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Workability and Compressive Strength Behavior of Glass Concrete Made Using Bagasse Ash Cement

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Abstract: ***This research work investigated the workability and compressive strength behavior of concrete made using crushed glass as part of fine aggregates and sugar cane bagasse ash as part of cement. The sugar cane bagasse ash (SCBA) was used to partially replace cement at 0%, 5%, 10%, 15% and 20% and crushed glass used to partially replace river sand at 30% by mass. The slump was maintained at 10-25mm for vibrated concrete and design mix ratio of 1:2:4 at water cement varying proportion of 0.50-0.65 was also used. The best results of concrete were achieved for 10% replacement of cement with SCBA and 30% crushed glass replacement of river sand. The 28 days' compressive strength rose to 22.03N/mm^2 at 0.61 water cement ratio, but lower than the control concrete strength of 23.06 N/mm^2; then started dropping. However, only 51.6% of the 28 days' strength had been achieved at 7 days for the mix, which was lower than the control mix of 70% at 28 days. This type of concrete is suitable for constructions of lightly loaded beams like lintels, and slabs of class 20 concrete mix design.***

Keywords: Sugar cane bagasse ash, crushed glass, workability, compressive strength

1. Introduction

Due to the increasing price, demand and consumption of cement, researchers and scientists are in search of developing alternatives to aggregates and binders, which are eco-friendly and contribute towards waste management. One of these alternatives to cement is the fibrous waste product obtained from sugar mills, sugar cane bagasse (SCB), once burnt, called sugar cane bagasse ash (SCBA). In previous studies, according to U. R. Kawade, (2013), SCBA has been used as a partial replacement of cement and the resulting concrete has shown experimentally to have higher compressive strength as compared to that of the concrete without SCBA. SCBA also has been found that at 30% replacement with cement, it increases workability of fresh concrete hence use of super plasticizer is not essential. Glass being non-biodegradable is one such material that is not suitable for addition to landfill. Fortunately, glass can be recycled indefinitely without any loss in quality, but first needs to be sorted by colour. This is an expensive process, and subsequently waste glass is increasingly being used in applications where mixed colour is not an issue, such as an aggregate in civil construction. When glass is crushed to a particle size finer than 75μm, concrete specimens are found to achieve prolonged compressive strength development, which can be attributed to the pozzolanic nature of very fine glass powder (Chen et al. 2006). M. Adaway & Y. Wang, (2015) found that the optimum percentage replacement of sand with fine glass aggregate was 30%. Compressive strength was found to increase with the addition of waste glass to the mix up until the optimum level of replacement. This was attributed to the angular nature of the glass particles facilitating increased bonding with the cement paste. In proportions exceeding the optimum level, waste glass was found to negatively impact the development of compressive strength. Previous studies by M. Adaway & Y. Wang, (2015) showed that concrete mixes containing glass exhibited lower slumps than that of the control mixes attributing the reduction in slump solely due to the angular geometry of glass particles, which reduces the availability of cement paste and hence the fluidity of the mix. This research paper investigates the effects of partially replacing cement with sugar cane bagasse ash (SCBA) and river sand with 30% crushed glass on workability and compressive strength of concrete.

2. Materials and Methodology

2.1 Materials

The partial replacement material to cement, that is, sugar cane bagasse ash (SCBA) was obtained from Muhoroni sugar company, Western Province in Kenya. Waste glass was obtained from Juja town, in Kenya. The other materials; cement (Nguvu CEM IV/B(P) 32,5N), river sand and ballast were obtained from local vendors in Juja town, Kenya

2.2 Methodology

The sugar cane bagasse obtained from Muhoroni sugar factory in Kenya was dried and sieved to ensure that only particles passing 0.075mm were collected for this study so as to conform with the maximum size of cement and eliminate the constituents of fine aggregates. Waste glass was obtained from Juja town, Kenya at selected collection points. Once the waste glass was obtained, it underwent manual crushing so as to reduce it to sand size and used to partially replace river sand at 30% by weight. Moisture content, silt content, specific gravity and bulk density tests of the river sand, crushed glass and ballast were done according to (BS1377–1:1990). The results are as shown in Table 1 below.

Table 1: Properties of sand, crushed glass and ballast

Material	Bulk density (Kg/m^3)	Moisture content (%)	Specific gravity	Silt content (%)
Sand	1410	1.52	2.79	0.78
Crushed glass	1374	0.1	2.64	-
Ballast	1612	0.92	2.81	-

For the bulk densities, aggregates weighing less than 1120 Kg/m^3 were light weight aggregates and more than 2080 Kg/m^3 were classified as heavy weight aggregates and anything in between were natural mineral aggregates used for producing normal weight concrete (NWC), hence the aggregates fell within normal mineral aggregates. On the specific gravity, most natural aggregates had specific gravities between 2.4 and 3.0 hence the aggregates fell within this range. Hence from these properties, the aggregates were okay for use in the research as they possessed the required engineering properties. Sieve analysis of river sand, crushed glass and ballast were done according BS812(1985) and all the aggregates fell within the grading envelope indicating that they were within the acceptable limits as shown in Figures 1, 2 and 3. The river sand and crushed glass were sieved through 5 mm sieve before they were used.

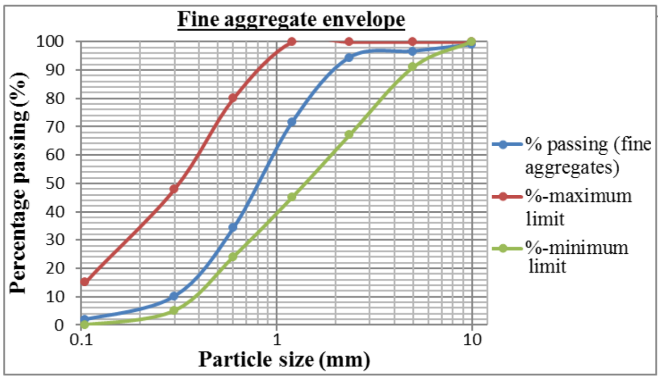

Figure 1: Fine aggregate grading

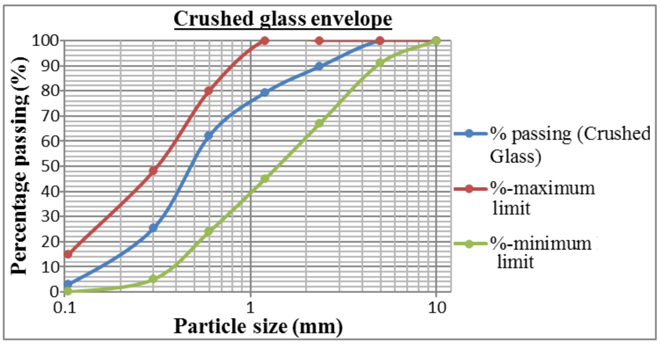

Figure 2: Crushed glass grading

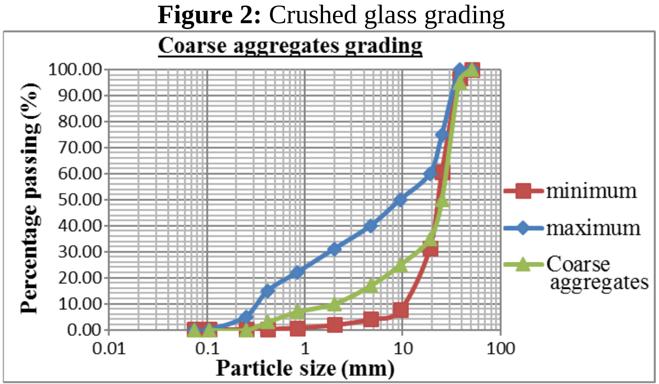

Figure 3: Coarse aggregate grading

In determination of the workability and compressive strength effects of sugar cane bagasse ash cement on glass concrete, concrete mix of the ratio 1:2:4 was used where the batching was done by weight. Cement replacement with sugar cane bagasse ash was done at 0, 5, 10, 15 and 20% intervals per given sample.

The slump test was performed according to BS EN: 12350: 2009 whereby the standard slump cone was filled with concrete in four layers, rodding 25 times per layer, then lifting the cone and measuring the extend to which the concrete collapsed. This concrete collapse (slump) was maintained between 10 – 25 mm as required for vibrated concrete. This was done for each sugar cane bagasse ash replacement at 0, 5, 10, 15 and 20% for cement in glass concrete production.

Compressive strength test was done to determine the strength of the hardened glass concrete containing bagasse ash cement. It was done in accordance to BS EN: 12390: 2000, whereby samples containing different proportions of bagasse ash cement were prepared and casted in moulds of internal dimensions of 150x150x150mm. Then the compressive strengths at 7, 14, 21, and 28 days were determined by crushing the samples in a universal testing machine as shown in Figure 4 below. For each proportion, three cubes were casted and the average taken, hence a total of 60 cubes were prepared.

a) Cube placing before testing b) Cube after testing

Figure 4: Compressive strength test

3. Results and Discussion

Table 2 shows the various percentages of material combination and the resulting water cement content and slump obtained. GCSCBAC XX-YY in Table 2 means glass concrete made using sugar cane bagasse ash cement, XX the proportion of glass in the fine aggregate (F.A) and YY is the proportion of sugar cane bagasse ash in cement. C.A means coarse aggregate proportion, W/C means water- cement ratio and SCBA means sugar cane bagasse ash. These descriptions of concrete were used throughout the study of the behavior of glass concrete made using sugar cane bagasse ash cement.

Table 2: Water cement ratio variations of glass concrete made using SCBAC

	Binder		F. A		C.A		
Specimen type	Cement	SCBA	Sand	Glass	Ballast	Slump	W/C ratio
GCSCBAC 00-00	100	0	100	0	100	24	0.55
GCSCBAC 30-05	95	5	70	30	100	25	0.58
GCSCBAC 30-10	90	10	70	30	100	24	0.61
GCSCBAC 30-15	85	15	70	30	100	24	0.62
GCSCBAC 30-20	80	20	70	30	100	25	0.65

From Table 2 above, it was observed that the water cement ratio increased with increase the SCBA content in cement for the slump level maintained within the margin of 25mm. Hence, for the allowed workability to be maintained in the mixes, the higher the SCBA content in cement, the higher water content as SCBA was seen to absorb a lot of water hence more water was required for the hydration process to take place. The variation graphically is explained by Figure 5 below.

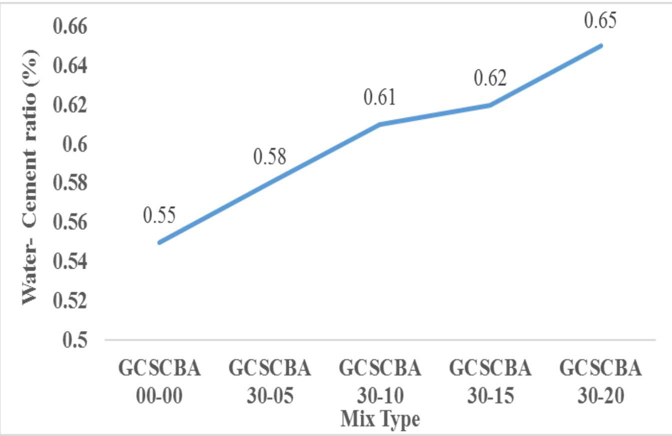

Figure 5: Water cement ratio variations of glass concrete made using SCBAC

From the results, in order to achieve good workability, the best water cement ratio can be maintained at 0.6 where by the percentage content of sugar cane bagasse ash is 10% and glass content is maintained at 30%. Table 3 shows the compressive strengths of each mix proportion and each value is the mean of triplicate results per test.

Table 3: Compressive strength variations of glass concrete made using SCBAC

	7 Days	14 Days	21 Days	28 Days	
	Strengths in Strength in ((N/mm^2)				F_{cu7}/F_{cu28} (%)
GCSCBAC 00-00	16.52	18.70	21.72	23.60	69.99
GCSCBAC 30-05	11.07	12.51	18.55	21.39	51.74
GCSCBAC 30-10	11.46	12.99	20.21	22.20	51.60
GCSCBAC 30-15	11.07	12.18	16.59	20.72	53.41
GCSCBAC 30-20	9.50	10.38	13.54	17.79	53.42

Comparatively, the strength of the glass concrete made using sugar cane bagasse ash cement was lower than the control experiment. Also, it was observed that, for the concrete containing both sugar cane bagasse ash and glass, the strength initially increased up to 10 % SCBA replacement in cement at 30% glass replacement in fine aggregates, but there after the strength dropped as the proportion of SCBA increased in the mix. This explains that, up to 10% SCBA replacement in cement increases the compressive strength glass concrete due to the increased amount of water cement ratio required for hydration process, but above 10% replacement of the cement with SCBA, the strength goes down as the content becomes saturated and the water is not useful in hydration process as it is being held between the SCBA pores. Graphically, the results are shown in Figure 6 below.

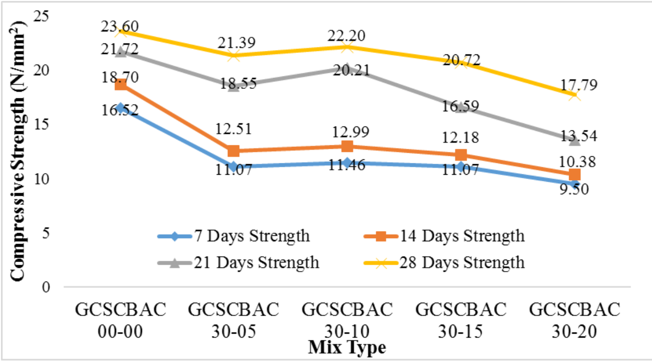

Figure 6: Compressive strength variations of glass concrete made using SCBAC

Figure 7 below shows the percentage of 28 days' compressive strengths achieved at 7 days for the various mixes.

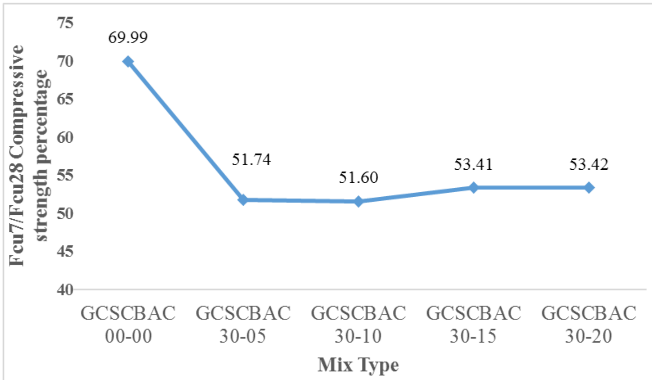

Figure 7: Percentage of 28 days' compressive strength achieved at 7 days of glass concrete made using SCBAC

From Table 7, it can be seen that the control mix achieved the required 70% compressive strength at 7 days but for the rest of the mixes, the compressive strength was lower than the required (between 50% to 55%). Also, there was increase in compressive strength as the age of curing increases. From Figure 7, the ratio of 7 days to 28 days' compressive strength shows that there was general increase in the rate of strength development as the replacement level increased. Also, the ratio of strength of the mixes to the control mix at the same age was as shown in the Table 4 below.

Table 4: Compressive strength percentages of various GCSCBAC mixes to that of control mix of the same age.

	7 Days	14 Days	21 Days	28 Days
GCSCBAC 00-00	100.00	100.00	100.00	100.00
GCSCBAC 30-05	67.00	66.90	85.40	90.63
GCSCBAC 30-10	69.35	69.47	93.05	94.07
GCSCBAC 30-15	66.98	65.12	76.36	87.78
GCSCBAC 30-20	57.51	55.49	62.33	75.36

From Table 4, it can be seen that the compressive strength of the various mixes was lower as compared to the control mix, but significant increase up to 10% replacement was noted then general drop for all mixes as shown in Figure 8 below.

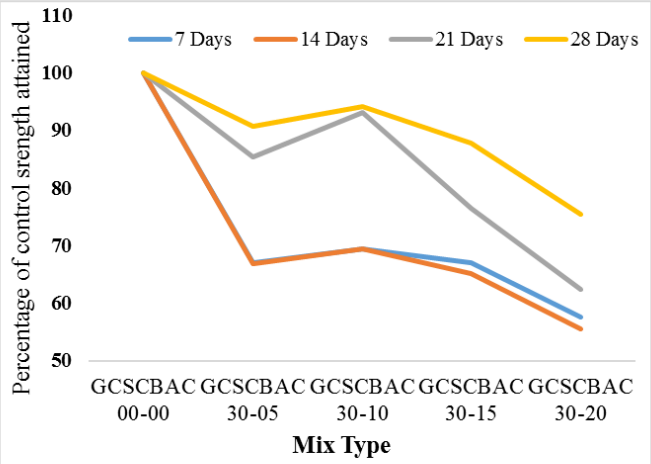

Figure 8: Percentage of control compressive strength achieved at same ages

4. Conclusions

From the results and discussions above, it may be concluded that:

1) Sugar cane bagasse ash (SCBA) is hygroscopic, as the higher the content in concrete; when cement is partially replaced with SCBA and crushed glass proportion to river sand maintained at 30%, the higher the amount of water required for good workability to be achieved.
2) In order to achieve good workability, the best water cement ratio should be maintained at 0.6 where by the percentage content of sugar cane bagasse ash in cement is 10% and glass content in river sand maintained at 30%.
3) The compressive strength showed that the strengths of the various mixes were lower as compared to the control mix, but significant increase up to 10% replacement of cement with sugar cane bagasse ash and 30% replacement of fine aggregates with crushed glass was noted.

5. Recommendations

From the experimental results and analysis, the following recommendations were made: -

1) In order to recycle and make our wastes useful especially in civil engineering, there is need to encourage researchers to take up research courses on these wastes to determine their engineering properties and where they can be used best. E.g. Recycled waste use in Civil Engineering.
2) Once cement is replaced with sugar cane bagasse ash at 10% and fine aggregates replaced with crushed glass at 30%, good workability is achieved and early strength developments of concrete of mix ratio of 1:2:4 are achieved of up to 51.6% in 7 days. This is possible at water cement ratio of 0.6. This mix can be used for lightly loaded beams like lintels and slabs in buildings.
3) There is also need to develop codes or guiding standards on the use of various wastes like sugar cane bagasse ash and glass in concrete. Once developed, there will be reduced cost of construction due to use of readily available wastes and solve the problem of environmental degradation.

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