodium oxide or potassium oxide (K_2O) have impurity in it.

Chemical Composition of Sanitary ware waste:

Observation: The X-ray Fluorescence result from fig 4 indicates silica has the highest percentage in the table, alumina was also indicated to be more abundant, potash feldspar had little percentage but iron oxide which is a sign of impurity was shown to have more content than alumina and potash. This results in the more sanitary ware waste is added to the composition the more it becomes reddish in nature.

Objective 2: Vary Kaolin Composition (%) to sanitary ware waste to determine its suitability for Ceramic Sockets Production: Each composition had a different colour outcome. Similar to the other samples, Sample A had a lighter colour than Sample B, and the more sanitary ware waste was present in the composition, the more the colour changed and intensified after being fired. At the dried state, all samples had the same colour which was white before it was fired.

Objective 3: Determine the Functionality, Physical, Strength, and Dielectric strength:

Dielectric Strength: This is the breakdown voltage at which the body of each sample cannot resist the current that passes through the materials. Each sample was tested at 1000 MΩ using an Insulation Tester at the National Electrical Management and Service Agency(Akure Area), Ministry of Power and Mines, Federal Secretariat, Igbatoro, Akure, Ondo State.

Dielectric Strength Test at 1000 MΩ: Table 3, it was found that samples D to F, which contained the highest amounts of sanitary ware waste, had greater dielectric strength than samples A to C at 1000 MΩ. This indicates that sanitary ware waste is an excellent material for boosting ceramic socket insulating strength. The sanitary ware waste has been fired and it has attained to it mullite phase before been reuse, when been re-fired it increases in strength and dielectric properties of sample D – F compare to sample A-C which has more of kaolin.

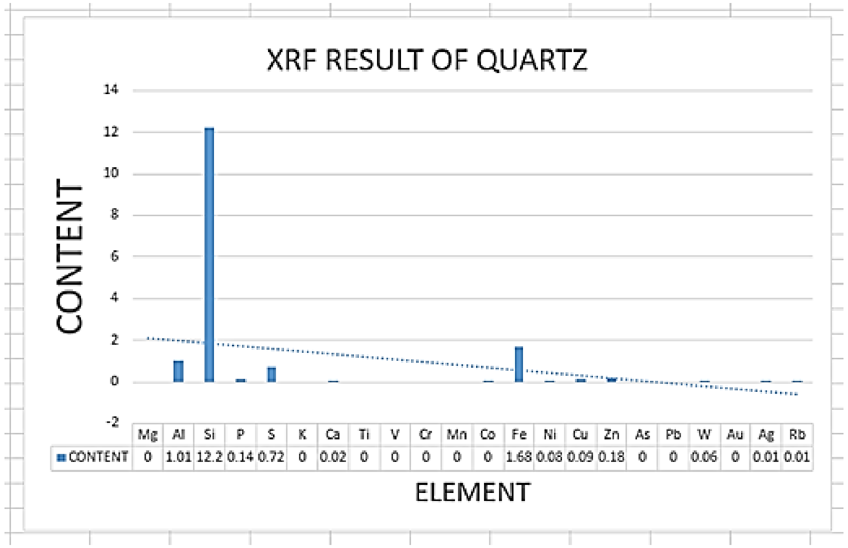

Fig. 1. XRF Result of Quartz Result

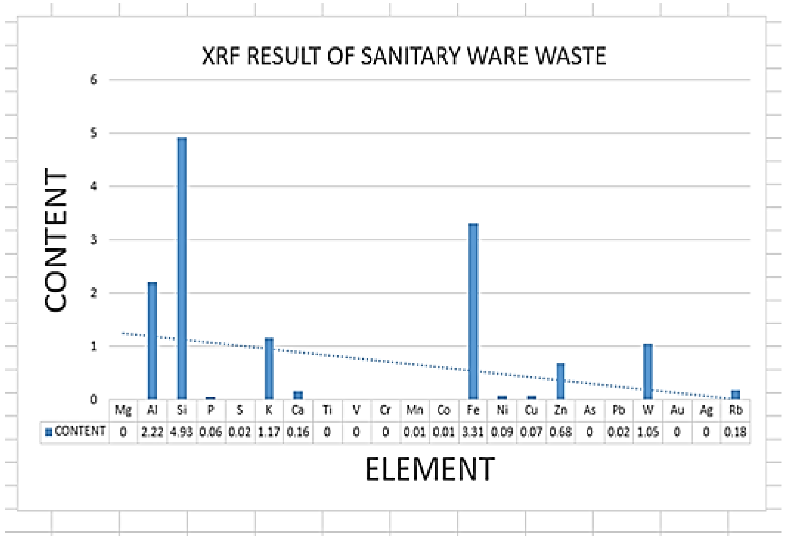

Fig. 2. XRF Result of Sanitary Ware

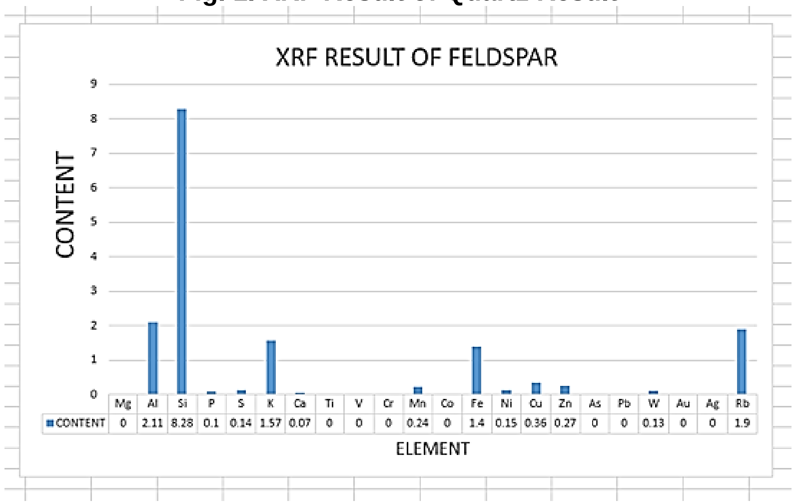

Fig. 3. XRF Result of Feldspar

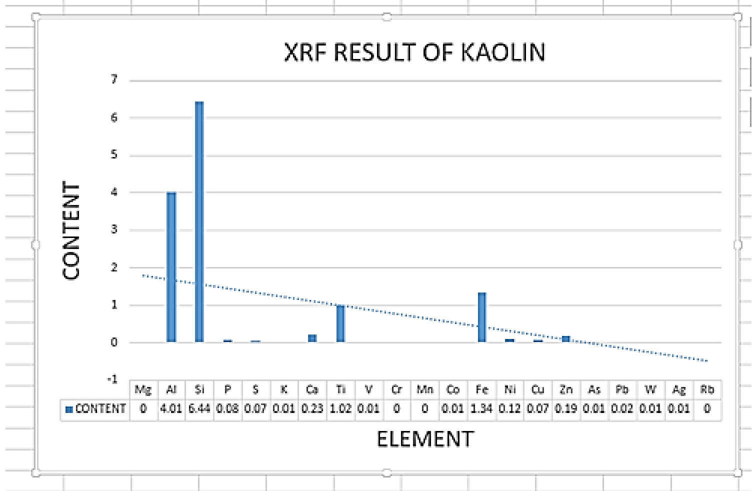

Fig. 4. XRF Result of Kaolin

Fig. 5. Wet sample

Fig. 6. Fired Sample

Table 3. Dielectric Strength Test at 1000 MΩ

Sample	1000MΩ
A	337
B	457.5
C	246
D	536
E	739
F	610.5

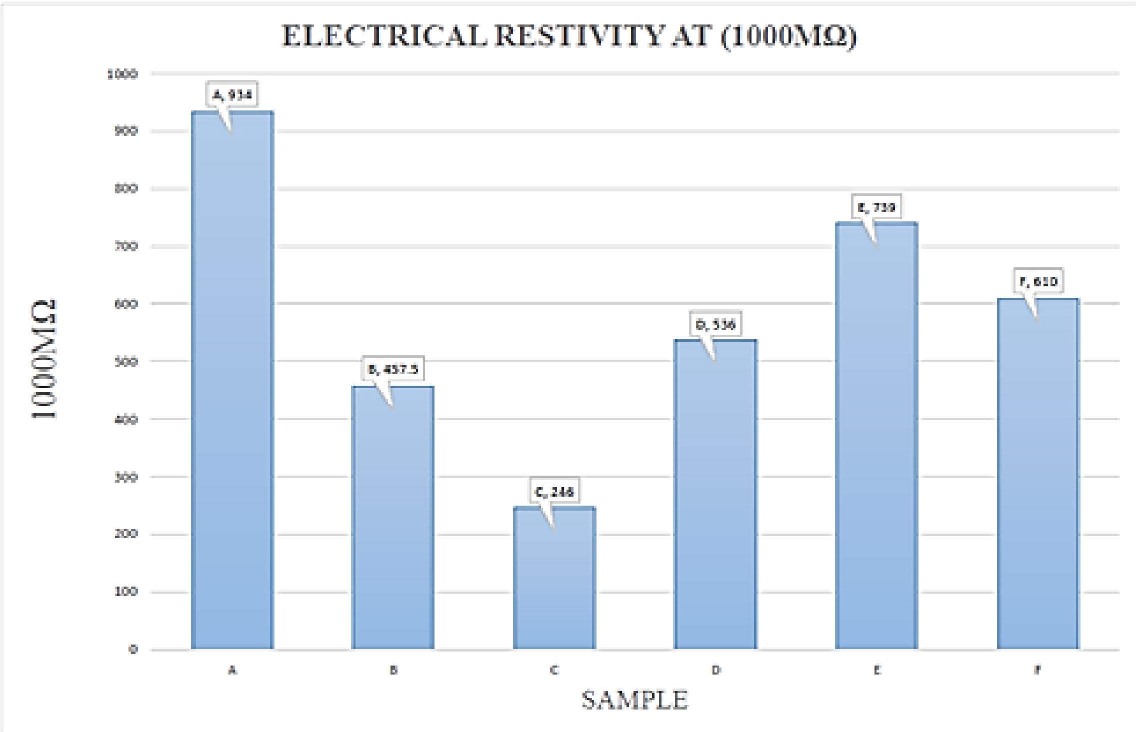

Fig. 7. Insulating Test at 1000MΩ

Observation: Fig. 4 graph displays the results of a dielectric strength test at 1000 M; samples A to C showed a downward trend and contained more kaolin than sanitary ware waste, whereas samples D to F contained more sanitary ware waste and showed a better upward trend. The graph showed that sample E was the highest and sample C was the lowest. The strength of the insulating increases with the amount of sanitary ware waste.

Fig. 8. Testing the Insulating sample

Compressive Strength Test: The result of this compressive strength Test was achieved at the Department of Civil Engineering, Federal University of Technology, Akure. Using a machine called Automatic Digital Readout Machine. Rasheed [11] the best mechanical and dielectric properties can be achieved by higher mullite and quartz content with a lower amount of glassy phase and the absence of microcracks, the increase in the re-use sanitary ware waste has help sample D-F have higher strength result compare to sample A – C which had more kaolin.

Table 4. Compressive Test result

Sample	MPA
A	9.75
B	11.5
C	10.45
D	15.35
E	14.4
F	19.75

Apparent Porosity Test: Table 5 shows Sample A had the highest apparent porosity and sample D had the lowest apparent porosity following the principle of ASTM C20/C20M-19 [12] which states that for refractory materials to act as an insulator it must have a low apparent porosity as possible because higher porosity might result in decreased strength, decreased resistance to thermal shock, and increased susceptibility to corrosion and erosion.

Shrinkage Test: The result shows that two samples each were produced and used to take the shrinkage their shrinkage level and the result of each sample at wet state remains constant within 60mm meanwhile the result dried state varies as they all tend to dry. Sample C and D had both results which are 56.5 at their fired state, this indicates that from 60mm sample C and D shrinkage by only 5.8% mm, the result from this shrinkage test was displayed in tabular form.

Objective 4: Produce Prototype from the Resultant Objectives: The design from the 3d modeling on Cinema 4d gives a unique description of how the mold would produce, the mold was produced using 1.2kg of Plaster of Paris to 1 liter of water. The model was built using asbestos and was cast with the mixed P.O.P and water, The casted molds were allowed to dry and used in pressing out 20 sockets in general.

The pressed socket was dried at room temperature and then fettled for a good finishing appearance, the socket was fired in an electric kiln for about 1150ºc the casted socket was glazed and then coupled with their switch, metals, and screw before it was been tested.

Objective 5: Glaze: The ceramic sockets that were fired were deep into an ash glaze that was produced by Jamiu and Fadairo [13], the total number of 7 ceramic sockets was glazed and the temperature attained was 1140ºC using an electric kiln in an oxidized state. The kiln was allowed to cool for two days before offloading the wares (sockets) from the kiln. The glaze came out in two different colour because of it position in the kiln, the colour was deep brown and brownish colour.

Table 5. Apparent Porosity Test

SAMPLE	The volume of the Sample (m^3)	W-D (gram)	APPARENT POROSITY TEST (%)
A	106.9	30.65	28.6
B	114.3	27.25	23.81
C	111.2	30.9	27.79
D	106.65	22.8	21.37
E	116.35	32.5	27.9
F	107.25	27.95	26.06

Table 6. Shrinkage Test result

SAMPLE	WET(mm)	DRY(mm)	FIRED(mm)	PERCENTAGE (%)
A	60	58.5	55.5	5.1
B	60	59	56	5.1
C	60	59	56.5	4.23
D	60	60	56.5	5.8
E	60	56.5	54	4.42
F	60	55.5	52.5	5.4

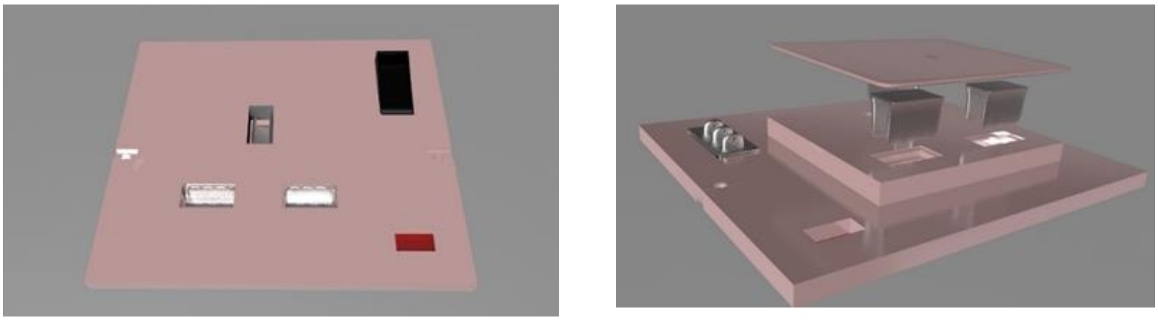

Fig. 9. Fired Samples of the Socket

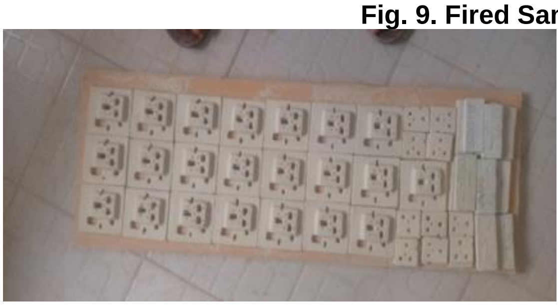

Fig. 10. Fired Samples of the Socket

Fig. 11. Fired Samples of the Socket

Fig. 12. Glazed Ceramic Sockets

Source: Author Fieldwork, 2023

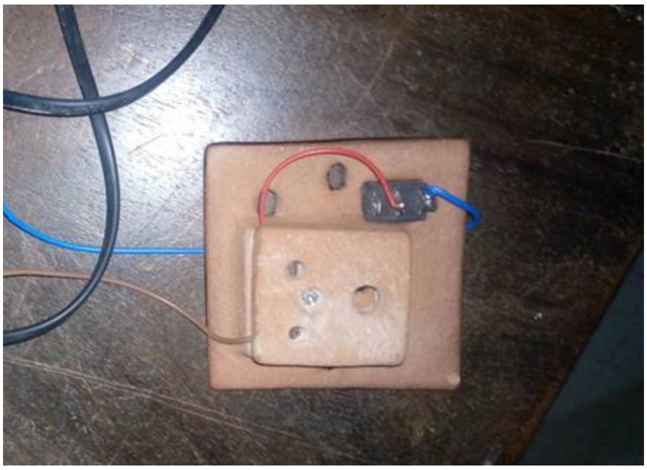

Fig. 13. Ceramic Socket Fixing
Source: Author Fieldwork, 2023.

Objective 6: Fixing of Ceramic Socket: The fixing of the ceramic socket was carried out by connecting the wire to their positive and negative part respectively, the live was connected to the switch while the neutral was connected to the copper element. This was coupled by using a screw and screwdriver, a meter was used to check the amount of current that flow into the ceramic socket [14,15].

4. CONCLUSION

The finding from this study has proven that the re-use of sanitary ware waste products can be varied with kaolin or used without kaolin in sample F, this study also shows that sanitary ware waste can solve the melting issue in a plastic socket from the result of the stated test that was carried out. The sanitary ware waste has been proven to have more strength compare to kaolin when it is been re-use. When a sanitary ware waste is been re-fired it helps to increase is needle like structure (mullite Phase) which helps in its dielectric strength and compressive strength property's.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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