Cylinder Tensile Split and Flexural Strength Behavior of Glass Concrete Made Using Bagasse Ash Cement

Brian Mwendwa Mutua[1], Dr. Timothy Nyomboi[2], Raphael Ndisya Mutuku[3]

[1]Department of Civil Engineering, Pan African University Institute for Basic Sciences, Technology and Innovations, JKUAT, Kenya

[2]Part time Senior Lecturer, Pan African University Institute for Basic Sciences, Technology and Innovations, JKUAT, Kenya

[3]Professor, Department of Building and Civil Engineering, Technical University of Mombasa, Kenya

Abstract: ***This research presents findings of cylinder tensile split and flexural strength behavior of concrete made using crushed glass as part of fine aggregates and sugar cane bagasse ash as part of cement. In trying to make industrial and agricultural wastes useful in the construction industry, 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 both tests; cylinder tensile split and flexural strength tests; showed that the strengths of the various mixes were lower as compared to the control mix. For the cylinder tensile split strength, the results showed that there was strength gain with increase in curing age but strength decrease with increase in composition of sugar cane bagasse ash in the mix., the ratio of 7 days' strength to 28 days' strength for mixes containing 5% and 10% sugar cane bagasse ash with 30% crushed glass content were 71.8% and 70.1% respectively, being higher than the control mix with 69.3%. The flexural strength results showed that there was notable increase in strength; for mixes containing sugar cane bagasse ash at 5% and 10% with crushed glass percentage at 30%; from 21.39 N/mm^2 to 22.20 N/mm^2 but still lower than the control mix, with 23.6 N/mm^2. Generally, for the cylinder tensile split and flexural strengths, the higher the content of sugar cane bagasse ash in concrete mix, the lower the strengths of concrete, hence that's why the need for the steel reinforcement in the concrete mixes to increase their strengths.***

Keywords: Sugar cane bagasse ash, crushed glass, glass concrete, bagasse ash cement, cylinder tensile split strength, flexural strength

1. Introduction

Concrete is a construction material composed of cement as well as other cementitious materials such as fly ash and slag cement, aggregate (generally, course aggregate e.g. gravel, limestone, or granite plus fine aggregate e.g. sand), water and may be chemical admixtures. 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). According to Baldisimo, (1988), the composition of waste is determined by various factors which include population, level of income, sources, social behavior, climate, industrial production and the market for waste materials. Recycled materials like waste glass are increasingly being used as partial replacement of natural aggregates in order to preserve natural resources (Padney et al., 2003). According to (Oliveira et al., 2013) and (Serpa et al., 2013), the increasing proportions of crushed glass as a replacement for fine aggregate results in an increase in ASR expansion. Saccani & Bignozzi, (2008) found that mixes containing up to 30% fine glass aggregate displayed levels of expansion that were below the deleterious limit set in ASTM C1260 (American Society for Testing and Materials, 2007). Furthermore, Zhu et al. (2004) identified that glass particles finer than 1.18 mm exhibited lower expansion than natural fine aggregate, even after extended testing. When glass was crushed to a particle size finer than 75µm, concrete specimens were found to achieve prolonged compressive strength development, which was attributed to the pozzolanic nature of very fine glass powder (Chen et al., 2006). U.R. Kawade, et al., (2013) found out in their study; on effect of use of bagasse ash on strength of concrete; that the strength of concrete increases when sugar cane bagasse ash is used to partially replace cement by 15% of weight. P.O. Modani & M. R. Vyawahare, (2012) in their study on the use of bagasse ash as a partial replacement of fine aggregates in concrete found out that, bagasse ash had lower specific gravity, bulk density and fineness modulus than the normal fine aggregates. This research paper investigates the effects of partially replacing cement with sugar cane bagasse ash (SCBA) and river sand with 30% crushed glass on tensile split and flexural strength behavior of concrete.

2. Materials and Methodology

2.1 Materials

For this research, sand was collected from Meru, Kenya. 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) and ballast were obtained from local vendors in Juja town, Kenya. Portable water from the laboratory was used for the tests.

2.2 Methodology

Waste glass underwent manual crushing so as to reduce it to sand size and used to partially replace river sand at 30% by weight. The sugar cane bagasse 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. Tests for 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) and the results shown in Table 1. Sieve analysis of river sand, crushed glass and ballast were done according (BS812–1:1985) and all the aggregates fell within the grading envelope indicating that they were within the acceptable limits.

Table 1: Material 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.

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.

In determination of the tensile split and flexural strengths, concrete mix of the ratio 1:2:4 was used where the batching was done by weight and the mix proportions are as shown in Table 2. Cement replacement with sugar cane bagasse ash was done at 0, 5, 10, 15 and 20% intervals per given sample. The following descriptions were used throughout the research work. SCSCBAC XX-YY 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 the binder. C.A means coarse aggregate proportion, W/C means water-cement ratio and SCBA means sugar cane bagasse ash.

Tensile split test was carried out according to BS EN: 12390: 2009 to determine the tensile strength of concrete in an indirect way. Standard test cylinders of concrete specimen of 300 mm X 150 mm were prepared for the various percentages of replacements of cement with bagasse ash in glass concrete at 0, 5, 10, 15, and 20%. For each replacement, three cylinders were cast, cured and tested and the results are shown in Table 3. The average tensile strength was taken for 7 and 28 days; hence a total of 30 cylinders were prepared.

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

Flexural strength test was carried out according to BS EN: 12390: 2009. The samples were prepared for the various percentages of replacement of sugar cane bagasse ash with cement in glass concrete and conducting three runs per replacement, then testing at 28 days after curing, hence 15 samples of dimensions 150 X 150 X 560 mm were prepared and tested as shown in Figure 1 using three point flexural test method where by the beam specimen was placed between two supports and load applied at the centre until failure using a universal testing machine and the results as shown in Table 4.

Figure 1: Flexural strength test

3. Results and Discussions

Table 3 shows the results of the 7 days and 28 days' cylinder tensile split strength of glass concrete made using sugar cane bagasse ash cement, each value being a mean of three-cylinder test results.

Table 3: Split tensile strength of glass concrete made using sugar cane bagasse ash cement

	Cylinder tensile split strength, Ft (N/mm^2)		
	7 Days	28 Days	F_{cu7}/F_{cu28} (%)
GCSCBAC 00-00	1.92	2.76	0.69
GCSCBAC 30-05	1.84	2.56	0.72
GCSCBAC 30-10	1.73	2.47	0.70
GCSCBAC 30-15	1.59	2.39	0.67
GCSCBAC 30-20	1.48	2.22	0.67

From the results in Table 3, the cylinder tensile split strength results showed that there was strength gain with increase in curing age but strength decrease with increase in composition of sugar cane bagasse ash in the mix as graphically shown in Figure 2. The ratio of 7 days' strength to 28 days' strength for mixes containing 5% and 10% sugar cane bagasse ash with 30% crushed glass content were 71.8% and 70.1% respectively, being higher than the control mix with 69.3%.

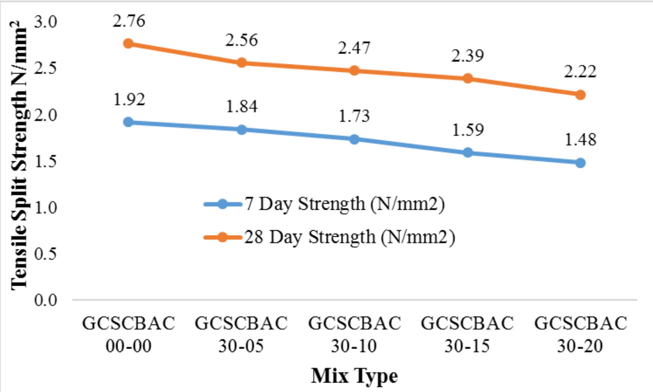

Figure 2: Cylinder tensile split strength of glass concrete made using sugar cane bagasse ash cement

Table 4 shows the flexural strengths of glass concrete made using sugar cane bagasse ash cement, each value representing the mean of triplicate results and tests were done at 28 days only. From the results, the flexural strength was lower than the control mix.

Table 4: Flexural strength of glass concrete made using sugar cane bagasse ash cement

	28 Days Flexural Strength (N/mm^2)
GCSCBAC 00-00	3.80
GCSCBAC 30-05	3.61
GCSCBAC 30-10	3.49
GCSCBAC 30-15	3.33
GCSCBAC 30-20	3.15

Generally, from Figure 3, it can be observed that the more the replacement of sugar cane bagasse ash in the mix while holding the proportion of glass to 30% of the fine aggregates, the flexural strength decreases.

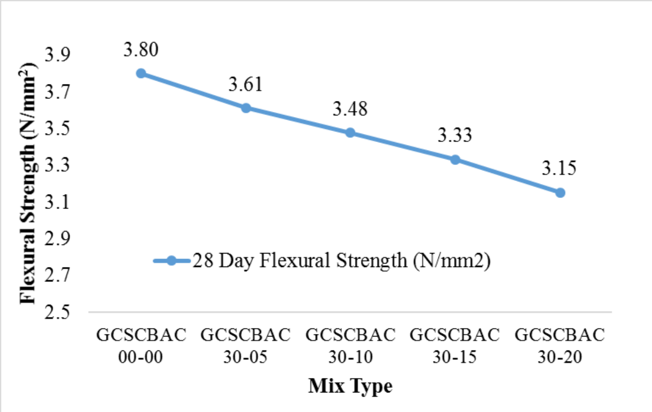

Figure 3: Flexural strength of glass concrete made using sugar cane bagasse ash cement

4. Conclusions

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

1) For the cylinder tensile split strength, the results showed that there was strength gain with increase in curing age but strength decrease with increase in composition of sugar cane bagasse ash in the mix. The ratio of 7 days' strength to 28 days' strength for mixes containing 5% and 10% sugar cane bagasse ash with 30% crushed glass content were 71.8% and 70.1% respectively, being higher than the control mix with 69.3%.
2) The flexural strength results showed that; for all the mixes, there was general decrease in strength as the composition of sugar cane bagasse ash increased in cement. This was attributed the fact that concrete is poor in tension but good in compression, so the less the cement content, the weaker the concrete.

5. Recommendations

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

a) Once cement is replaced with sugar cane bagasse ash at 10% and fine aggregates replaced with crushed glass at 30%, good tensile split strengths of more than 70%; 28 days' strengths at 7 days are achieved hence very good for early tensile split strength developments of structural members which might experience some tensile forces.
b) All the mixes are weak in taking up flexural or bending stresses, hence not recommended unless these stresses are taken up by reinforcements in structural members.
c) Development of codes or guiding standards on the use of various wastes like sugar cane bagasse ash and glass in concrete are needed. Once developed, there will be reduction in cost of construction due to use of readily available wastes and solve the problem of environmental degradation.

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Author Profile

Brian Mwendwa Mutua; a Kenyan, currently M.Sc. Student in Civil Engineering / Structural Engineering option at the Pan African University Institute for Basic Sciences Technology and Innovations at Jomo Kenyatta University of Agriculture and Technology Main Campus, Kenya

Timothy Nyomboi; Civil Engineer, M.Sc., Ph.D. in Civil Engineering, is a part time Senior Lecturer at Pan African University Institute for Basic Sciences Technology and Innovations at Jomo Kenyatta University of Agriculture and Technology Main Campus, Kenya. He is a Registered Engineer with Engineers Board of Kenya and a Member of the Institution of Engineers of Kenya

Raphael Ndisya Mutuku Civil Engineer, M.Sc., Ph.D. in Civil Engineering is a Professor of Civil Engineering, a Registered Engineer with Engineers Board of Kenya, a Fellow of the Institution of Construction Project Managers of Kenya, a Member of the Kenya National Academy of Sciences and a Member of the Institution of Engineers of Kenya. His research interests are in the fields of construction engineering materials, structural dynamics, civil/structural engineering analyses and designs