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# DEVELOPMENT AND PRODUCTION OF CERAMIC TILES FROM WASTE BOTTLE POWDER (MILLED GLASS)

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## ABSTRACT
Ceramic tiles were produced from a varying mixture of clay and milled glass and the physio-chemical properties of the samples were determined. 0–70% weight milled glass was added to clay mineral. Seven samples were obtained before the clay which serves as binder was not able to hold the mixture together. It was discovered that the porosity of the tiles increased as the percentage weight of the clay material decreased and milled glass increased. Also, the compressive strength of the tiles peaked at sample 5 (60% clay & 40% milled glass). Results obtained showed that samples containing from 30-60% weight of milled glass in proportion with clay percentage had the best formulation properties.

**Keywords:** Clay, Milled glass, Ceramics, Tiles.

## INTRODUCTION
Ceramics tiles are inorganic, non-metallic solid materials comprising of metals, nonmetals or metalloid atoms that are primarily held in ionic and covalent bonds. They are usually used for covering roofs, flooring and wall beautification.

The bodies for the industrial production of "traditional" ceramic materials (tiles, bathroom fixtures, tableware) are composed of various typologies of raw materials in amounts characteristic of the product desired. The composition of the body and the conditions of treatment determine the transformation that involves the raw material and mainly defines the final characteristics and field of employment of the finished product [1, 2, 3].

Raw materials required for the production of ceramic tiles includes: quartz & Feldspar (which serve as a source of Silica and Alumina to give the tiles the desired strength) and clay from a good source to serve as binder. For the sake of this research, milled glass was used as the primary source of Alumina and Silica. Clay is a common name for a number of fine-grained, earthy materials that become plastic and tenacious when moist, and that becomes permanently hard when baked or fired [4, 5, 6].

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Throughout the world, clays are the main raw materials exploited in the fabrication of various ceramic products for building construction.

Clay products such as ceramics wares, burnt bricks, and roofing and floor tiles are cheaper and durable building materials than cement especially under tropical conditions. They should therefore be utilized to reduce over dependency on cement particularly in Nigeria [7, 8, 9]

## RAW MATERIALS PREPARATION

### Clay material

The clay material was sourced from Afuze, Owan-east area of Edo state. The samples were dark grey in color and dry in appearance. The clay material was beneficiated by soaking it in water for 2 days and then sieved with a mesh of 350µm to eliminate ions and other debris materials. The clay was then further characterized and the chemical analysis is shown in the table below:

**Table 1.** Chemical Analysis

| S/N | Parameter | Level of Detection (%) |
|---|---|---|
| 1 | $SiO_2$ | 46.09 |
| 2 | $Al_2O_3$ | 35.38 |
| 3 | $Fe_2O_3$ | 0.200 |
| 4 | CaO | 0.126 |
| 5 | MgO | 0.055 |
| 6 | $Na_2O$ | 0.050 |
| 7 | $K_2O$ | 0.044 |
| 8 | MnO | 0.005 |
| 9 | Moisture | 2.341 |
| 10 | L.O. I | 0.002 |

### Milled glass

The glass was sourced from different areas of Lagos state, milled to powder and sieved with a 100µm mesh. The milled glass was then added to the clay material in different proportions, which is shown in the table below:

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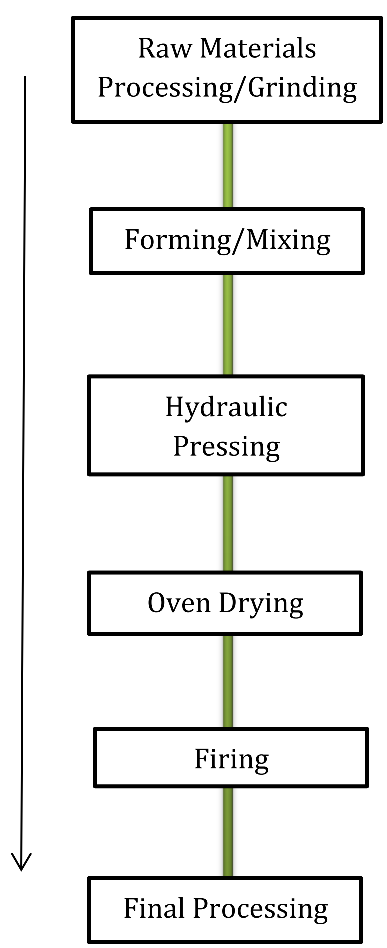
**Table 2.**

| S/N | Clay Material (%Wt.) | Milled glass (%Wt.) |
|---|---|---|
| 1 | 100 | 0 |
| 2 | 90 | 10 |
| 3 | 80 | 20 |
| 4 | 70 | 30 |
| 5 | 60 | 40 |
| 6 | 50 | 50 |
| 7 | 40 | 60 |
| 8 | 30 | 70 |
| 9 | 20 | 80 |
| 10 | 10 | 90 |

**PROCESS TECHNOLOGY**

A flow chart of the process technology:



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**TILES PRODUCTION**

Clay and milled glass were measured in the right proportions according to the chart shown in the table above, using a 0.001mg sensitivity weighing scale. The samples were sieved with a 100µm mesh and mixed to homogeneity. The granulated powder mixtures were then uniaxially compacted using hydraulic press under a pressure of 50 MPa for the tiles (12 cm ×13 cm) and circular-shaped test specimens (3 cm ×7 cm). The pressed specimens were held overnight and then dried at 90±100°C for 48hrs in an oven. Dried specimens were fired in a laboratory-type electrical furnace (Thermolyne 46200) at the rate of 5 °C/min). Technological parameters values were measured after firing steps. The firing procedure used involved heating the samples at a temperature of 1100°C and soaking for 2–3 hours.

This procedure was repeated for all the formulations in the table above, and after sample 7, the formulation was not effective again for tiles production.

**Plate 1.** Fired tile samples

**TEST PROCEDURE**

1. **Green Shrinkage**
   The original length of the tiles was measured and recorded, and after oven drying the length was measured again. The green shrinkage ($G_S$) was given as:
   $$G_S = Shrinkage\ after\ oven\ drying \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$
2. **Fired Shrinkage**
   After firing the length of the sample was measured and recorded. The Fired shrinkage ($F_S$) was then given as:
   $$F_S = Shrinkage\ after\ firing \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

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3. **Porosity**
   The sample was soaked in water for 2 hours and after which the weight was recorded. Porosity which is the amount of void in the solid was calculated by:
   $$\frac{M_2 - M_1}{D} * \frac{1000}{V} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$
4. **Apparent Porosity**
   This is the ratio of the volume of open pore spaces in the sample, to the volume of the entire solid. It was calculated by:
   $$\frac{W_{sa} - W_{da}}{W_{sa} - W_{sw}} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (4)$$
   Where; $W_{sa}$ is Saturated weight, $W_{da}$ is dry weight in air and $W_{sw}$ is weight when soaked in water.

5. **Linear Shrinkage**
   The bricks were pressed in green condition in a rotary disc of size (3 cm ×7 cm). The linear shrinkage was calculated using the formula below:

   Linear shrinkage = percentage of dried shrinkage + percentage of fired shrinkage.

6. **Compressive Strength**
   The compressive strength test was done using the Tensometric Machine. The samples of diameter 3cm was subjected to compressive force, loaded continuously until failure occurred. The load at which failure occurred was then recorded.

7. **Bulk Density**
   The bulk density ($D_b$) was calculated for each test specimen using the results of the apparent porosity test, thus:

   $\boldsymbol{Db}$ =$\boldsymbol{True\ eightBulk\ Volume}$ = (Wda/Wsa-Wsw) …………(5)

**RESULTS & DISCUSSION**

Tests were carried out on the circular-shaped test specimens (3 cm ×7 cm) and the results obtained are discussed below:

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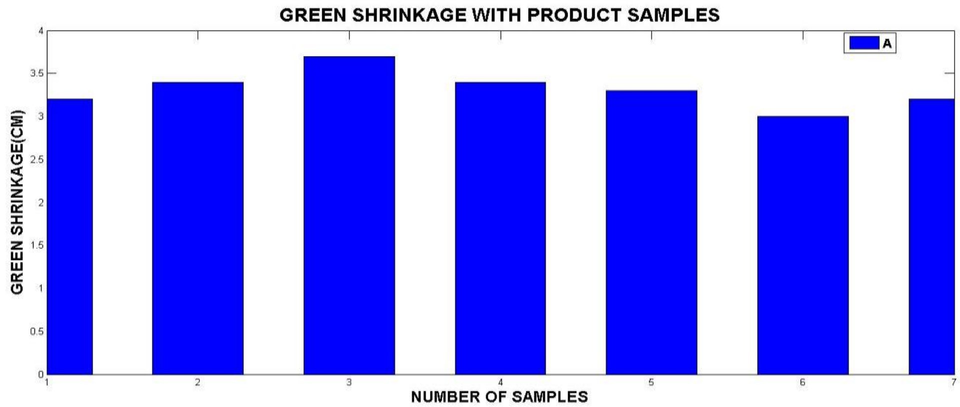


**Figure 1.**

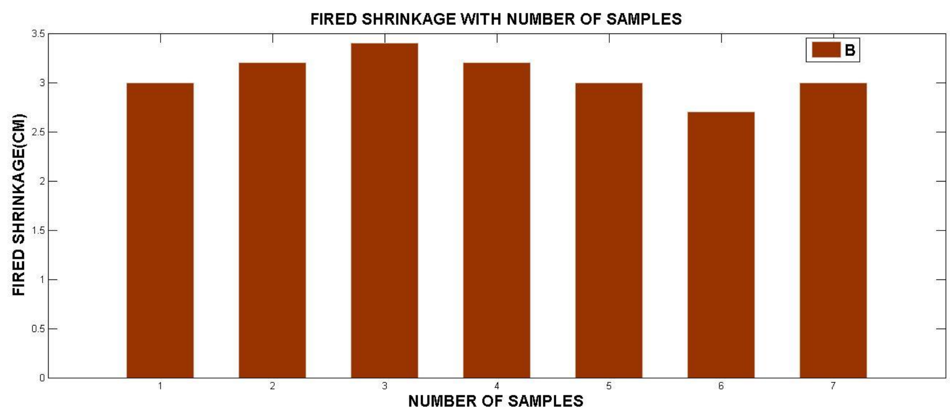


**Figure 2.**

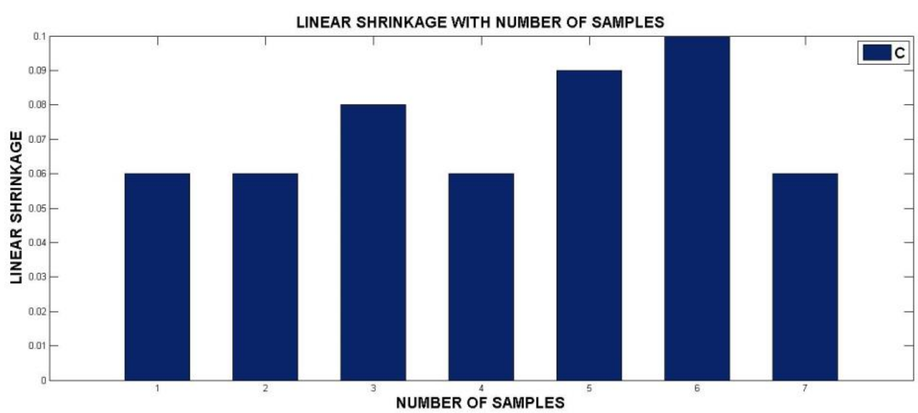


**Figure 3.**

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Comparing figure 1, 2, 3, with Figure 4, there seems to be a correlation between green shrinkage, fired shrinkage and linear shrinkage of the samples with their density, as they appear to be inversely proportional. Low density resulted to a high shrinkage value in the samples.

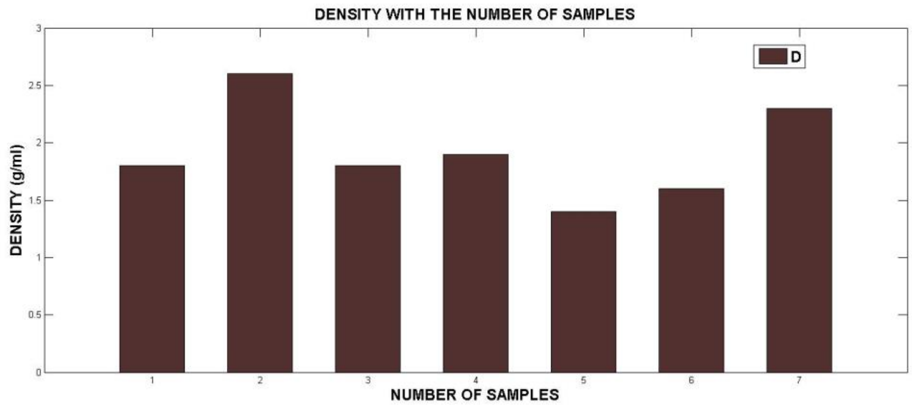


**Figure 4.**

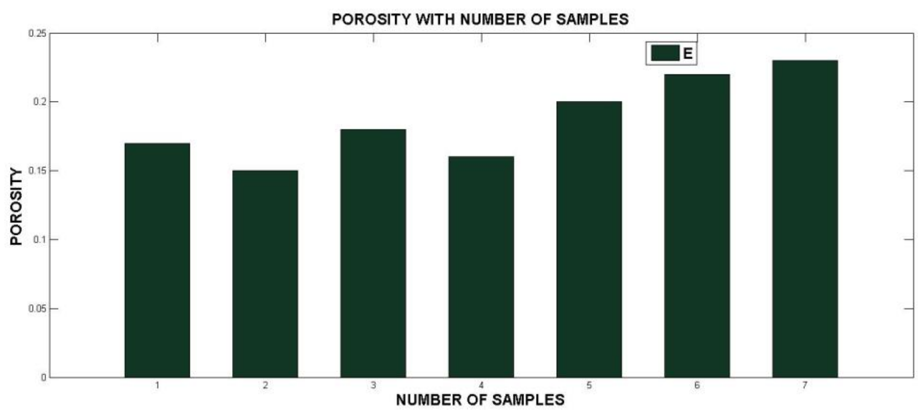


**Figure 5.**

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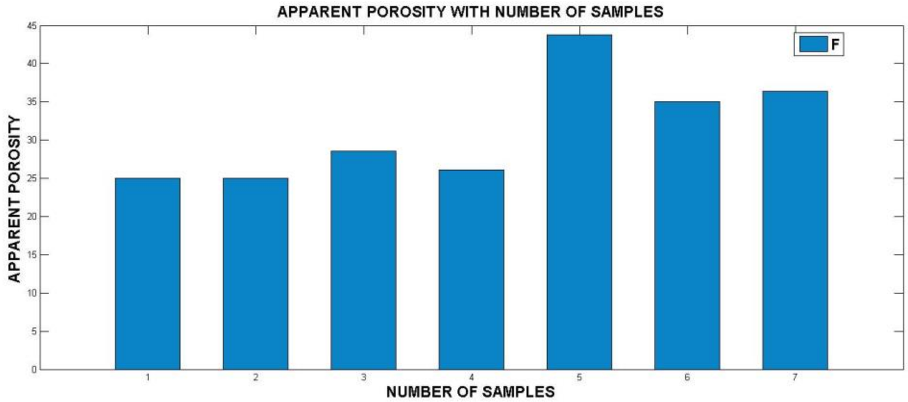


**Figure 6.**

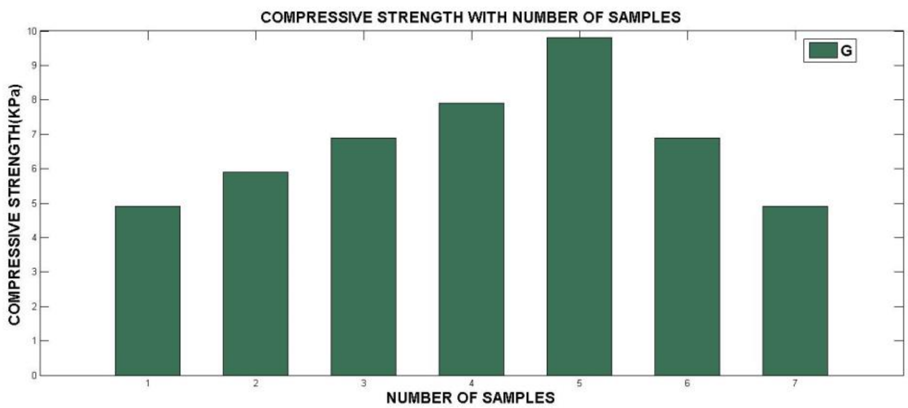


**Figure 7.**

From figure 5, 6 and 7, it is observed that the porosity of each sample varies directly with its compressive strength.

The average compressive strength values are given in Figure 7. The compressive strength of the samples peaked at sample 5 with samples 3, 4, and 6 falling within the acceptable ranges.

## CONCLUSION

The physical properties of milled glass were evaluated to determine its suitability as industrial raw material. From the study, it is obtained that milled glass could be used as a rich source of silica and alumina for ceramic products. Obviously, different sets of criteria are important to the production of any specific blend for a specific industry. From this study, it is inferred that, milled glass can be used for tiles, sanitary wares, utensils and refractory production.

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