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Crushed Waste Glass as a Partial Replacement of Cement in Normal Concrete Production with Sugar Added as an Admixture

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Abstract: This study investigates the possible use of crushed waste glass as a partial replacement of cement in normal concrete with sugar added as an admixture. The variable in this research is crushed waste glass while the sugar content is held constant at 0.05% by weight of cement in the concrete mix. The crushed waste glass content was varied from 5-25% in steps of 5% by volume of cement. Tests were carried out on 140 concrete cube specimens of size 150×150×150 mm. The specimens were prepared using a concrete mix proportion of 1:2:4 (cement:fine aggregate:granite), water/cement ratio of 0.65. It was observed that the 28th day compressive strength of the concrete cubes for 5% replacement of cement with CWG was 27.11 N mm^{-2} which is 12% above that for the concrete cube control specimen (without replacement of cement with CWG and without sugar). For cube specimen where sugar is added as an admixture (without CWG), the 28th day compressive strength of the cube is 28.15 N mm^{-2}. It was also observed that the compressive strength of the specimens decreased as the percentage of crushed waste glass in the mix increased. Concrete cube made with 20% CWG content is suitable for low-cost housing development.

Key words: Crushed waste glass, admixture, compressive strength, concrete, CWG, Nigeria

INTRODUCTION

Large quantities of waste materials and byproducts are generated from manufacturing processes, service industries and municipal solid wastes, etc. Research by concrete engineers has clearly suggested the possibility of appropriately treating and reusing such waste as aggregate in new concrete (Sagoe-Crentsil *et al*., 2001; Nixon, 1984; Hendriks and Janssen, 2003). As a result, solid waste management has become one of the major environmental concerns in the world. With the increasing awareness about the environment, scarcity of landfill space and due to its ever increasing cost, waste materials and byproducts utilization has become an attractive alternative to disposal. High consumption of natural sources, large production of industrial wastes and environmental pollution require obtaining new solutions for a sustainable development.

Utilization of waste materials and byproducts is a partial solution to environmental and ecological problems. Use of these materials not only helps in getting them utilized in cement, concrete and other construction materials, it helps in reducing the cost of cement and concrete manufacturing but also has numerous indirect benefits such as reduction in land-fill cost, saving in energy and protecting the environment from possible pollution effects. Further, their utilization may improve the microstructure, mechanical and durability properties of mortar and concrete which are difficult to achieve by the use of only ordinary Portland cement.

The use of crushed waste glass as material for concrete has been attempted decades ago. Those early efforts were thwarted by the problem of Alkali-silica Reaction (ASR). However, there are a number of measures to avoid ASR or its damaging effects (Meyer *et al*., 2001). Two of such measures are grinding the glass to pass at least US standard mesh size #50 (0.0117 in), adding mineral admixtures that can effectively suppress the reaction.

Naik and Wu (2001) studied the feasibility of using crushed, post-consumer glass as a partial replacement of sand in concrete and concluded that the compressive strength of concrete is slightly reduced when sand is partially replaced by crushed glass. Oyekan (2008a) found out that crushed waste glass has a significant effect on the compressive strength of sandcrete blocks. Shayan and Xu (2004) opined in their research on Value-added utilisation of waste glass in concrete that glass powder could replace up to 30% of cement in some concrete mixes with satisfactory strength development. Ashworth (1965) noted in his report on the effect of sugar on concrete that the most noticeable effect is the influence on the rate of setting, hence on early strength development. He also reported that once the retardation

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effect is over. The concrete hardens at the normal rate. Sugar has a significant effect on the compressive strength of the blocks increasing it by 17% at 28th day (Oyekan, 2008b). Oyekan and Ikponwonsa (2009) revealed that in addition to its retarding action, sugar has a significant effect on the strength properties of both normal and laterized concrete.

MATERIALS AND METHODS

Materials and manufacture of normal concrete specimen: The material constituents, their mix, admixtures and manufacturing process are important factors that determine the property of normal concrete.

Cement: In this research, Burham cement which is of the ordinary Portland cement type was used. The cement which confirms to BSI (1971) is commercially available in Nigeria. The properties of the cement are shown in Table 1.

Water: The water used was potable, fresh, colourless, odourless and tasteless water that is free from organic matter of any type.

Sand: The fine aggregate used for the experiment is sharp sand with sizes not >5 mm diameter from Ogun riverbed [Ogun state]. The sand was first air-dried in order to reduce considerably its moisture content.

Coarse aggregate (Granite): The coarse aggregate used for this research is granite from the crushing of quarried rock. The size of the granite is not >19 mm and before use, it was thoroughly cleaned to remove impurities such as dirt, clay and silt.

Crushed Waste Glass (CWG): The crushes glass was processed at Federal Institute Industrial Research Oshodi (FIIRO) in Oshodi, Lagos Nigeria. The chemical analysis of the glass was also done at University of Lagos. Table 1 shows the break down of the compositions.

Admixture: The domestic sugar is used is a white crystalline solid readily soluble in water and sweet in taste. It is readily available in the local markets.

Sieve analysis: Sieve analysis was carried out for the sand and granite used in the concrete mix. The results are shown in Fig. 1 and 2.

Mix proportion: One mix ratio, 1:2:4 of cement +CWG, sand and granite coarse aggregate was used. Sugar was

Table 1: Chemical analysis result of burham portland cement and crushed waste glass

Name of compounds	Burham cement (%)	CWG (%)
Total organic content (Toc)	1.70	0.01
Calcium Oxide (CaO)	62.32	7.52
Silicate (SiO_2)	18.72	71.86
Aluminate (Al_2O_3)	4.90	0.80
Ferrite (Fe_2O_3)	6.20	7.40
Magnesium Oxide (MgO)	1.62	1.02
Sulphur trioxide (SO_3)	1.10	2.10
Sodium Oxide (Na_2O)	0.34	12.79

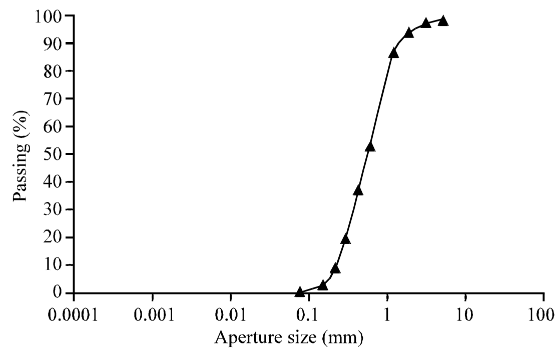

Fig. 1: Particle size distribution curve for unsieved sand

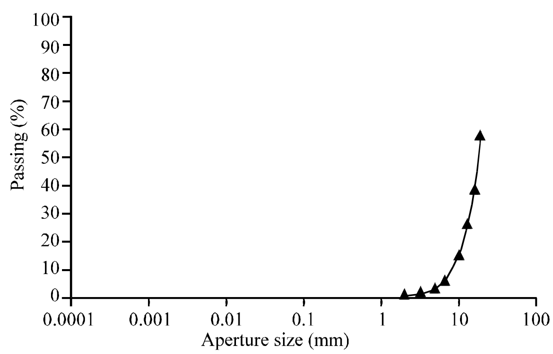

Fig. 2: Particle size distribution curve for granite

added as an admixture at 0.05% by weight of cement in the concrete mix. A constant water/cement ratio of 0.65 was also used.

For the preparation of the normal concrete specimens, the percentage of CWG was varied in steps 5% up to 25% by volume of cement.

Preparation and casting of test specimens: A total of 20 concrete cube specimens were prepared for each proportion in the concrete mix. The batching of the materials was done by volume except the sugar admixture that was done by weight of cement.

The cube specimens were cast by filling each cube mould in 3 layers each layer having been compacted normally with 25 blows from a steel rod of 25 mm diameter before the next layer was poured. After casting, the cube was demoulded and transferred to a curing tank containing clean water where they were kept until the day for their testing. The curing water was left at room temperature.

Testing of test specimens: The cubes were tested at ages 7, 14, 21 and 28th day using 150 kN Brudensberg hydraulic compressing machine. Five specimens were tested at each age and the highest and lowest values were discarded. The average of the remaining three values was used to determine the mean strength for each group.

RESULTS AND DISCUSSION

The results are presented in graphical forms. Figure 3 shows plot of the compressive strength against percentage crushed waste glass content in the mix and Fig. 4 shows plot of compressive strength against age.

Effect on compressive strength: The highest compressive strength (28.15 N mm^{-2}) of the cube specimens was obtained at the control test (i.e., without replacement of cement with CWG) but where sugar is added as an admixture.

This value is 16.6% higher the control value. Figure 3 reveals that CWG does appreciably enhance the compressive strength of the cube specimen. The 28th day compressive strength of 27.11 N mm^{-2} was achieved at 5% replacement of cement with CWG while the control cube specimen has a 28th day compressive strength of 24.15 N mm^{-2}.

This is an increment of 12.3% above the control value. As CWG content increased >5% value, there are reductions in compressive strength values. The increase in strength at 5% cement replacement with CWG can be attributed to better bonding achieved with the surrounding cement matrix in the presence of sugar as an admixture.

In addition when the lime in the cement reacts with the silica in the crushed waste glass in the presence of moisture, calcium hydroxide and tobermorite gel which are the hydration products of two compounds, namely, tricalcium silicate and dicalcium silicate are the result. The tobermorite particles are responsible for the cementing properties as well as other engineering properties such as strength and shrinkage.

The further decrease in compressive strength of the cube specimens as the percentage of the CWG content in the mix increased may be due to the fact that the depleted lime in the cement reacts with the surplus silica in the CWG resulting in the formation of weak cementituous compounds producing strength.

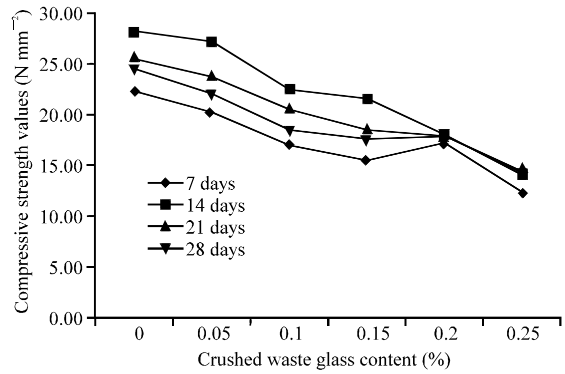

Fig. 3: Plot of compressive strength against percentage CWG content (with 0.05% sugar by weight of cement)

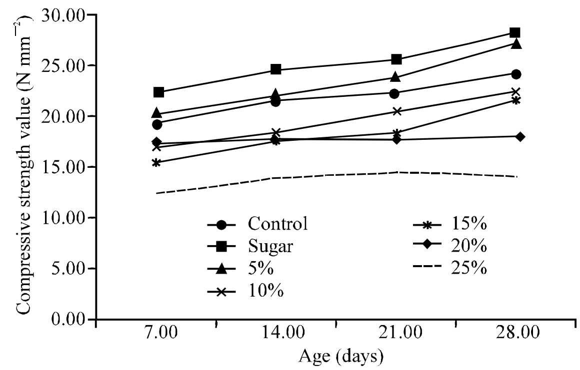

Fig. 4: Plot of compressive strength against age

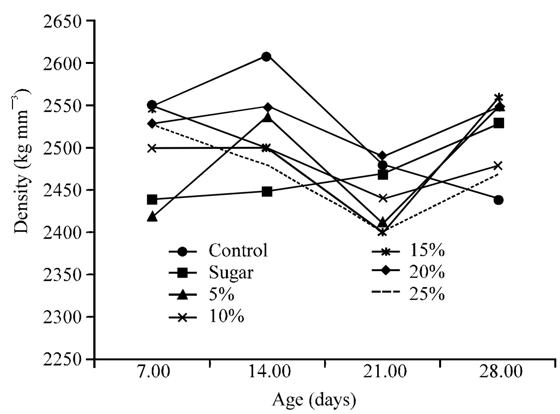

Fig. 5: Plot of density against age

Effect on density: The density values plotted in Fig. 5 revealed that concrete cube density where cement is replaced with CWG with sugar added as an admixture are in the same range with that of the control (without replacement with CWG and without sugar).

CONCLUSION

The main research derived from this investigation are as follows:

- Crushed waste glass has a significant effect on the compressive strength characteristics of cube specimens when sugar is added as an admixture
- There is an optimum CWG content above which the compressive strength of the cube specimen began to fall as the CWG content in the mix increases
- The optimum CWG content was found to be at 5% cement replacement with CWG
- The compressive strength decreased as the percentage of crushed waste glass content increased >5%
- The maximum compressive strength was attained at 28th day compressive strength for the control where sugar is added as an admixture
- The compressive strength of the cube specimens increased with age for all the replacements of cement with CWG
- Concrete cube made with 20% CWG content is suitable for low-cost housing development

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