

# Characterization of Combination of Glass and Porcelain Waste in Ceramic Production

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## Abstract

*Ceramics have become well known all over the world due to its properties, such as hardness, corrosion-resistant and withstand high temperatures. Ceramics are made up of three components which are clay, quartz and feldspar. The shortage and rising cost of ceramics raw materials leads to the use of glass waste as the alternative raw material to replace the conventional raw material (feldspar). The environmental issue like pollution also can be reduced since the glass waste can be treated wisely. The percentages of glass waste addition used in this study are 0 wt.%, 2 wt.%, 4 wt.%, 6 wt.%, 8 wt.% and 10 wt.% respectively. The sintering temperatures used are 1100 °C, 1150 °C and 1200 °C. The physical properties, mechanical properties, microstructure studies were the parameters used to measure the compatibility of addition of glass waste to porcelain waste in ceramic production. 1200 °C and 2 wt.% of glass waste were the optimum sintering temperatures and weight percent of glass waste addition to the porcelain waste that produced the best sample of ceramic.*

**Keywords:** Glass waste (GW), Porcelain, Ceramic, Compressive Strength and Bulk Density.

## 1. Introduction

Ceramics can be described as inorganic, non-metallic solid made up of either metal or non-metal that can withstands high temperatures. Generally, ceramic properties includes hardness, corrosion-resistant and brittle. Basically, the ceramics are made up of clay, quartz and feldspar as the raw materials but nowadays waste materials like glass waste (GW) powder are used in ceramic production. Clay contributes to the mullite formation during firing and eases the shape-forming process. Quartz acts as filler that can reduce the deformation and shrinkage of fired body. Feldspar acts as fluxing agent during firing that improves the growth of mullite crystals as well as allows the densification of ceramic body through filling the interconnected pores ( Garba et al., 2019).

Production of vitrified and translucence porcelain have been one of the most important development in the history of Ceramic industries (Owoeyen et al., 2019).

Due to the recent increasing interest in the environmental preservation and solid waste management, use of waste glass and porcelain as substitute of traditional ceramic materials have interestingly increased (Owoeye et al., 2019). Porcelain is a durable and harder material used to produce tiles, mugs cookware and have similar compositions with ceramics (Bertolissi, 2014). Research by Durumin iya et al., 2020 found out that, as a result of porcelain durability and non-degradability, its disposal as landfill lead to the environmental pollution such as soil damage and ground water contamination (Duruminiya et al., 2020).

It was reported that, use of waste glasses have proven to have potential alternative and the way forward as an alternative industrial product. It was further revealed that, use of waste glasses as replacement of sand improved physical and mechanical properties of ceramic such as volume shrinkage, apparent porosity and water absorption (Bendjama et al., 2020).

For this study, the combination of glass waste (GW) and porcelain waste (PW) were used as the raw material in the production of ceramics. The samples were tested in order to analyze whether the combination was compatible and able to use in the production of ceramics (Jasim et al., 2019).

The glass waste has the good potential of becoming the alternative raw material in ceramic production. This is due to its properties of acting as a fluxing agent that can replace the feldspar. Addition of glass waste also lead to the formation of vitreous microstructures during the sintering process (Durumin iya et al., 2019).

## 2. Materials and Methods

### 2.1 Sample preparation

Glass and porcelain waste were crushed with agate mortar, sieve and treated with 1 molar of HCl acid to increase the purity of the sample and remove unwanted material. The powder was dried in an oven at 110 °C for 24 hours to remove the moisture content and mixed using ball mill machine at a speed of 250 rev/sec. PVA was added to each composition as a binder, grind with agate mortar and dry pressed into pallets using Hydraulic Pressed Carver at 200 mm diameter by 3 mm thickness in a cylindrical shape. The solid sample is then vacuum pressed with American Cold Isostatic pressing machine (CIP360) for about 5 min and then sintered at different sintering temperature of 1100 °C, 1150 °C and 1200 °C in a Prothern Furnace at a heating and cooling rate of 1 °C/min and 5 °C/min respectively. Scanning Electron Microscopy (SEM) and X-Ray Diffraction analysis (XRD) were used to find the effect of glass waste and porcelain waste on physical and mechanical properties of ceramic.

## 3. Results and Discussions

### 3.1 Physical Properties

To determine the effect of glass and porcelain waste on ceramic production, physical properties such as mass loss, volume shrinkage and bulk density were determined. Figure 1 shows the graph of mass loss vs composition. From figure 1, it is clearly shown that, the pattern of mass loss for all sintering temperatures are similar, which is decreasing order. The highest of mass loss was the sample with 0 wt.% of GW at 1150 °C which was 9.8505 g while the lowest of mass loss was the sample with 10 wt.% of GW at 1100 °C which was 1.8560g. (Durumin iya et al., 2019) relate the increase in the mass loss to the increase in the number of closed porosity. Overall, the additions of GW contribute to the decreasing mass loss of sample for all compositions and sintering temperatures. Figure 1 shows the graph of mass loss vs composition.

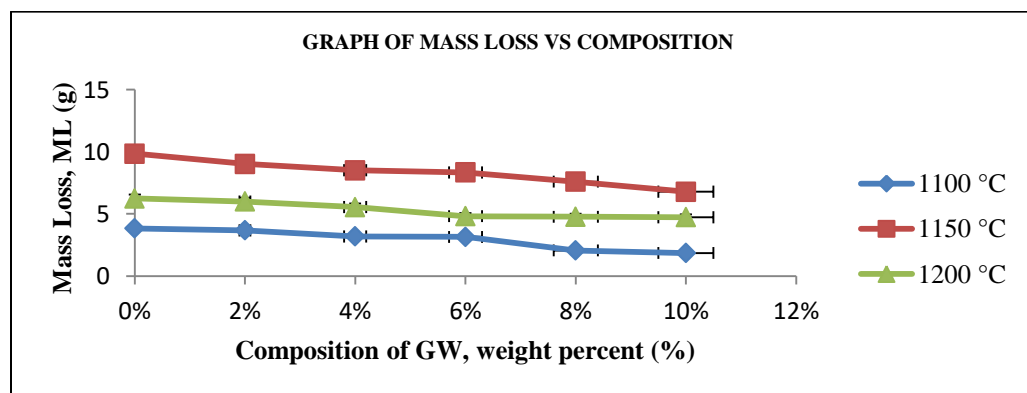


Figure 1: Graph of mass loss vs composition

Figure 2 shows the graph of shrinkage vs composition. It is important to note that, the patterns of volume shrinkage for all the sintering temperatures shows an increasing order. But, there is slightly decrease of volume shrinkage for the sample that contained 6 wt.% of GW at 1100 °C, this is probably due to the lower sintering

temperature and composition of Glass Waste. The highest value of volume shrinkage was the sample with 10 wt.% of GW at 1150 °C which is 64.71 mm<sup>3</sup> while the lowest value of volume shrinkage is the sample with 0 wt.% of GW at 1100 °C which is 16.25 mm<sup>3</sup>. Overall, the additions of Glass Waste contribute to the increase of volume shrinkage of sample for all compositions and sintering temperatures. Figure 2 shows the graph of volume shrinkage vs composition.

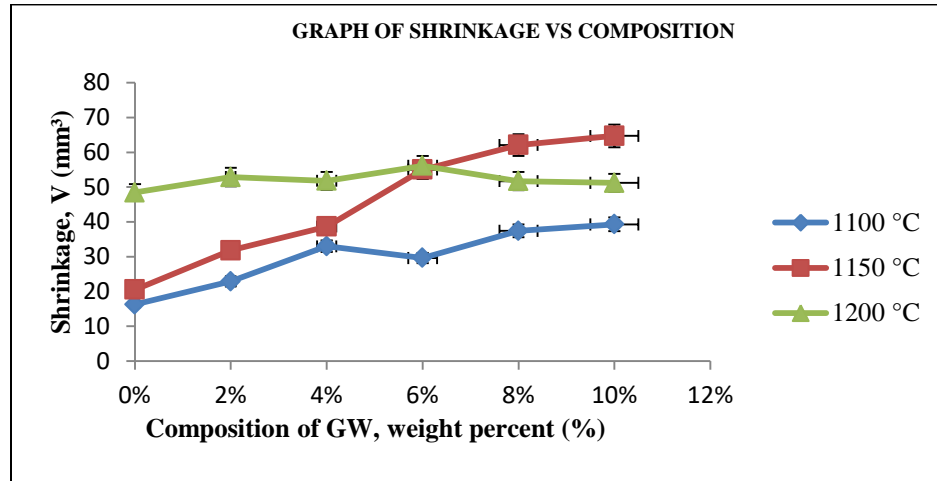


Figure 2: Graph of shrinkage vs composition

Figure 3 shows the graph of bulk density vs composition. It may be observed that, the patterns for all sintering temperatures shows an increasing trend. But, there is slightly decrease of bulk density for the sample that contained 4 wt.% and 6 wt.% of GW at 1100 °C, 6 wt.% and 8 wt.% of GW at 1150 °C and 8 wt.% of GW at 1200 °C. The highest of bulk density was the sample with 10 wt. % of GW at 1100 °C which is 1.7577 g/cm<sup>3</sup> while the lowest of bulk density was the sample with 6 wt. % of GW at 1100 °C which is 1.6845 g/cm<sup>3</sup>. Overall, the additions of GW contribute to the increase of bulk density of sample for all compositions and sintering temperatures, Durumin iya et al., 2019 related this to the mullitisation and increase in the liquid phase which lead to complete densification (Durumin Iya et al., 2019). Figure 3 shows the graph of bulk density vs composition.

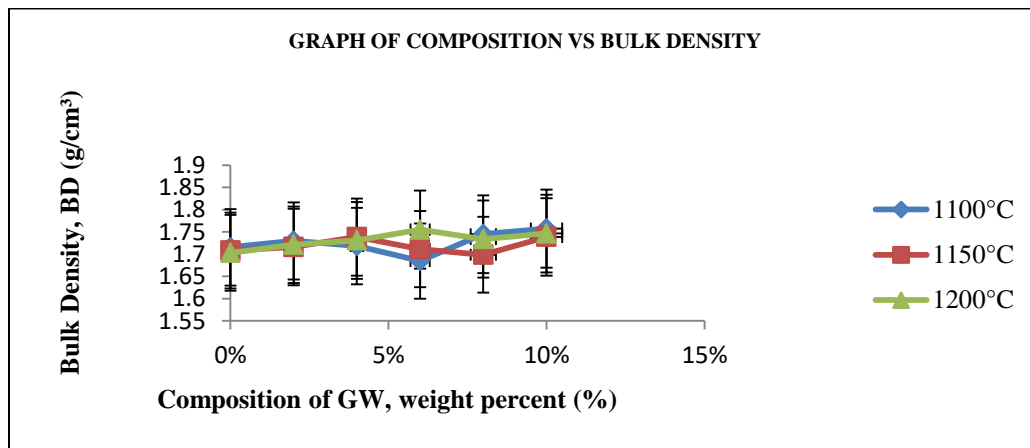


Figure 3: Graph of bulk density vs composition

### 3.2 Mechanical Property

The mechanical property measured in this study is compressive strength. This is because compressive strength of ceramic determines its mechanical property (Durumin Iya et al., 2020). To determine the effect of glass waste on ceramic production, compressive strength is one of the most important parameter. Figure 4 shows the graph of compressive strength vs composition of glass waste.

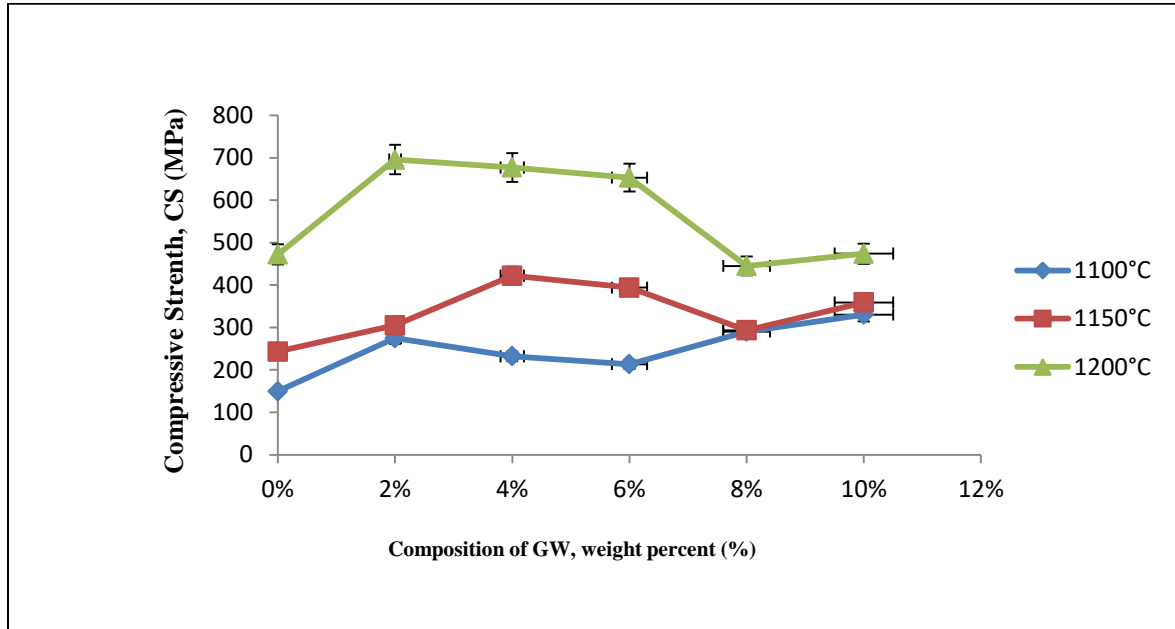


Figure 4: Graph of compressive strength vs composition

From the above figure, the compressive strength shows an increasing trend due to addition of Glass Waste and sintering temperature, but there is slight decrease of compressive strength for the samples that contain 6 wt.% of GW at 1100 °C, whereas for sintering temperature 1150 °C the decrease was noticed at 6 wt.% and 8 wt.% of GW addition and 4 wt.%, 6 wt.% and 8wt.% of GW at 1200 °C respectively. The highest value of compressive strength was determined at sample with 2 wt.% of GW at 1200 °C which is 695.882 MPa while the lowest value at sample with 0 wt. % of GW at 1100 °C which is 149.450 MPa. Overall, the additions of Glass Waste contribute to the increase of compressive strength of the samples for all compositions and sintering temperatures.

### 3.3 Microstructure Studies.

#### 3.3.1 X-Ray Diffraction Analysis (XRD)

Figure 5 shows the result of XRD of the samples that are sintered at different sintering temperatures and compositions. First, the samples sintered at 1100 °C with 10 wt. % addition of Glass Waste has a crystalline phase named Quartz (22%) and Anorthite (78%). Similarly, the samples sintered at 1150 °C with 10 wt. % of GW has a crystalline phase named Quartz (41.6%) and Anorthite (58.4%). Thus, the samples sintered at 1200 °C with 2 wt. % of GW has crystalline phases named Quartz (69.9%) and Mullite (30.1%). Quartz is one of the main mineral in the raw material, while anorthite is one of the members from feldspar group that appeared according to the increasing percentage of glass and mullite transform during the high firing temperatures, and this lead to complete densification and thus improved mechanical property of ceramic.

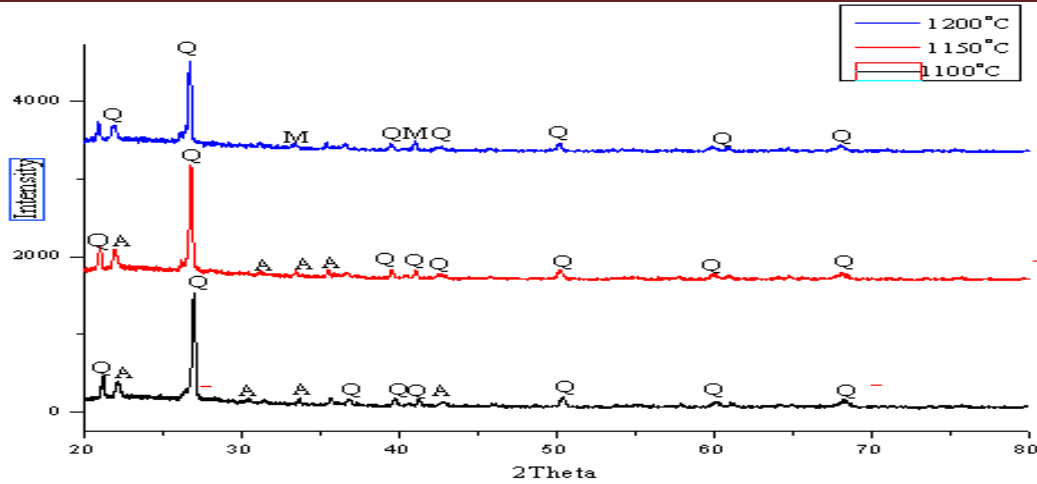


Figure 5: XRD sintered at 1100°C, 1150°C and 1200°C.

### 3.3.2. Scanning Electron Microscopy (Sem)

Figure 6 (a)-(c) shows the topographic image of samples that are sintered at different sintering temperatures and compositions. From the figures, it is clearly revealed that there is formation of porosity. Addition of Glass Waste drives the densification process that gives the effects on porosity. The small amount of glass waste addition lower the formation of open porosity compared to the higher amount of glass waste that leads to more closed porosity. Figure 6 (d) shows the image of crystalline phases for different compound that used the back scattered electron (BSE) detector.

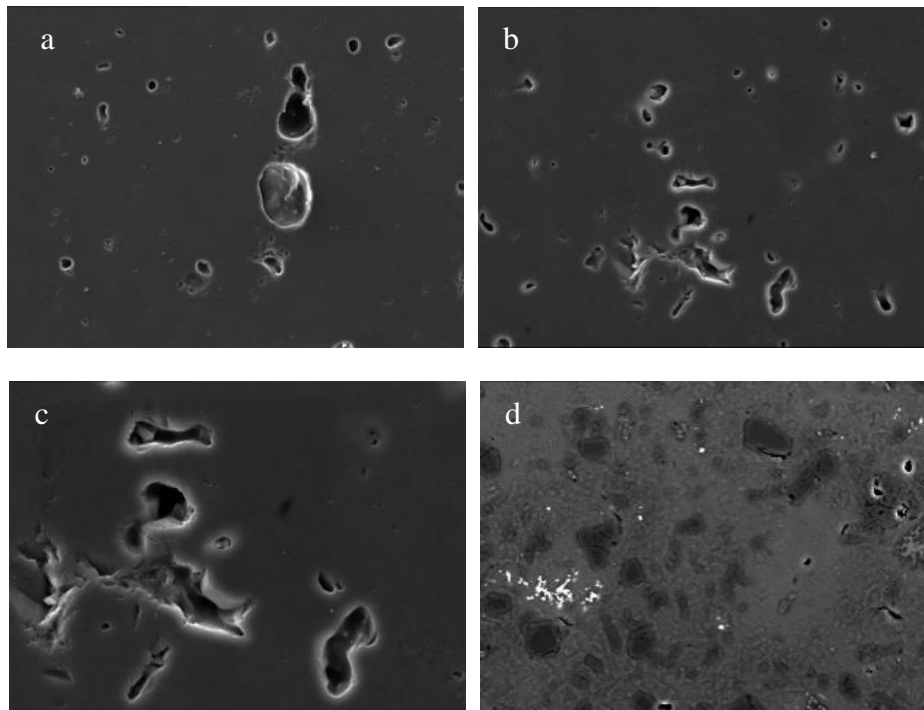


Figure 6: SEM images (a) 10 wt.% GW, 1100 °C, (b) 4 wt.% GW, 1150 °C (c) 6 wt.% GW, 1200 °C (d) Crystalline phases using BSE detector.



#### 4, Conclusion

This study analysed the effect of glass waste addition in ceramic production. The findings of this research shows that, the optimum sintering temperature and weight percent of glass waste addition are 1200 °C and 2 wt.% respectively, this is because, optimum physical and mechanical properties of ceramic were obtained. The higher sintering temperature leads to the formation of higher compressive strength compared to lower sintering temperatures. As the weight percent of Glass Waste addition increased, the mass loss decreased but the shrinkage, bulk density and compressive strength of sample increased.

#### References

- Durumin Iya S. G, Mohamad Z. N., Siti Noraiza A. R., Norazreen S. and Nur Azureen A. K. (2019). Effect of Iron (III) Oxide ( $Fe_2O_3$ ) as an additive and substitution of quartz with POFA on physico-mechanical properties of Porcelain. *International Journal of Nanoelectronics and Materials* Volume 12, No. 2, Apr 2019 [175-184].
- Owoeye, S. S., Toludare, T. S., Isinkaye, O. E., & Kingsley, U. (2019). Influence of waste glasses on the physico-mechanical behavior of porcelain ceramics. *Boletín de la Sociedad Española de Cerámica y Vidrio*, 58(2), 77-84.
- Bertolissi, N. (2014). Difference between porcelain and ceramic, or between fine china and bone china. [Online] Available at:<http://www.nicolettbertolissi.com/difference-between-porcelain-and-ceramic/> (Accessed: 21 July 2018).
- Durumin-Iya S. G., Mohamad Z. N., Siti Noraiza A. R., Norazreen S., Muhammed J. J. and Nur Azureen A. K. (2020). Developed formulation model by addition of  $SiO_2$  for optimum physico-mechanical properties of porcelain using modified palm oil fuel ash (POFA). *International Journal of Nanoelectronics and Materials* Volume 13, No. 2, Apr 2019.
- Adel B., Mohd Fadzelly A. B., Siti Fatimah S. and Sani G. D (2020). Preparation and Characterization of PMMA-AgNPs Polymer Composite as a Dental Prosthesis *Asian J. Chem.* 2020, 32(6) pp 1451-1455.
- Mohammed J. J., Mohamad Z. N., Shihab A. Z., Mohd Haziman W. I., Sani G. D., Mahdi M. A. (2019). Thermal Properties of Concrete by Replacement Sand with Porcelain Waste. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, 59, Issue 2 (2019) 291-298.
- Durumin iya S. G, Mohamad Z. N., Nur Azureen A. K., Siti Noraiza A. R., Warikh A.R. M., Julie J. M., and Mohd A. M. N. "Effect of palm oil fuel ash treatment on physico-mechanical properties of porcelain." In *AIP Conference Proceedings*, vol. 2068, no. 1, p. 020093. AIP Publishing LLC.