EFFECT OF WASTE GLASS AS PARTIAL REPLACEMENT FOR COARSE AGGREGATE IN CONCRETE

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Abstract

The concrete industry uses cement, sand (fine aggregate) gravel (coarse aggregate) and water. These are all natural resources which are depleting world-wide. The production of cement and mining of sand and gravel lead to degradation of the environment. This research focuses on the partial replacement. of coarse aggregate with Waste Glass (WG). A total of 54 concrete cubes using 100% natural coarse aggregate, as well as 5%, 10%, 15%, 20% and 25% Waste Glass (WG), replacing coarse aggregate.. Concrete mix ratio of 1:2:4 with a constant water/cement ratio of 0.4 was adopted. The various percentage replacements were cured and tested after 7, 14 and 28 days for the following concrete properties: density, compressive strength and workability. Compressive strength decreased as the quantity of WG was increased for 7, 14 and 28 days tests. The workability of the concrete increased as the quantity of the WG was increased up to 15% replacement level, thereafter it decreased as the quantity of the WGs was increased. Adequate compressive strength was achieved at between 5-10 replacement level.

Key Words: concrete, coarse aggregate, waste glass, compressive strength, workability.

1. INTRODUCTION:

Concrete is a composite material composed of sand and gravel chemically bonded together by hydrated Portland Cement (McGregor, 1997). As a result of the fact that concrete is fire resistant and can withstand dead and live loads, it is the most widely used construction material.

Most of the aggregates are obtained from the environment and numerous environmental problems and natural disasters have occurred due to extraction of metal and sand (Gayal et al, 2012).

These facts have led researchers to focus on future development of alternative materials for use in concrete construction industry.
(Concrete Institute Australia, 2008) found in a survey that world-wide each year, the making of concrete consumes 1.6 Billion tons of Ordinary Portland Cement (OPC), 10 Billion tons of sand and rock and 1 Billion tons of water, making the concrete industry the largest user of natural resources in the world. A large amount of useless glass residue, by products and waste materials are produced by different industries on regular basis. The residual and unused wastes are disposed into the environment and act as a burden on the environment without any commercial benefit (Serniabat et al, 2014). It is well known that addition of these wastes in concrete as a supplement of cement generally reduces the construction cost and more or less maintains the properties of concrete. In addition waste materials when properly processed, have shown to be effective as construction materials and readily meet the design specifications (Parviz, 2012) and (Meyer et al, 2001).
Several decades ago, attempts had been made to use waste glass in concrete (Johnston, 1974) and (Schmidt et al, 1963). The limited use of WG in concrete is due to the well known problem of Alkali-Silica Reaction (ASR), caused by the reaction between hydroxyl ions within the concrete and the silica that is contained in the glass material (Abdelmaseeh et al, 2014).
(Zhu et al, 2005) and (Shayan, 2002), studied the use of waste glass in normal concrete. They concluded that amongst the advantages of using crushed glass as aggregate in concrete is that water absorption of glass is nearly zero. This makes it a very durable material. They also found out that glass has excellent hardness and this gives the concrete high abrasion resistance. (Liang et al, 2007), used coloured glass as a coarse and fine aggregate in order to achieve a high performance and aesthetic level of concrete. They proved that high compressive strength concrete with the value above $40N/mm^2$ can be obtained by using coloured glass as aggregates beside other materials as partial replacement of cement.
(Topcu et al,2004), established that using waste glass gathered from coloured soda bottles as partial replacement for coarse aggregate (with proportion up to 60%) did not have a significant effect upon the workability of the concrete and only slight reduction was reported in its strength. Also (Verdugo 2013) investigated the practicability, versatility and feasibility of utilizing recycled glass as a concrete aggregate in the form fine aggregates, coarse aggregates and fine glass powders. He concluded that the results looked promising since strength tests showed that the concrete mixes in question have moderate to high strengths, and hence that the concrete derived from recycled glass could be effectively applied to a multitude of services including structural applications.
(Abdullah, 2007) investigated the possibility of improving the compressive strength of concrete over a range of waste glass percentages as replacement for fine and coarse aggregate. He concluded that the optimum value of concrete mix with water-cement ratio of 0.4 was determined as approximately 0.265. This study investigated the use of WG as partial replacement of coarse aggregate in concrete.
The concrete cube specimens were tested for density, compressive strength and workability at 7, 14 and 28 days, with various glass to coarse aggregate proportions of (0%, 5%, 10%, 15%, 20% and 25%).

2. MATERIALS AND METHOD

2.1 MATERIALS

2.1.1 Cement

The cement used in the study was OPC (Grade 42.5) produced at DANGOTE CEMENT INDUSTRIES Plc. It conformed to (BS EN196-0;2010).

2.1.2 Fine Aggregate

Fine aggregate used was obtained from clean river sand at Oyigbo, a suburb of Port Harcourt. The maximum size was 4.75mm. Impurities were removed and it confirmed to the requirements of (BS 882; 1992).

2.1.3 Coarse Aggregate

WG were gathered from the disposal dumps of reconstruction and building demolishing projects in the Rivers State University of Science & Technology, Nkpolu, Port Harcourt. The broken glass primarily originated from pure and clear glass windows. The WG were cleaned out of the dirt materials and impurities, then crushed manually and sieved through 14mm sieve.

2.1.4 Coarse Aggregate

Coarse aggregate used is crushed angular and rough textured granite obtained from Ishiagu in Ebonyi State in South Eastern Nigeria.. Maximum size was 20mm.

2.1.5 Water.

Potable water used was obtained from the Civil Engineering Laboratory of the Rivers State University of Science & Technology

2.2 METHODOLOY

2.2.1 Preparation of the Waste Glass into Coarse Aggregate.

The WG was crushed and sieved to a size of 14mm. Physical tests on coarse aggregate, the blend of the broken glass with fine sand were carried out in order to determine their gradations and relative densities.

2.2.2 Concrete Mixture

The mix ratio used for the experiment is 1:2:4 by weight (cement: fine aggregate: coarse aggregate), while the water/cement ratio of 0.4 was used. Coarse aggregate was replaced with WG at 0%, 5%, 10%, 15%, 20% and 25% replacement levels. For each replacement level, three concrete cubes specimens were prepared for the compressive strength and workability tests. The average values were obtained from the three tests specimens.

2.2.3 Sieve Analysis

Sieve analysis of the fine aggregate, coarse aggregate, WG aggregate was carried out to determine the particle size distribution. The sieve analysis was carried out in accordance with (BS 410; 1969).

2.2.4 Specific Gravity

Test was performed in accordance with (BS 1377-4; 1996).

2.2.5 Bulk Density

Test was performed in accordance with (BS 812-2; 1995).

2.2.6 Compressive Strength

A total of 54 concrete cubes were prepared using 100% natural coarse aggregate (granite) as well as a 5%, 10%, 15% 20% and 25% WG replacing coarse aggregate. The concrete cubes were cured and crushed after 7, 14 and 28 days and the compressive strengths were recorded as observed.

Test was performed in accordance with (BS 1881-116; 1983). Table 1 shows the Concrete Mix Design for the Compressive Strength.

Table 1: Concrete Mix Design Summary for Strength Tests.

%	Cement	Fine	Coarse	Glass
0	3.44	6.88	13.77	0.00
5	3.44	6.88	13.08	0.69
10	3.44	6.88	11.77	1.31
15	3.44	6.88	10.00	1.77
20	3.44	6.88	8.00	2.00
25	3.44	6.88	6.00	2.00

2.2.7 Workability

Slump test was carried out to determine the workability of the concrete with 0%, 5%, 10%, 15%, 20% and 25% WG replacement. Test was performed in accordance with (BS 12350-2; 2009).

3.0 RESULT AND DISCUSSIONS

3.1 Chemical Composition of WG

Table 2 shows the chemical composition of the WG. SiO_2 is 52.89% which forms the largest constituent of glass, while Lead Oxide is 22.30% is the second largest constituent. Cement has approximately 21.38% SiO_2.

Table 2: Chemical Composition Of Broken Glass

S/No	Parameter	Test Method	Result	Standard
1	Silicon Oxide (%)	ALPHA 3114B [18]	52.89	45-90
2	Magnesium Oxide (%)	"	3.79	2.5-75
3	Sodium Oxide (%)	"	11.60	14.20 max
4	Aluminium xide (%)	"	8.14	0.5 -16.0
5	Potassium oxide (%)	"	11.62	12.0 max
6	Ferric Oxide (%)	"	0.08	0.1
7	Calcium Oxide (%)	"	6.69	10.0 max
8	Boric Oxide (%)	"	7.17	4.0- 12.0
9	Zinc Oxide (%)	"	1.33	1.5 max
10	Lead Oxide (%)	"	22.30	25.0 max

3.2 Particle Size Distribution

Table 3 shows the gradation of fine, coarse WG aggregates. The WG was further subjected to a mechanical sieving process with fractions in excess of 14.00mm being discarded.

Table.3: Gradation Of Coarse Aggregate And Recycled Glass Aggregate

Sieve Size (mm)	**Accumulate % Passing**	
	Coarse Aggregate	Recycled Glass Aggregate
25.4	100.00	-
19.1	60.67	100.00
12.7	30.42	62.85
9.52	6.67	26.50
6.35	0.42	0.15
4.75	0.00	0.00

3.3 Physical Properties of Aggregates

Table 4 shows the physical properties of the fine, coarse and WG aggregates. The Specific gravity of WG is slightly higher than that of fine aggregate. This is the reason why the strength of the decreased as the quantity of WG was increased. Table 5 also shows the density of fresh concrete with various ratios of WG. The density of fresh concrete decreased as the percentage of WG was increased. The result compares favourably to those obtained by Abdelmasseh et al, 2014. The decrease in density is not significant with the increase in percentage of WG. The variation is shown in Fig. 1.

Table.4: Physical properties of Aggregate

Property	**Coarse Aggregate**	**Recycled Glass Aggregate**	**Fine**
Specific Gravity	2.76	1.8	1.65

Table 5: Density of fresh Concrete with Various ratios of Coarse recycled glass

Percentage of glass Replacement % By Weight	Density(Kg/m^3)	Percentage of Reduction (%)
0	2419.76	0.00
5	2333.10	3.60
10	2311.00	4.50
15	1896.30	9.00
20	1888.90	21.90
25	1883.70	22.20

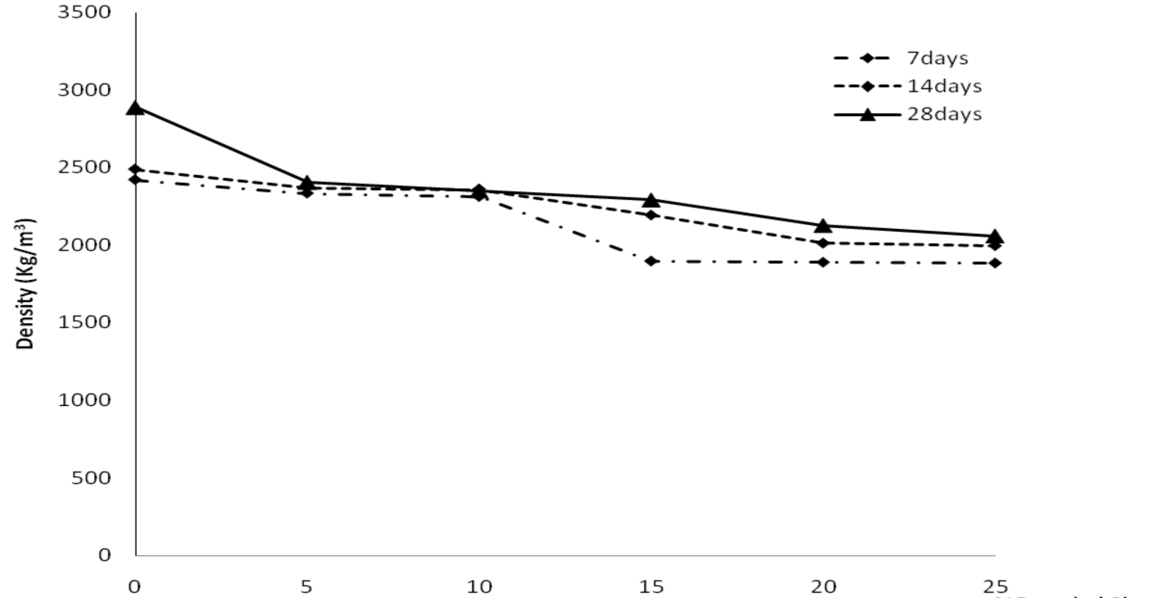

Fig. 1: Variation of Density of Concrete with Percentage Replacement of Recycled Glass

3.4 Workability

Fig. 2 shows the variation of the slump against the various percentage replacement of coarse aggregate with WG. From the plot it shows that the slump increases as the quantity of WG increased in the concrete. The slump peaked at 55mm at 15% WG replacement, after which the slump started to reduce and fell to zero at 25% WG replacement. WG as a coarse aggregate affects the flow or workability of concrete. This may be attributed to the fact that as WG percentage increases, additional cement paste attaches to the surface of the waste glass, which results in less available cement necessary for the fluidity of the concrete. Moreover, the WG aggregate has sharper and more angular grain shapes compared to the rounded shapes of gravel, which results in less fluidity (Abdelmasseh et al, 2014).

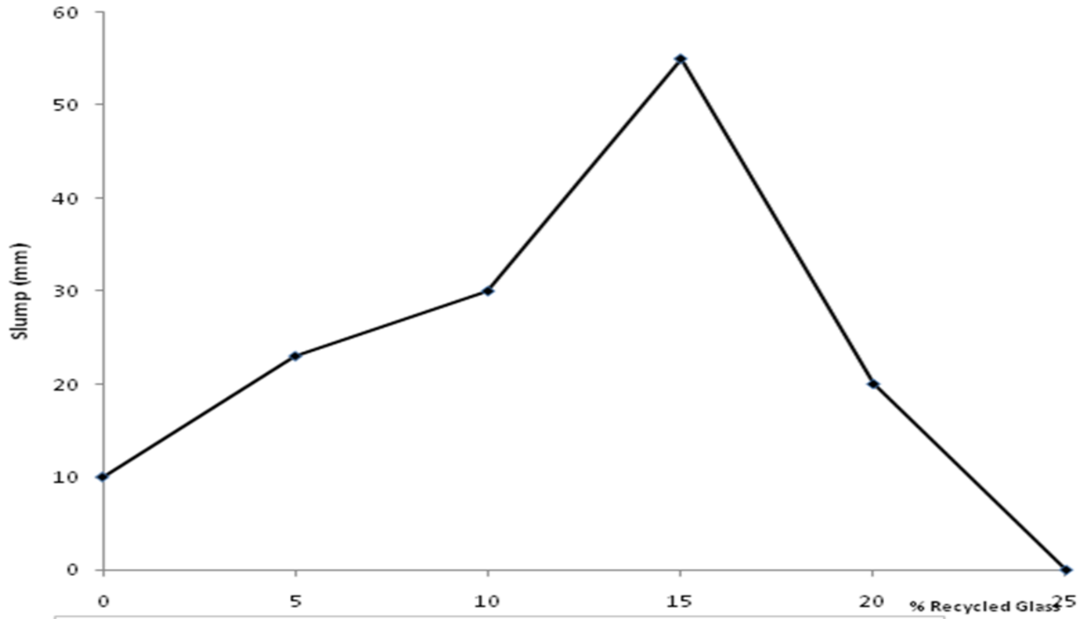

Fig. 2: Variation of Slump with Percentage Replacement of Recycled Glass

3.5 Compressive Strength

Fig. 3 shows the results of the compressive strength of concrete mixed with different WG percentages at 7, 14 and 28days respectively.

At 7 days, the compressive strength decrease as the percentage of WG increases. At 5% WG replacement level, there is a 6.5% decrease in the compressive strength (23.1N/mm^2) compared to the control 24.7N/mm^2. At 14 days, the result is slightly different, the compressive strength decreases as the WG content is increased up to 5% replacement level. After 5 % replacement level, the compressive strength starts to increase as the WG content increases Control value was 29.2N/mm^2, while the compressive strength was 24.7N/mm^2 at 5% replacement level and 25.9 N/mm^2 at 10% WG replacement which represents a 5% increase. The same trend was observed at 28 days, decrease in compressive strength between 0 - 5% % WG replacement level (32.3N/mm^2 – 26.7 N/mm^2), 17% decrease and 27.4N/mm^2 at 10% WG replacement level, representing 3% increase.

(Abdelmasseh et al, 2014), established that the decrease in compressive strength to be due to the fact that the particle size of the WG aggregates was more edged and angular compared to the rounded shape of the natural coarse aggregate, resulting in best interlocking effect and higher friction forces inside the concrete mix. The drop in the compressive strength beyond 10% replacement level may be explained by the fact that with increasing WG content, the compressive strength of concrete will decrease due to the smooth surface and friability of the WG particles compared to those of natural coarse aggregate.

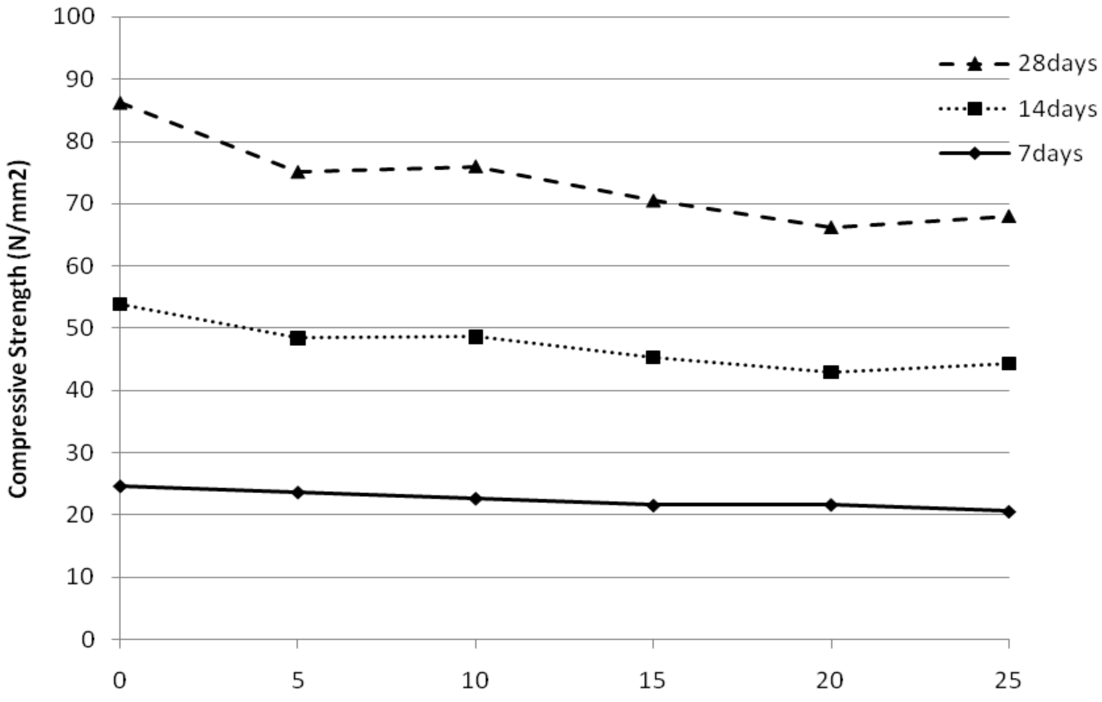

Fig. 3: Variation of Compressive Strength with % replacement of Coarse Aggregate with Recycled Glass

4.0 CONCLUSION

From the analysis of the results, the following conclusions were drawn:

(a) the density of the concrete decreased as the percentage of the WG increased at 7, 14 and 28 days curing period.

(b) the workability of the concrete increased as the content of the WG was increased in the concrete between (0 and 15% replacement level)., Thereafter, (between 15-25% WG replacement) the workability started to decrease as the WG content was increased. This result is close to the result obtained by (Abdelmasseh et al, 2014). They observed an increase of workability as the content of WG was increased at (20-25% replacement level). They posited that the edged and angular grain shape of the coarse WG aggregate was responsible for this phenomenon.
(c) the compressive strength at (0-5% replacement level) 7, 14 and 28 days decreased as the content of WG was increased in the concrete. However, between (5-10% replacement level), an increase in the compressive strength was observed at 7, 14 and 28 days.
(d) in general, it can be concluded that 5-10% WG replacement level will achieve adequate compressive strength while still being economical in terms of savings from the quantity of coarse aggregate required to produce one cubic metre of concrete.

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