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Original Research Article

Suitability of Crushed Glass Wastes as Fine Aggregates in Concrete Production

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ABSTRACT

The usage of industrial wastes such as crushed glass wastes as construction materials will not only help to reduce the cost of construction, but significantly helps in the management of such wastes. Waste bottles where obtained from a dumpsite at Yenagoa, Nigeria, washed, dried and crushed to smaller particle sizes passing the 1.18 mm sieve size. Some of the preliminary tests done on the crushed glass wastes (CGW) include specific gravity, sieve analysis, density, water absorption. Also, workability, compressive, tensile, and flexural strengths tests were also done on the fresh and hardened concrete prepared with 5 to 25% of CGW in steps of 5 as substitutes for river sand. The workability increased with increase in CWG content. The compressive, tensile and flexural strengths were 31.33 N/mm^2, 2.50 N/mm^2, 8.0 N/mm^2 at 10% CGW after 28 days of curing. Hence, 10% of CWG replacement for river sand in concrete was sufficient to give the designed strength. Therefore, CGW can be suitably used as a replacement material for fine aggregates without compromising the concrete strength.

1. INTRODUCTION

The application of waste materials in construction works has been encouraged across board as it reduces the cost of construction and environmental pollution (Scivacharam 2015). Waste glass is generated in a high volume across the globe. Glascrete is a concrete produced by using broken glasses as partial or wholly replacement of aggregates. Glass can be recycled numerously without modifying the chemical properties. The issue of managing wastes is a major challenge to the society today, and glass which is not a biodegradable material, is unfit to be used for landfill, and hence, poses a serious problem on the environment. Therefore, there is need for studies on recycling as a result of the massive usage of materials for construction works. Glass waste usage as aggregates in concrete production will have a lot of merits.

One of the major materials used for construction works on daily basis is concrete due to its good strength, development and durability (Guatam *et al.,* 2012) . In a report presented by Otunyo and Okechukwu, (2017) it was observed that, broken glass with lower particles sizes less than 1.18 mm are low in expansion compared to natural fine aggregates, and concrete samples with broken glasses of lower particle sizes than 75 μm exhibited prolonged compressive strength development, possibly as a result the pozzolanity of glass powder. Shayan and Xu (2006) reported that, broken glasses are more suitable to be used as substitutes for fine aggregates than cement in concrete production. Guatam *et al.* (2012) presented usage of waste glasses as aggregates in concrete that showed good strength development, hence, indicated its fitness as fine aggregates for mortar/concrete production. Scivacharam et al. (2015) also presented in a report that, the usage of waste glasses as aggregates in concrete will not only reduce construction cost but will also make the concrete to be durable by reducing water absorption. Most works that have been done on the application of crushed glasses in concrete production are limited to their usage as substitutes for coarse aggregates (i.e. granites) and compressive strength study. Therefore, this study intends to examine the concrete strength properties produced with CWG as substitutes for river sand.

2. MATERIALS AND METHODS

2.1. Materials

The CGW used was produced from some bottles obtained from a dumpsite at Agudama-Epie, Yenagoa, Bayelsa State, Nigeria The waste glass was properly cleaned and sun dried for 8 hours before crushing to have finer particles of 1.18 mm size. The Dangote brand of Portland Limestone Cement (PLC) that is conventionally used for building works such as structures, pavement, and general works etc, was used in this study. The fine aggregates were clean river sands obtained from a sand dump in Amassoma community in Bayelsa State, which were free from any form of visual impurities and organic matter. The coarse aggregate was high quality granite retained on the 3.75 sieve obtained from the Amassoma market.

2.2. Methods

2.2.1. Preliminary tests

The initial tests done include sieve analysis which was performed in accordance with BS 882 (1983), specific gravity which was determined as reported in BS 812-2 (1995), bulk density which was determined as reported in BS 812-2(1995) and water absorption test which was done as reported in the BS 812-2 (1995).

2.2.2. Preparation of specimens

The concrete moulds used in this study where cubes; 100 mm, cylinders; 100 mm by 200 mm, beam; 100 mm by 100 mm by 500 mm in dimension. The moulds were properly cleaned and lubricated with oil for easy removal of the test specimen before casting the fresh concrete on it and tampered in three equal layers.

2.2.3. Mixing

A mix ratio (1:2:4) and water/cement ratio (0.5) were used. The sand was partially substituted with CGW fraction of 5%, 10%, 15%, 20% and 25% in this study. The mixing of the dry concrete constituents was done manually with shovel until a uniformly distributed mixture and color was achieved, before adding the measured volume of water to produce a workable concrete.

2.2.4. Concrete curing and testing

The concrete samples were prepared to be demolded after 24 hours' rest period after casting. The samples were then cured on a concrete curing tank and tested after 7, 14, 21, and 28 days. The following tests were performed on the concrete:

i. Workability: This was done using the slump test method on the fresh concrete as reported in BS 1881-102 (1983).

ii. Compressive strength: Concrete cubes of 100 mm were produced and tested with the universal testing machine (UTM) in line with BS 1881-116 (1983) after curing.

iii. Splitting tensile strength: Concrete cylinders of 100 mm by 200 mm were casted and tested with UTM in accordance with BS 1881-117 (1983).

iv. Flexural strength: Concrete beam specimens of 100 mm by 100 mm by 500 mm cross-section were casted and tested in accordance with BS 1881-118 (1983).

3. RESULTS AND DISCUSSION

3.1. Sieve Analysis

Sieve analysis of sand and CGW are presented in Table 1. The fraction of CGW in excess of 1.18 mm were not used in the study to prevent alkali silica reaction. This was done to ascertain the fineness modulus of the sand and CGW as presented in Table 2.

Table 1: Particle size distribution of sand and crushed glasses

Sieve size (mm)	%passing (sand)	%passing (CGW)
4.75	100.00	100.00
2.36	92.54	100.00
1.18	71.62	92.20
0.60	46.43	55.34
0.425	36.48	39.67
0.300	21.51	24.69
0.150	2.79	8.12
0.075	0.35	1.65

3.2. Physical Properties of Aggregates

Table 2 presents some properties of coarse aggregates (CA), fine aggregates (FA), CGW which are in conformity with values obtained by Otunyo and Okechukwu, (2017). The fineness modulus of the sand and CGW were 2.62 and 2.10 respectively, which are below 3.2 as required by the BS 882 (1983). Also, all other properties met requirements by the British Standard.

Table 2: Properties of aggregates

Property	CA	FA	CGW
Fineness modulus	--	2.62	2.10
Specific gravity	2.81	2.86	2.65
Density (saturated) (kg/m^3)	2664	2587	2440
Density (dry) (kg/m^3)	2583	2476	2330
Water absorption (%)	3.00	0.5	0.46

3.3. Workability

The concrete workability is shown by the slump test result on Figure 1. It showed that, the slump value (i.e. the workability) increased with the increase in CGW from 0 to 20% replacement, and started to reduce at 25% of CGW. This may be as a result of the low level of water absorption of the CGW and angular nature of the particles glass, hence, causing more voids in the concrete (Scivacharam et al., 2015).

3.4. Compressive Strength

Compressive strength variation observed for 7, 14 and 28 days are shown in Figure 2. It was revealed that, there was increase in strength when CGW content increased up to 10% to obtain 31.33 N/mm^2 as the maximum compressive strength after 28 days, and decreased thereafter. This may be due to the lower strength of the CGW together with less bonding between the CGW and the cement past. This was also confirmed by Otunyo and Okechukwu, (2017).

3.5. Splitting Tensile Strength

Figure 3 presents the result of splitting tensile. The tensile strength of the concrete increased with increasing curing days generally. However, there was reduction in strength with increase in CGW in all samples. The maximum tensile strengths in all mixes where obtained at 28 days as; 3.86, 3, 2.58, 2.45 2.32, and 2.21 N/mm^2, for 0, 5, 10, 15, 20, and 25% CWG contents respectively. The highest tensile strength after the control was obtained as 3 N/mm^2 from sample with 5% CGW content.

3.6. Flexural Strength

Figure 4 presents the result for the flexural strength which revealed that there was no meaningful variation in in the strengths (6 N/mm^2, 6.8 N/mm^2, 7.02 N/mm^2, 7.2 N/mm^2) after 7, 14, 21 and 28 days respectively at 15% CWG. The maximum strengths (i.e. 6.5 N/mm^2, 6.8 N/mm^2, 7.75 N/mm^2, 8 N/mm^2) for 7, 14, 21 and 28 days respectively, where obtained at 10% CWG content. However, there were some fluctuations in the results. A similar behavior was also reported by Abdallah and Fan (2014).

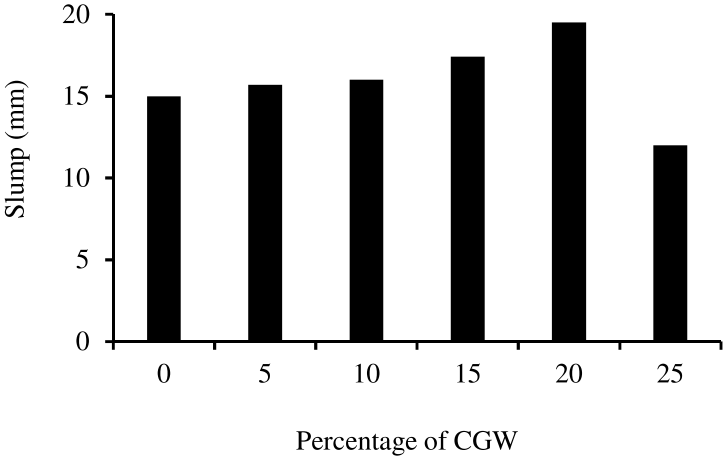

Figure 1: Slump test results

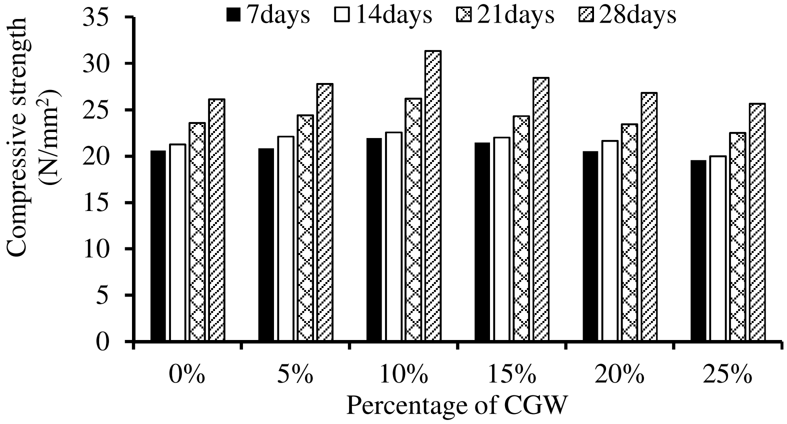

Figure 2: Compressive strength of concrete

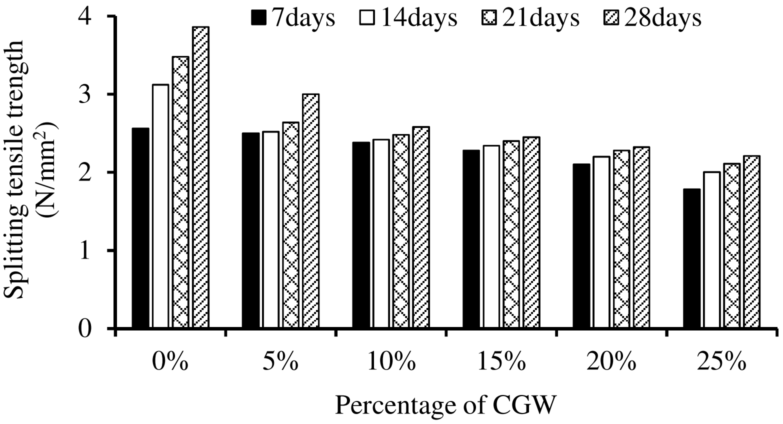

Figure 3: Splitting tensile strength of the concrete

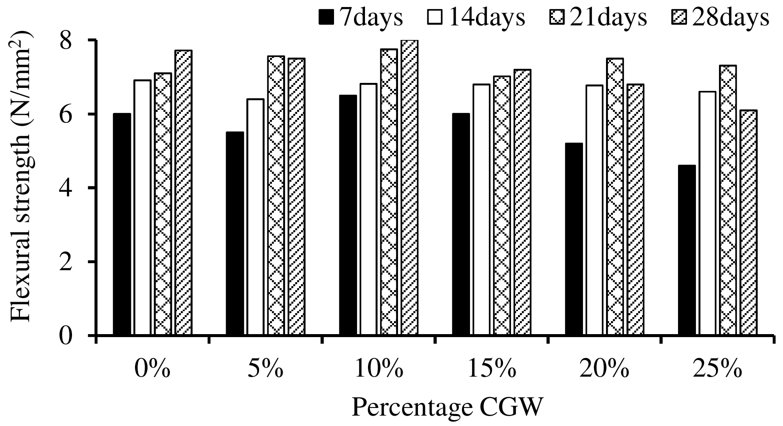

Figure 4: Flexural strength of the concrete

4. CONCLUSION

Based on this study which incorporated CGW as substitutes for fine aggregates in concrete production, it was revealed that the concrete workability increased with the increase in CGW from 0 to 20% and decreased thereafter. The compressive strength also increased as CGW increased from 0 to 10%, and decreased thereafter. The maximum compressive strength obtained in 28 days was 31.33N/mm^2 at 10% CGW. The splitting tensile strength increased to attain a maximum strength at 5% CGW and decreased thereafter. Much difference was not observed in flexural strength until 10% CGW replacement level before the strength decreased thereafter. Hence, a maximum of 10% CGW replacement in fine aggregates can be used to produce a structural concrete.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

Abdallah S. and Fan M. (2014). Characteristics of concrete with waste glass as fine aggregate replacement. *International Journal of Engineering and Technical Research*, 2(6), pp. 11-17.

BS 1881-102 (1983). Testing of Concrete: Slump Test, British Standards Institute. London, United Kingdom.

BS 1881-116 (1983). Testing Concrete. Method for determination of compressive Strength of concrete cubes. British Standards Institute. London, United Kingdom.

BS 1881-117 (1983). Testing Hardened Concrete. Splitting tensile strength of test Specimens. British Standards Institute. London, United Kingdom

BS 1881-118 (1983). Testing Hardened Concrete. Flexural Strength of test Specimens. British Standards Institute. London, United Kingdom.

BS 812-2 (1995). Testing aggregates Methods for determination of density. British Standards Institute. London, United Kingdom.

BS 882 (1983). Specification for aggregates from natural sources for concrete. British Standards Institute. London, United Kingdom.

Guatam, S. P., Vikas, S. and Agarwal, V. C (2012): Use of glass wastes as fine aggregate in Concrete. *International Journal of Academic Industries Research.* 16, pp. 320-322.

Otunyo, A.W. and Okechukwu, B. N. (2017). Performance of concrete with partial replacement of fine aggregates with crushed waste glass. *Nigerian Journal of Technology*, 36(2), pp. 403-410

Shayan, A. and Xu, A. (2006). Performance of glass powder as a pozzolanic material in concrete: A field trial on concrete slabs. *Cement and Concrete Research,* 36(3), pp. 457-468.

Scivacharam, S., Vikas, S. and Agarwal, V. C (2015). Glass Waste in Concrete: Effect on Workability and Compressive Strength. *International Journal of Innovative Research in Science, Engineering and Technology*, 4(9), pp. 8142-8150.