PARTIAL REPLACEMENT OF FINE AGGREGATE WITH WASTE GLASS IN CONCRETE MADE FROM BIDA NATURAL AGGREGATE

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Abstract

This study reports the experimental investigation on the suitability of waste glass as partial replacement for fine aggregate in concrete made using Bida natural aggregates (BNA). Glass is widely used in our daily lives through manufactured products such as sheet glass, bottles, glassware, and vacuum tubing. It is an ideal material for recycling. The increasing awareness of glass recycling speeds up inspections on the use of waste glass with different forms in various fields. Mix ratio of 1:2:4 batched by weight with water – cement ratio of 0.55 was used. The percentage replacement varied from 0% to 40% at 5% intervals. Slump test was conducted to assess the workability of the fresh concrete. The compressive strengths and densities of cured concrete cubes of sizes 150mm x 150mm x 150mm were evaluated at 7, 21 and 28days. A total of 81 concrete cubes were cast and tested. It was observed that an increase in the percentage replacement of fine aggregate with waste glass reduces workability, density and compressive strength. The compressive strength and density vary with days of curing. The findings of this study indicated that the optimum replacement percentage of waste glass with conventional fine aggregate was 20%. However waste glass can effectively be used as fine aggregate replacement (up to 40%) without substantial change in concrete strength.

Keywords: Bida Natural aggregates, Concrete, Fine Aggregates, Recycling, Waste glass

1.0 INTRODUCTION

Concrete is a man-made composite, a major constituent of which is natural aggregate such as gravel and sand or crushed rock. Alternatively, artificial aggregate such as blast furnace slag, expanded clay, broken bricks and steel shots may be used where appropriate. It is obtained by mixing cementitious material, water and aggregate (and sometimes admixtures) in required proportion. The mixture when place in form and allowed to cure hardens into a rocklike mass known as concrete. The hardening of concrete is cured by chemical reaction between cement and water and continues for a very long time and consequently the concrete grows stronger with age (Bamigboye *et al.*, 2015). The hardened concrete may be consider as an artificial stone in which the void of larger particles (coarse aggregate) are filled by the smaller particle (fine aggregate) and void of fine aggregate are filled with cement. The cementitious material and water forms a cement paste which in addition to the filling of the void of fine aggregate coats the surface of fine and coarse aggregate together to form a compact mass (Bamigboye *et al.*, 2015). In its hardened stage concrete is a rocklike material with high compressive strength while in its plastic stage it can be easily moulded into virtually any shape. It may be used as an architectural advantage or solely for decorative purposes. Normal concrete has a comparatively low tensile strength and for structural application it is normal practice to either incorporate steel bars to resist any tensile force (reinforced concrete) or to apply compressive forces to the concrete to counteract this tensile forces (pre-stressed concrete). Concrete is also used in conjunction with other materials for example it may form a compression flange of a box section, the reminder of which, steel (composite construction) is used structurally in building, foundation, column, beams, slabs, shell construction, bridges (Shabana *et al.*, 2011). Concrete occur in both fresh and hardened state. Its fresh state must undergo proper workability, consistence, setting, handling placing, transportation and compaction for it to be satisfactory. This fresh concrete solidified and hardened after placement and develops strength over time (Bartos *et al.*, 2002). Concrete can be consider to be an artificial stone made by binding together the particles of relatively inert fine and coarse materials with cement paste.

Glass is a transparent material produced by melting a mixture of materials such as silica, soda ash, and $CaCO_3$ at high temperature followed by cooling where solidification occurs without crystallization. Glass is extensively used in our lives through manufactured products such as sheet glass, bottles, glassware, and vacuum tubing. Glass is an ideal material for recycling. The use of recycled glass saves lot of energy and the increasing awareness of glass recycling speeds up focus on the use of waste glass with different forms in various fields. One of its significant contributions is the construction field where the waste glass was reused for concrete production. The application of glass in architectural concrete still needs improvement. Several study have shown that waste glass that is crushed and screened is a strong, safe and economical alternative to sand used in concrete. During the last decade, it has been recognized that sheet glass waste is of large volume and is increasing year by year in the shops, construction areas and factories. Using waste glass in the concrete construction sector is advantageous, as the production cost of concrete will go down. The amount of waste glass is gradually increased over the years due to an ever-growing use of glass products. Most of the waste glasses have been dumped into landfill sites. The land filling of waste glasses is undesirable because they are non-biodegradable, which makes them environmentally less friendly. There is huge potential for using waste glass in the concrete construction sector. When waste glasses are reused in making concrete products, the production cost of concrete will go down (Topcu and Canbaz, 2004). Crushed glass or cullet, if properly sized and processed, can exhibit characteristics similar to that of gravel or sand. When used in construction applications, waste glass must be crushed and screened to produce an appropriate design gradation. Glass crushing equipment normally used to produce a cullet is similar to rock crushing equipment, it has been primarily designed to reduce the size or density of the cullet for transportation purposes and for use as a glass production feedstock material, the crushing equipment used is typically smaller and uses less energy than conventional aggregate or rock crushing equipment (Egosi,1992).

2.0 MATERIALS AND METHODS

2.1 SOURCING OF MATERIALS

Cement: in this work, ordinary Portland cement (OPC) was used. Cement is a kiln-dried and finely pulverized mixture of natural materials. The cement most commonly used for structural concrete is the ordinary Portland cement (OPC), other types of cement available include; Rapid- hardening Portland cement, Portland- Blast furnace cement, Low-heat Portland cement, sulphate-resisting cement, super-sulphate cement and High- alumina cement (Neville, 2000).

Typical Portland cement are mixture of Tricalcium silicate ($3Cao.Sio_2$), Dicacium Silicate ($2Cao.Sio_2$), Treicalcium Aluminates ($4Cao.Al_2O_3$), and Tetracalcium Alumino ferrite ($4Cao.Al_2O_3Fe_2O_3$), in varying proportions. In addition to the main compounds listed above there exist minor compounds, such as magnesium oxide (MgO), titanium dioxide (TiO_2), manganese oxide (Mn_2O_3), potassium oxide (K_2O), sodium oxide (Na_2O); they usually amount to not more than a few percent of the mass of cement (Neville and Brookes, 2008).

Fine Aggregate: Aggregate passing B.S sieve 5mm are termed fine aggregates. Fine aggregates generally consist of natural sand, or crushed stone sand or crushed gravel with most particles smaller. The natural sand can be classified as coarse sand, medium sand and fine sand in accordance to Table 4 (B.S 882-103.1).

Coarse Aggregate (Bida Natural Aggregate): The coarse aggregate used for this study was obtained from Bida town. It passes through sieve size 20mm.

2.2 METHODOLOGY

In order to study the effect of waste glass as partial replacement of cement on the strength of concrete, 81 cubes of size 150 mm × 150 mm × 150 mm were cast with different percentage of demolished waste glass ranging from 5% to 40% and 0% as the control. An effort has been made here to compare the strength of cubes made up with different percentage of demolished waste to the respective strength of conventional concrete at the end of 7, 21 and 28 days of moist curing and to have an idea about the optimum percentage of demolished waste which does not affect the strength of recycled concrete considerably. Similarly, fine aggregate was also partially replaced by waste glass and only cubes were cast and tested after 7, 21 and 28 days for mix of 1:2:4 at a w/c of 0.55.

3.0 RESULTS AND DISCUSSION

Table 1.0: Physical properties of Aggregates

Properties	Waste Glass	Sand	Gravel
Loose bulk Density (g/cm^3)	1.53	1.96	1.34
Compacted bulk Density (g/cm^3)	1.65	1.8	1.5
Moisture content (%)	5.09	8.26	6.42
Specific Gravity	2.43	2.61	2.59
Water Absorption (%)	12.39	13.78	4.89

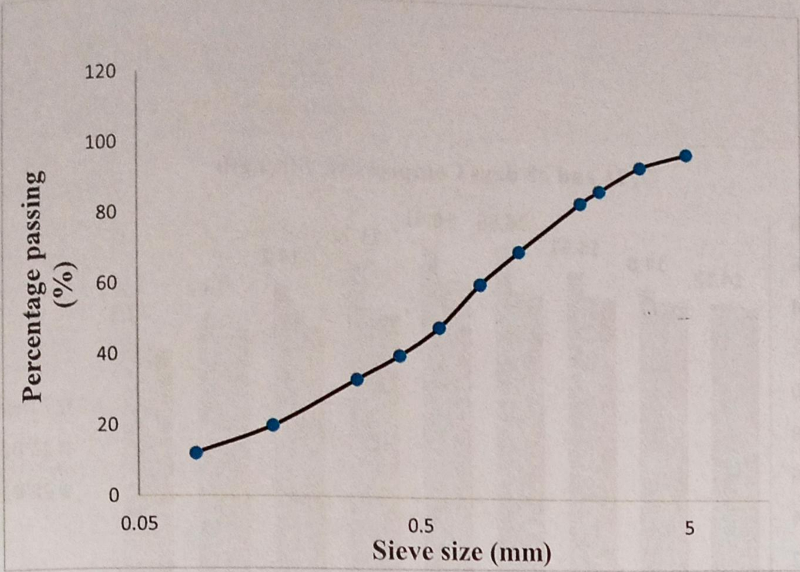

Figure 1.0: Particle Size Distribution for Waste Glass

Specific gravity value of 2.43 placed the waste glass in the same category as lightweight aggregate while the specific gravity of sand and the gravel were 2.61 and 2.59 respectively, both fall within the acceptable natural aggregates range of 2.0 – 2.6 (BS EN 1097-6, 2013). However, the compacted and loose bulk densities of waste glass are 1.65 and 1.53 respectively. Waste glass is found to have a lesser water content compared to the fine sand which in turn reduces the workability of fresh concrete.

Table 2 presents a summary of compressive strengths obtained utilising waste glass aggregate in concrete production.

Table 2.0: Compressive Strength Results (N/mm^2)

% Replacement	7 Days	21 days	28 Days
0	15.61	15.97	16.61
5	15.10	14.93	16.56
10	13.93	14.34	15.51
15	13.75	14.30	15.41
20	13.35	13.55	14.12
25	13.3	13.54	13.90
30	12.58	13.40	13.80
35	12.45	13.10	13.20
40	11.87	11.73	12.10

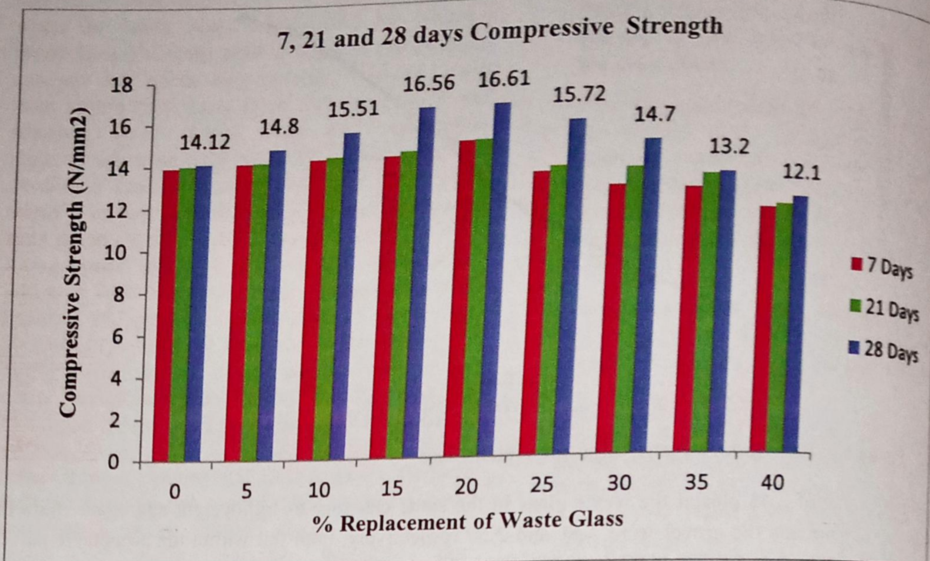

Figure 1.0: Compressive strength of concrete against percentage replacement of waste glass at 7, 21 and 28 d

It is observed from Table 2.0 and Figure 1 that for control (0% replacement), there is a minimal increase in compressive strength as the curing age increases. 7 days curing age has a compressive strength of 14.01 N/mm^2 while 28 days curing age has a compressive strength of 14.12N/mm^2. The compressive strength however kept increasing as the percentage replacement level increased from 5% to 20% replacement level of waste glass with fine aggregate at the 7, 21 and 28 days replacement, after which a gradual reduction in strength was observed until the 40% replacement level. The results for the 28 days curing prove that waste glass can be used as a substitute for fine aggregate in concrete production, with the optimum strength obtained at 20% replacement of Fine aggregate with glass. This result is in line with that of Srivastava *et al.* (2017).

4.0 CONCLUSION

It can be seen from the results of this study that replacement of conventional fine aggregate with waste broken glass in the production of concrete for the construction industry would result in structures with reasonable structural characteristics. The following conclusions were drawn from the study:

While using waste glass as fine aggrega replacement, 28 days strength was found slightly increase at 5-10% percentage replacem levels when compared to the control. A simi trend was observed in the variation of propert such as workability, unit weight and compact factor of concrete with an increase in t percentage replacement of fine aggregate w waste glass.

Hence, Waste glass can effectively be used as fi aggregate replacement, with the optim replacement level of 20%.

Waste glass is a reliable material that could be us in concrete to lower the amount of glass being la filled. The recycling of glass into aggreg applications is an economically feasible a environmentally friendly approach in tackling t problem of landfilling usually encountered w broken waste glass.

There exists a potential reduction in the cost concrete production by replacing fine aggreg with waste glass.

Concrete containing glass as fine aggregate shou be placed in applications where cracking and hi strength are not of importance.

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