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Partial Replacement of Granites with Glass Chips (Glassorazzo) in Concrete Tiles

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Abstract— This study evaluates the effect of partially replacing granite with glass chips (Glassorazzo) in concrete tiles. Two types of Glassorazzo were produced (Louver and broken bottles) and comparisons were made to evaluate the effect of varying percentages of glass in Glassorazzo. Glassorazzo samples having 0%, 5%, 10%, and 15% glass content for both types of glass were produced. A maximum curing period of 28 days, and a 0.6 Water-Cement ratio was observed for all samples. Flexural Strength, Total Water Absorption, and Surface Water Absorption tests were carried out using British Standard. Tests results showed that Broken bottle glassorazzo were denser than their corresponding Louver glassorazzo. Addition of both Louver and Broken Bottle glass saw an increase in flexural strength as the percentage of glass content increased from 0-15%. Also, glassorazzo containing Broken Bottles had higher flexural strength than their corresponding Louver glassorazzo samples including the control sample. At 15 percent glass content, the Broken Bottles performed the most with an overall 14 percent increase in flexural strength as compared with the control sample. For Total and Surface Water Absorption, an increase in the percentage of glass content resulted in a decrease in the quantity of water absorbed by the samples. Broken bottles showed the lowest water absorption. At 15 percent broken bottle content, the average total water absorption was reduced by 49 percent when compared to the control terrazzo specimens.

Index Terms— Glassorazzo; Glass; Louver; Broken Bottles; Flexural Strength; Water Absorption

1 Introduction

The National Terrazzo and Mosaic Association (NTMA) define Terrazzo as follows: "Terrazzo consists of marble, granite, onyx, or glass chips in Portland cement, polyacrylate modified Portland cement, or resinous matrix binder [1]. The demand for terrazzo floor tiles in Nigeria is estimated to be around 18% of the nation's total requirement of flooring tiles. It is however important to note that, the demand is expected to increase at the rate of 5% every year. Hence, there is a good reason for the invention of new creative ways to manufacture terrazzo tiles [2].

In achieving sustainability, recycling plays an important role. In the production of any product, it is evident that the processes involved will always generate some form of waste, and that all materials placed on the market are certainly going to become waste at one time or another [3]. With the steady increase in population, and by implication, a rise in the volume of waste regeneration, the need for sustainable solutions to the problem of waste management in a country like Nigeria becomes more glaring by the day, especially as developing countries are often associated with poor waste disposal and recycling facilities. Recycling is a solution currently being deployed all over the world, especially in developed countries as a sustainable way of dealing with the problem of waste. Many studies have found that, recycling waste is healthier for the environment instead of incinerating or landfilling it. It has also been discovered that recycling lessens the demand for raw materials and so lowers the impact of human activities on the environment [4]. In dealing with the amount of waste generated, recycling has been encouraged globally.

Glass by nature do not decompose easily but gradually degrade in a similar pattern to rocks. Hence, the need to provide alternative use of glass waste becomes eminent.

Generally, glass bottles are often 100 percent recyclable and this process can be repeated without a decrease in the quality and will maintain its purity depending on the recycling process. Glass is a precious material with the ability of endless recycling [5].

Glass products consume significant amount of energy during its production, however, recycling of glass material requires

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lower amount of energy when compared with the energy used in production. In addition to saving energy, recycling of glass material helps in reducing industrial pollution. This study therefore seeks to investigate an alternate use for waste glass in order to further reduce the effects that improper waste disposal, especially landfilling a non-biodegradable material like glass has on the environment.

2. Experimental

Louver glass blades were obtained from old, rehabilitated buildings, while Schnapps Bottles were collected from consumers of the product in Ibadan, Oyo State. Glassorazzo was produced with moulds of 250mm x 350mm x 20mm in dimension. The control specimen was prepared without glass. Afterwards, broken glass (both Louvers and bottles) were used to prepare glassorazzo tiles at 5%, 10% and 15% of broken glass. Generally, coarse aggregate passing through sieve size 13.2 mm, but retained on sieve size 9.5mm; and fine aggregates passing through sieve size 2.36mm were used for this study. A mix ratio of 1:4 for cement to coarse aggregate was used, and all mixes were prepared with 0.6 water-cement ratio. The glassorazzo tiles produced were then allowed to cure in a curing tank for 28 days, after which they were removed for various tests.

The grain size distribution of the sand and granite was determined using particle size distribution method in accordance with BS 1377-1:1990. The glassorazzo tiles to be tested were cured for 28 days, after which the 250 mm x 350 mm x 20 mm size samples were tested for flexural strength using the Universal Testing Machine. Readings for the breaking force and the displacement were obtained from the computer interface program, and the Modulus of Rupture (MR) was derived.

Water absorption tests were carried out to determine the amount of water absorbed by Glassorazzo. For the surface water absorption test, the tiles were put face down in 5 mm of water for 24 hours; while for total water absorption, the tiles were immersed completely in water for 24 hours. After 24 hours of immersion, surface water was carefully wiped off the tiles with a damp cloth, and each specimen weighed to the nearest gram immediately after removing from water. Tests for Flexural Strength and Water Absorption (Total and Surface) were done in accordance with EN 13748-1:2004 [6] which specifies the materials, methods and testing for unreinforced cement-bound Terrazzo tiles to be used for both internal purposes.

2.1 Particle size analysis

The grain size distribution of the sand and granite was determined using particle size distribution method in accordance with BS 1377-1:1990. The weights of the oven dried samples were determined using a weighing balance. Each of the sieves was arranged in descending order with regards to the size of their openings, from top to bottom, including the receiver at the bottom. The sample was carefully poured into the sieve and shaken vigorously for fifteen minutes, so that each particle size was distributed according to their various sizes. The material retained in each sieve was weighed and recorded.

The sand passing through sieve size 2.36 mm; and glass/granite passing through sieve size 13.2mm were used.

2.2 Flexural Strength Test

Flexural Strength Test is a way of determining the tensile strength of unreinforced slabs and beams, in this case, Terrazzo tiles. It is the stress in a given material at the exact moment it yields in a flexure test. This was done in accordance with EN 13748-1:2004 and EN 13748-2:2004 which specify the materials, methods and testing for unreinforced cement-bound Terrazzo tiles.

The glassorazzo tiles to be tested were cured for 28days, after which the 250mm x 350mm x 20mm size samples were tested for flexural strength using the Universal Testing Machine. The specimens were placed on the machine, in a properly levelled and centred position with two opposite edges of the glassorazzo specimen simply supported, and the other two edges free. A central line load was applied to the specimen through 12 mm diameter high carbon steel bar parallel to the simply supported edges. The load was applied to mid-span starting

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from zero and increased steadily until the specimen failed. Readings for the breaking force and the displacement were obtained from the computer interface program, and the Modulus of Rupture (MR) was derived from formula as follows:

$$MR = \frac{3PL}{2bt^2}$$

Where P is the applied load to failure,

L is the distance between supports (mm),

t is the average thickness of the specimen,

b is the width of the specimen at the failure plane.

The average modulus of rupture will be based on average value of at least three test specimens

Plate 1 Specimen undergoing Flexural Strength test

2.3 Water absorption tests

Water absorption test is a test used to determine the amount of water absorbed by Glassorazzo under given conditions. This test was carried out in accordance with EN 13748-1:2004 and EN 13748-2:2004 which specify the materials, methods and testing for unreinforced cement-bound Terrazzo tiles.

The glassorazzo tiles to be tested were cured for 28 days, after which they were dried in an oven at a temperature of 105°C to 110°C till they obtained constant weight and cooled. After cooling, Total water absorption, and Surface water absorption test were conducted.

For the surface water absorption test, the tiles were put face down in 5 mm of water for 24 hours; while for total water absorption, the tiles were immersed completely in water for 24 hours. After 24 hours of immersion, surface water was carefully wiped off the tiles with a damp cloth, and each specimen weighed to the nearest gram immediately after removing from water.

The percentage of water absorption was determined by formula:

$$\frac{m_t - m}{m} \, x \, 100\%$$

Where

m_t = weight of specimen after 24hours immersion in water,

m = weight of dry specimen

3. Test results and Discussion

3.1 Grading of aggregates (Sand, Granite and Glass)

Tables 1 and Table 2 shows the sieve analysis of sand and granite results.

Table 1 - Particle Size Analysis for Sand

Sieve size	Retained (g)	Retained (%)	Passing (%)
2.36mm	10	2	98
1.18mm	15	3	95
0.85mm	20	4	91
0.6mm	145	29	62
0.425mm	170	34	28
0.212mm	120	24	4
Pass 0.212mm	20	4	0

Table 2 - Particle Size Analysis for Granite

Sieve size	Retained (g)	Retained (%)	Passing (%)
19mm	61	6.11	93.89
13.2mm	96	15.73	84.27
12.5mm	319	47.73	52.27
9.5mm	355	83.30	16.7
6.7mm	107	94.02	5.98
4.75mm	58	99.83	0.17
Pan	1.7	100	0

The values from Table 1 and Table 2 were used to plot the grading curve as shown in Figure 1.

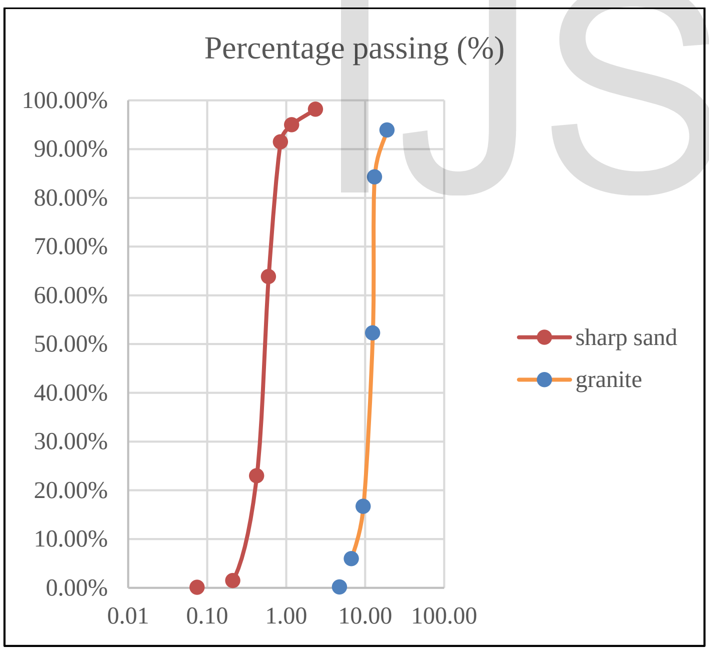

Figure 1. Particle Gradation Curve for Sand and Granite

The Coefficient of Uniformity (C_u) and the coefficient of curvature (C_c) are determined from the particle size distribution curve of sand shown in Figure 1 above.

From the graph;

D_{10} = 0.31mm,

D_{30} = 0.47mm,

D_{60} = 0.59mm.

Thus, the Coefficient of Uniformity (C_u) is:

$$C_u = \frac{D_{60}}{D_{10}} = \frac{0.59}{0.31} = 1.90$$

And the coefficient of curvature (C_c) is:

$$C_c = \frac{(D_{30}^2)}{D_{10} \times D_{60}} = \frac{(0.47^2)}{0.31 \times 0.59} = 1.21$$

According to Bardet (1997), if C_u<6.0, then the soil is poorly graded (SP). The value for C_u for this soil is found to be 1.90<6.0, therefore the soil used for this research is a poorly graded (SP) sand.

Likewise, the Coefficient of Uniformity (C_u) and the coefficient of curvature (C_c) are determined from the particle size distribution curve of granite shown in Figure 1 above.

From the graph;

D_{10} = 8mm,

D_{30} = 10.2mm,

D_{60} = 10.4mm.

Thus, the Coefficient of Uniformity (C_u) is:

$$C_u = \frac{D_{60}}{D_{10}} = \frac{10.4}{8} = 1.3$$

And the coefficient of curvature (C_c) is:

$$C_c = \frac{(D_{30}^2)}{D_{10} \times D_{60}} = \frac{(10.2^2)}{8 \times 10.4} = 1.25$$

According to Bardet (1997), if C_u<4.0, then the material is poorly graded. The value for C_u for granite is found to be 1.30<4.0, therefore the granite used for this research is a poorly graded granite (GP).

Furthermore, Table 3 shows the result from the particle size

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analysis for Louver glass chips and Figure 2 shows its particle graduation curve.

Table 3 - Particle Size Analysis for Louver Glass Chips

Sieve size	Retained (g)	Retained (%)	Passing (%)
19mm	40	4.0	96.0
13.2mm	147	14.7	81.3
12.5mm	302	30.2	51.1
9.5mm	310	31.0	20.1
6.7mm	114	11.4	8.7
4.75mm	73	7.3	1.4
Pan	14	1.4	0

Table 3 values were used in obtaining the particle grading curve for louver glass as presented in Figure 2 .

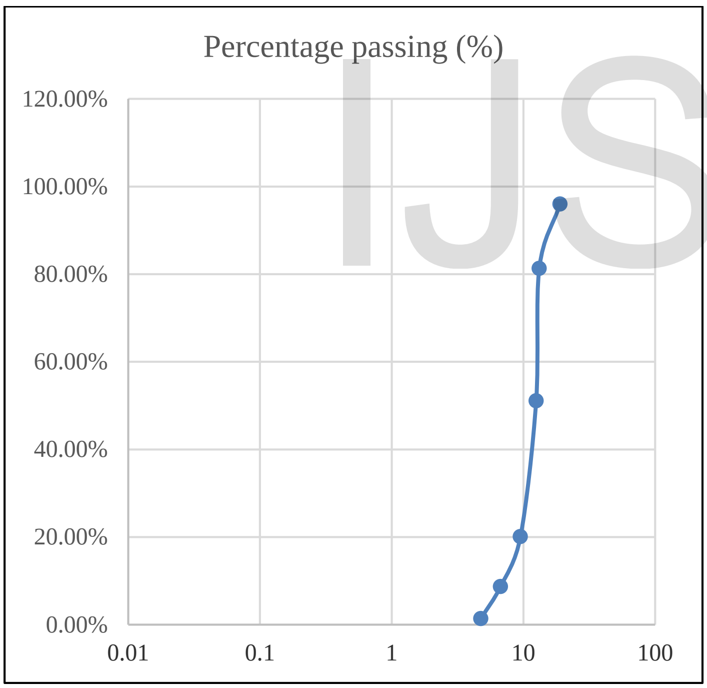

Figure 2 Particle Gradation Curve for Louver Glass Chips

The Coefficient of Uniformity (C_u) and the coefficient of curvature (C_c) are determined from the particle size distribution curve of sand shown in Figure 2 above.

From the graph;

D_{10} = 7mm,

D_{30} = 10.2mm,

D_{60} = 10.4mm.

Thus, the Coefficient of Uniformity (C_u) is:

$$C_u = \frac{D_{60}}{D_{10}} = \frac{10.4}{7} = 1.49$$

And the coefficient of curvature (C_c) is:

$$C_c = \frac{(D_{30}{}^2)}{D_{10} \times D_{60}} = \frac{(10.2^2)}{7 \times 10.4} = 1.43$$

According to Bardet (1997), if C_u<4.0, then the material is poorly graded. The value for C_u for Louver glass is found to be 1.43<4.0, therefore the Louver glass used for this research is a poorly graded material (GP).

3.2 Density:

Table 4-7. shows the density of various glassorazzo samples (Louver and Broken bottles) with their different percentages of glass content. It can be observed that the densities of the glassorazzo containing broken bottles are generally higher than those of the control samples and the Louver glassorazzo. Similarly, the Louver glassorazzo densities are generally higher than those of the control samples. This is can be due to glass being denser than granite, as they do not possess as much pores as granite.

Table 4 - Density of Control Samples (0 % Glass Content)

Sample	Density (kg/m³)
1	2297
2	2383
3	2451

Table 5 - Density of 5 % Glass Content for Glassorazzo

Sample	Density (kg/m³)	
	Louver glassorazzo	Broken Bottles glassorazzo
1	2565	2371
2	2274	2863
3	2623	2526

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Table 6 - Density of 10 % Glass Content for Glassorazzo

Sample	Density (kg/m^3)	
	Louver glasso-razzo	Broken Bottles glassorazzo
1	2349	2600
2	1960	2611
3	2457	2571

Table 7 - Density of 15 % Glass Content for Glassorazzo

Sample	Density (kg/m^3)	
	Louver glasso-razzo	Broken Bottles glassorazzo
1	2126	2366
2	2631	2583
3	2565	2565

3.3. Flexural Strength:

The glassorazzo tiles containing 0% of glass (control samples) have the least value of Modulus of Rupture. An average of 21.38 N/mm² was recorded for the control sample. An increase is observed in the Modulus of Rupture of the glassorazzo tiles as the percentage of glass increases for both Louver and Broken Bottle glass from 0% to 15% as shown in Figure 3.

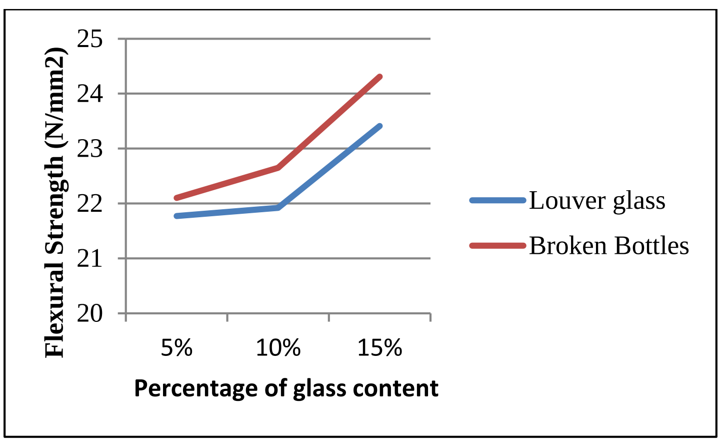

Figure 3 - Flexural Strength with Varying Percentages Of Glass Content.

In Figure 3, It can be observed that, the greatest flexural strength is obtained from broken bottles at 15% glass content with a value of 24.31 N/mm² as against 23.41 N/mm² of Lourver glass with the same glass content. There is a significant rise in flexural strength for both types of glassorazzo when the glass content exceeded 10 percent. The Broken bottle performed the most with about 14 percent increase in flexural strength when compared with the control sample at 15 percent glass content.

3.4. Total Water Absorption:

The average total water absorption for control samples value was obtained at 2.41 percent. The average total water absorption for those containing glass are shown in Figure 4. It can also be observed that the two different types of glassorazzo (Louver and Bottles) used for this research absorbed water differently. The more the quantity of glass chips present in the samples, the lesser the water absorption capacity of glassorazzo. In other words, as the quantity of glass in glassorazzo increases, the water absorption capacity decreases. This can be attributed to glass having lesser air voids than granite.

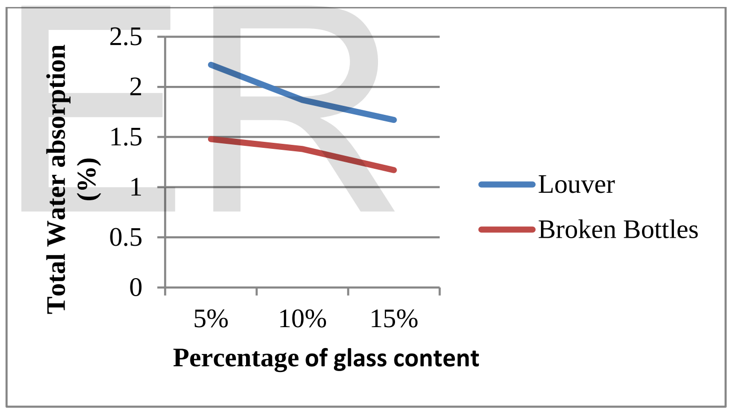

Figure 4 - Total water absorption with varying glass content.

Comparing the values in Figure 4 with the control sample, it can be seen that the control sample absorbed water the most (2.41 percent) followed by Louver glass at 5 percent glass content (2.22 percent). Broken bottles show the lowest water absorption. At 15 percent broken bottle content, the average total water aborption was reduced by 49 percent when compared to the control terrazzo specimens.

3.5 Surface Water Absorption:

The glassorazzo tiles behaved in a similar way when subjected to Surface Water Absorption Test as when they were subjected to Total Water Absorption Test with a decrease in the amount of water passing the face of glassorazzo as the percentage of glass content increases. The average surface water absorption value was recorded to be at 1.46 percent.

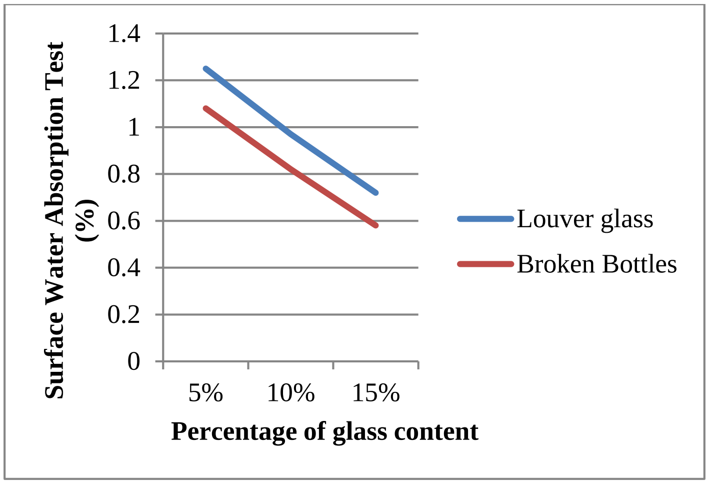

Figure 5 - Surface Water Absorption with Varying Glass Content.

Comparing the values in Figure 5 with the control sample, it can be seen that the control sample absorbed surface water the most (1.46 percent) followed by Louver glass at 5 percent glass content (1.25 percent). Broken bottles show the lowest surface water absorption. At 15 percent broken bottle content, the average surface water absorption was 0.58 percent as against the control terrazzo specimens (1.46 percent) which indicated at overall 40 percent drop.

4 Conclusion

The samples composed of broken bottles have the highest densities, when compared to those without glass and louver glass. The modulus of rupture of the glassorazzo generally increased as the quantity of glass chips increased. For both modulus of rupture, louver glass samples had lower values than their corresponding broken bottle samples. As percentage of glass content increased from 0 – 15%, total water absorption capacity of the samples decreased. Likewise, as percentage of glass content increased from 0 – 15%, surface water absorption capacity of the samples decreased. For both total and surface water absorption, Louver glass samples absorbed more water than their corresponding Broken bottle samples. Therefore, broken glass chips can be used as partial replacement of fine aggregate (granite) in concrete tiles. this also doubles as a means of mitigating cost of constructing concrete tiles.

References

[1] The National Terrazzo & Mosaic (2014), http://ntma.com/wp-content/uploads/2016/03/2016-Terrazzo-Systems-Reference-Guide.pdf accessed 3:07am on 03/02/2017

[2] Foramfera, (2016). "Terrazo Floor Tiles {Pre-Cast} Production in Nigeria, How Viable?"
Retrieved from https://www.foramfera.com/terrazo-floor-tiles-pre-cast-production-in-nigeria-how-viable/ Accessed 1:45am, 23/3/2017

[3] Kögler, K., (2007), "LIFE and Waste Recycling: Innovative Waste Management Options in Europe". European Commission – Directorate-General for the Environment. (2007, 60p.- ISBN 978-92-79-07397-7 - ISSN 1725-5619)

[4] Friends of the Earth, (2008). "Recycling: Why it's Important and How To Do it" www.foe.co.uk/sites/default/files/downloads/recycling.pdf accessed 2:35am, 20/3/2017.

[5] Glass Packaging Institute. http://www.gpi.org/recycling/glass-recycling-facts. Accessed 4.35 pm, 27/12/2018.

[6] British Standards Document BS EN 13748-1:2004. Terrazzo Tiles for Internal Use