Study of the Effects of Waste Glass Additives on the Properties and Compliance level of Fired Ceramic Bricks

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Abstract: *In the course of producing durable bricks for masonry, waste glass powder sieved to 150μm was added to clay, mixed with water and fired to 1000C. Effects of waste glass addition were investigated by subjecting 242 ceramic bricks produced to test. From the results obtained, the physical and mechanical properties were improved as waste glass content increased in the samples. Values of properties obtained were compared with existing standard values for bricks and it was observed that compliance level at 0% waste glass was 50%, at 10% waste glass addition, it was 75% and at 15% to 40% waste glass addition, compliance was 100%. Therefore, waste glass addition to bricks improved properties of bricks for construction purpose.*

Keywords: *fired ceramic bricks, compliance level, waste glass, properties, construction*

1.0 Introduction

Clay is a naturally occurring kind of soil which is sticky when wet and contains different minerals like silica, alumina, iron oxide, magnesia, calcium oxide and other trace minerals. The plastic nature clay exhibits when in contact with water makes it very easy to be moulded into different shapes. Different products have been made using clay and these include products like bricks and pottery including pots, plates and other kitchen wares. Mixture of some additives to clay also resulted into some advance products like ceramic tiles and white wares. Clay is in abundance in Nigeria and all over the world, hence can be regarded as cheap industrial raw material for different uses. Due to its availability and its good workability, clay is been employed in making fired bricks for houses. In the production of fired masonry ceramic bricks, various additives had been mixed with clay and different properties have been observed in such bricks. Additives added include fly ash [11,18] in the production of flash bricks, industrial sludge in the production of fired bricks [15] and shale in the production of biobricks [16]. Others include plant sludge and rice husk [6], saw dust [4, 8], tobacco [12], polystyrene [19], plastic fiber [10] and recycled paper [17].

2.0 Materials and Method

Clay soil used were dug out from borrow pits in two different locations (which are 20m apart) in Ire-Akari community, Akure, Nigeria. The clay samples were mixed together in equal proportion while the waste glass bottles used were obtained from a waste glass retailer. Clay samples collected were milled and sieved to -150 µm and waste glass bottles collected were crushed, milled and sieved to -150 µm. Rectangular bricks samples of 190 x 60 x 60 mm were made by mixing 0, 10, 15, 20, 25, 30 and 40% of waste glass to clay, with water addition and compacted by a pressure of 10MPa. The samples were exposed to the atmosphere for 24hours, after which they were dried for 12hours. Dry samples were fired to 1000 C in an electric furnace and allowed to cool in the furnace. Fired samples were examined for firing shrinkage as per [1], apparent porosity and water absorption as per [2], bulk density, percentage weight loss, compressive and flexural strength as stated in [3]. Wear rate was carried out in line with [13] and the effects of waste glass on the properties of fired bricks were investigated. Three samples were used for each composition in conducting the test and the results were recorded and the mean values obtained were used for analysis.

3.0 Results and Discussion

Table 1: Values of properties of bricks samples obtained

Waste glass content (%)	0	10	15	20	25	30	35	40
Firing shrinkage (%)	4.85	3.62	3.78	3.56	3.11	2.32	2.34	2.11
Weight loss (%)	8.30	8.14	6.23	6.78	4.11	3.21	3.10	3.10
Apparent porosity (%)	23.1	21.5	18.6	16.5	14.4	11.5	9.7	8.2
Water absorption (%)	22.4	17.8	15.9	12.5	10.9	7.9	6.4	5.9
Bulk density (g/cm^3)	1.56	1.61	1.68	1.74	1.82	1.90	1.94	2.01
Compressive Strength (MPa)	7.2	8.8	9.4	11.1	12.6	12.9	12.1	11.7
Flexural strength (MPa)	1.57	1.96	2.38	2.98	3.18	3.22	3.24	3.41
Wear depth (mm)	4.76	3.87	2.41	2.11	1.87	1.99	1.54	1.22

3.1 Firing shrinkage and Percentage weight Loss

With increasing volume addition of waste glass, dimensional stability was impacted in the samples resulting to reduction in firing shrinkage as the additives increased (table 1 and fig 1). Loss in weight in fired bricks is explained by shrinkage experienced during firing and loss of volatile and organic content present in the samples. At high temperature glass phase expansion leads to increased compactment, hence with increasing volume of waste glass content there was reduction in weight loss.

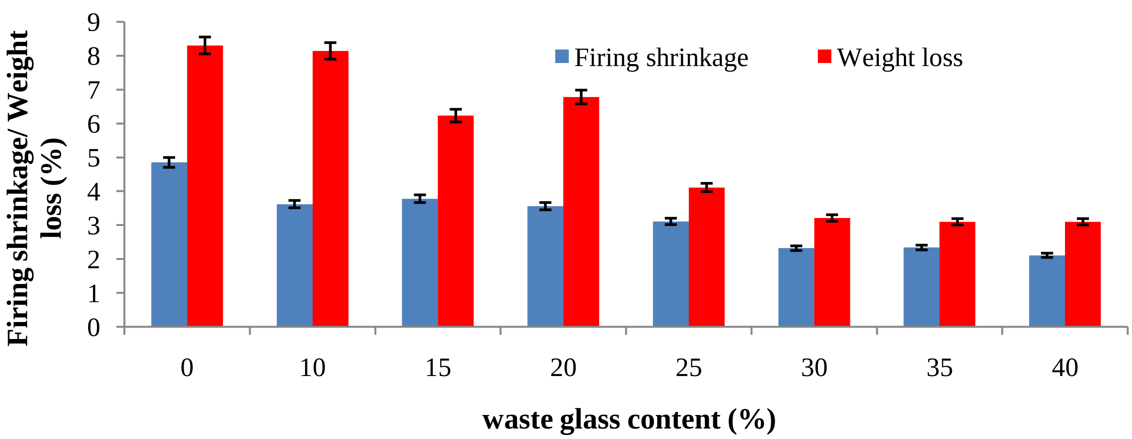

Fig1: Effect of waste glass addition of firing shrinkage and percentage weight loss

3.2 Apparent porosity and Water absorption

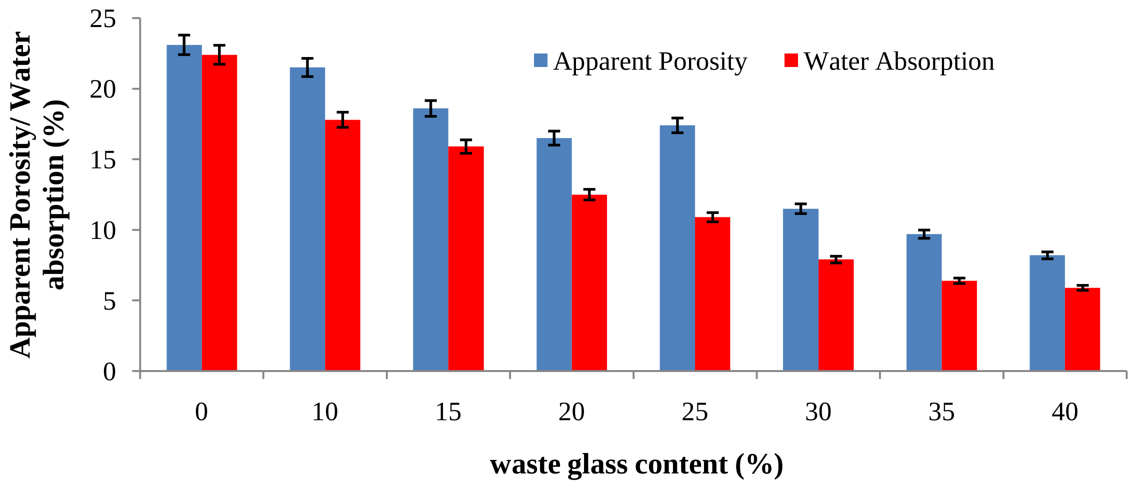

Fig 2: Effects of waste glass addition on apparent porosity and water absorption

Waste glass presence in the bricks samples reduced porosity due to in filling of available pores in the bricks. This enhanced compactment leading to reduction in porosity. During sintering, densification was enhanced which further reduced volume of pores. At high temperature, vitrification was enhanced leading to further fusing of the particles, hence, porosity was reduced. Similarly, as porosity reduced, water absorption in the samples reduced with increasing waste glass content. Apparent porosity reduced from 23.1% with no waste glass content to 8.1% at 40% waste glass content, porosity reduced with increasing amount of waste glass, which also reflected in water absorption capacity as it reduced from 22.4% (0% waste glass) to 5.9% (40% waste glass)

3.3 Bulk Density

The purpose of adding waste glass to clay is to improve the properties of fired clay produced during firing. Reduced porosity results into compaction and densification in the samples. At high sintering temperature, vitrification process leads to further densification and compaction resulting into increased cohesion within the particles. As waste glass content increased in the bricks, bulk density increased gradually from 1.56g/cm^3 (0% waste glass) to 2.01g/cm^3 at 40% waste glass addition (table1 and fig. 3).

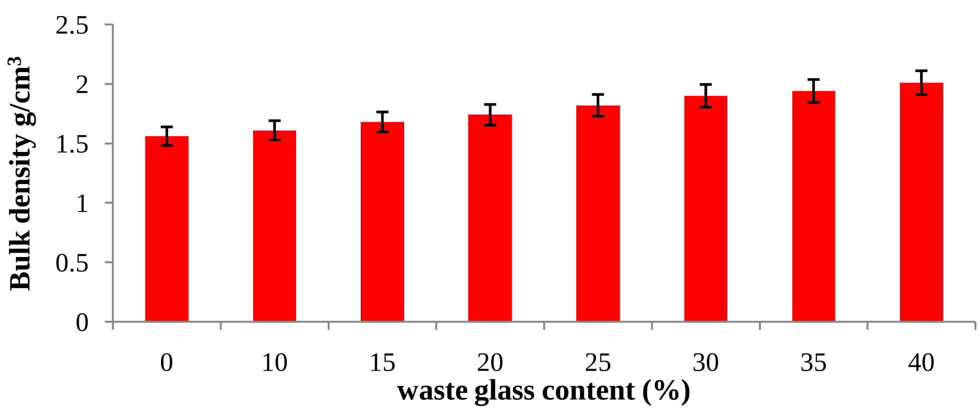

Fig3: Effects of waste glass addition on bulk density

3.4 Compressive Strength and Flexural Strength

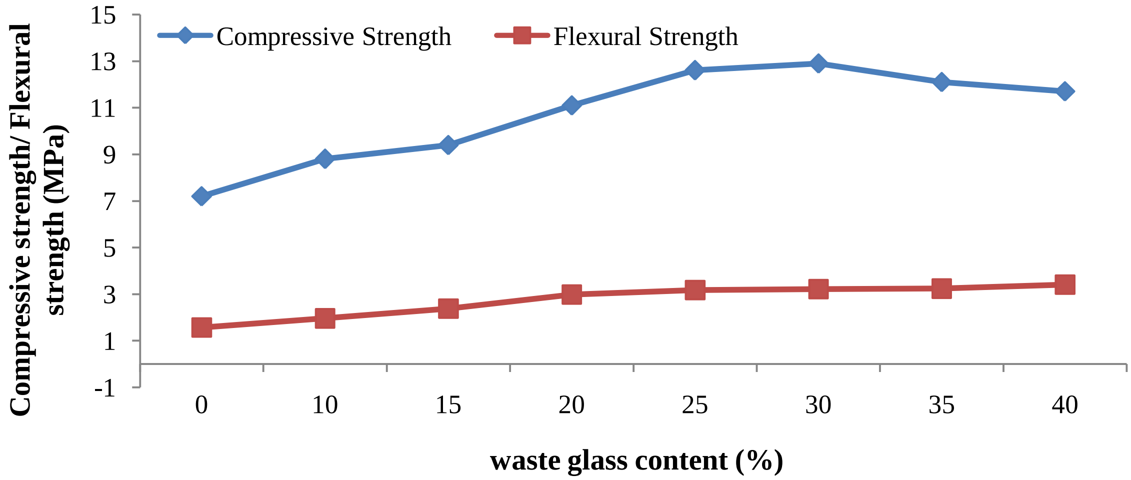

Fig 4: Effect of waste glass addition on compressive and flexural strength

With increased amount of waste glass content, compressive strength increased gradually from 7.2MPa to 12.9MPa (table 1and figure 4) as a result of reduced interparticle distance and reduced volume of pores within the bricks. At high temperature, there was increased glass phase volume, which further reduced volume of pores, hence leading to enhanced compaction. At 30% waste glass content compressive strength rose to a peak of 12.9MPa but fell at 35% waste glass addition, also fell a bit further when waste glass increased to 40%. This is due to increased in volume of brittle glassy phase formed during sintering. In the case of flexural strength, the value rose from 1.54MPa to a peak of 2.41MPa at 40% waste glass addition.

3.5 Wear Rate

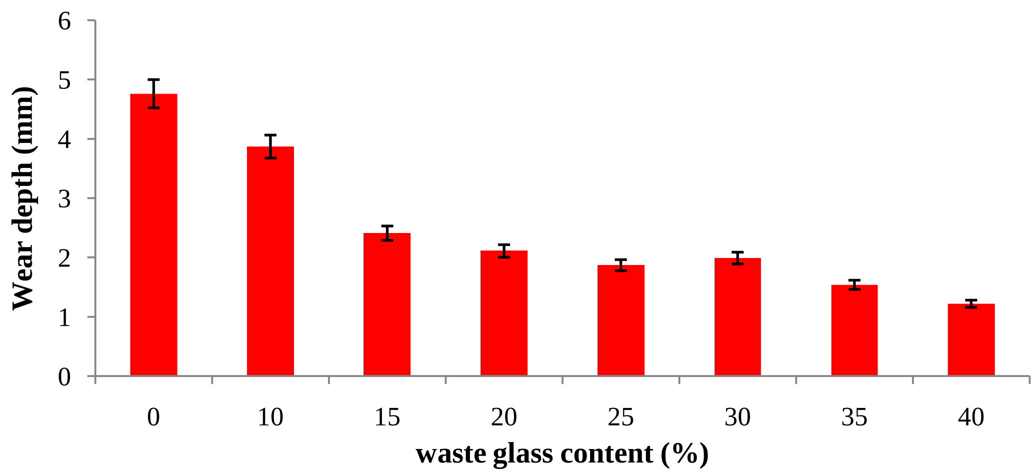

Fig 5: Effect of waste glass addition on wear rate

The wear rate reduced as waste glass content increased in the samples, showing that as waste glass content increased hardness and wear resistance increased, due to enhanced cohesion within particles as a result of reduced interparticle distance and presence of strong glass phase.

4.0 Property Evaluation

Table 2: Property evaluation of brick samples

			Various content of waste glass (%)							
Properties	**Standard Value**	**Source**	Control X (0% WG)	10	15	20	25	30	35	40
Firing Shrinkage	< 8 %	[16]	1	1	1	1	1	1	1	1
Weight loss index	< 15%	[20]	1	1	1	1	1	1	1	1
Apparent Porosity	< 30 %	[7]	1	1	1	1	1	1	1	1
Water Absorption	< 18 %	[20]	0	1	1	1	1	1	1	1
Wear depth	< 3mm	[21]	0	0	1	1	1	1	1	1
Bulk density	>1.6 g/cm^3	[16]	0	1	1	1	1	1	1	1
Compressive Strength	>5 MPa	[7]	1	1	1	1	1	1	1	1
Flexural Strength	>2MPa	[5]	0	0	1	1	1	1	1	1
Total Value			4	6	8	8	8	8	8	8

The values obtained for the properties of samples were compared with existing standards which were seven in this study. Compliance level can therefore be calculated as ratio of total value for each sample to total expected value which is 7 in this case.

Table3: Compliance level of samples

Waste glass (%)	**0**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
Compliance (%)	50	75	100	100	100	100	100	100

5.0 Conclusion

Waste glass powder, sieved to -150 µm was added to clay in this study, to investigate the effects on the properties of fired ceramic bricks produced and to compare the values obtained with existing standard in order to check level of compliance with those standards. It can be concluded that

1. addition of waste glass improved the properties of fired bricks produced,
2. increase in amount of waste glass content increased the compliance level of bricks produced when compared with existing standard values;

Therefore waste glass addition to bricks is useful in obtaining better performance for masonry works can be encouraged.

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