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Relationship between Cylinder Tensile Split and Flexural Strengths with Compressive Strength of Glass Concrete Made Using Bagasse Ash Cement

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Abstract: ***This research presents strength comparisons of cylinder tensile split strength and flexural strength with compressive strength of concrete made using sugar cane bagasse ash as part of cement and crushed glass as part of fine aggregates. In the research exercise, 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 mathematical relationship between the compressive strength ($F_{cu}28$) at 28 days and the corresponding cylinder tensile split strength (F_t28) at 28 days obeyed the relationship represented in the polynomial equation*** $Fcu28 = -13.366Ft28^2 + 76.601Ft28 - 86.188$ ***with R^2 value of 0.93. The values of tensile strength of concrete are usually 10-15% of compressive strength but not more than 20%. From the equation, the estimated values were within the range of 10-15%. The mathematical relationship between the 28 days flexural (F_f28) and the compressive strengths ($F_{cu}28$) of glass concrete made using sugar cane bagasse ash cement obeyed the relationship represented in the polynomial equation*** $Fcu28 = -9.39Ff28^2 + 73.251Ff28 - 119.54$ ***with R^2 value of 0.89. The usual relationship between compressive strength and flexural strength of concrete is that the compressive strength is approximately 8-10 times the flexural strength, hence the estimated values of equation were within the required range.***

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

1. Introduction

The increasing price, demand and consumption of cement has made researchers and scientists to search for alternatives to aggregates like crushed waste glass; and alternatives to binders like sugar cane bagasse ash, which are eco-friendly and contribute towards waste management. Sugar cane bagasse (SCB) is a fibrous waste product obtained from sugar mills. Once this fibrous material is burnt, it becomes a powdery material 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 relationship between compressive strength with cylinder tensile split strength and flexural strength of concrete made by partially replacing cement with sugar cane bagasse ash (SCBA) at various proportions; 0%, 5%, 10%, 15% and 20%; and river sand with 30% crushed.

2. Materials and Methodology

2.1 Materials

River sand used for this research was collected from Meru, Kenya. Sugar cane bagasse ash (SCBA) used to partially replace cement, 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

Sugar cane bagasse ash 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 also eliminate the fine aggregates constituents. Waste glass underwent manual crushing so as to reduce it to sand size and used to partially replace river sand at 30% by weight. 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 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 compressive, cylinder 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 and for each sample, river sand was replaced with crushed glass at 30% proportion by weight.

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.

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

Compressive strength test was carried out to determine the strength of the hardened glass concrete containing bagasse ash cement. It was done in accordance to BS EN: 12390: 2000 and the results are shown in Table 3, 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 28 days were determined by crushing the samples in a universal testing machine as shown in Figure 1 below. For each proportion, three cubes were casted and the average taken, hence a total of 15 cubes were prepared.

a) Cube placing before testing b) Cube after testing

Figure 1: Compressive strength test

Tensile split test was carried out 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 according to BS EN: 12390: 2009 and the results are shown in Table 3. The average tensile strength was taken for 28 days; hence a total of 15 cylinders were prepared.

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 2 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 3.

Figure 2: Flexural strength test

3. Results and Discussions

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

Table 3: Compressive, cylinder tensile split and flexural strengths of glass concrete made using sugar cane bagasse ash cement

	28 Days compressive strength (N/mm^2)	28 Days tensile split strength (N/mm^2)	28 Days flexural strength (N/mm^2)
GCSCBAC 00-00	23.60	2.76	3.80
GCSCBAC 30-05	21.39	2.56	3.61
GCSCBAC 30-10	22.20	2.47	3.48
GCSCBAC 30-15	20.72	2.39	3.33
GCSCBAC 30-20	17.79	2.22	3.15

From the results in Table 3, the compressive strength of glass concrete made using sugar cane bagasse ash cement was lower than the control experiment. Also, it is observed that, for the concrete containing both sugar cane bagasse ash and glass, the compressive 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 of 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 anymore as it is being held between the SCBA pores.

The cylinder tensile split strength results in Table 3 showed that there was strength decrease with increase in composition of sugar cane bagasse ash in the mix by retaining the proportion of crushed glass in fine aggregates to be 30%. Also noted was that the tensile split strength was lower than the flexural strength of all the mixes.

In establishing the relationship between the compressive strength and tensile strength of glass concrete made using sugar cane bagasse ash cement at 28 days, Figure 3 was used to explain the relationship based on the strengths at 28 days.

The mathematical relationship between the compressive strength ($F_{cu}28$) at 28 days and the corresponding split tensile strength (F_t28) at 28 days is represented in the equation below with R^2 value of 0.93.

$$Fcu28 = -13.366Ft28^2 + 76.601Ft28 - 86.188$$

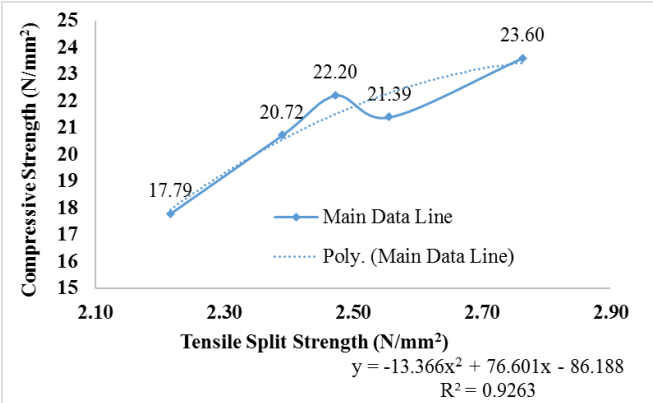

Figure 3: Relationship between compressive strength and cylinder split tensile strength of glass concrete made using sugar cane bagasse ash cement

The values of tensile strength of concrete are usually 10-15% of compressive strength but not more than 20%. From the equation, the estimated values were within the range of 10-15%. From the results in Table 3, the flexural strengths of all mixes were lower than the control mix but higher than the cylinder tensile split strengths. Generally, it was observed that the more the replacement of sugar cane bagasse ash with cement in the mix while holding the proportion of glass to 30% of the fine aggregates, the flexural strength decreased.

To explain the mathematical relationship between the flexural strength and the compressive strength of glass concrete made using sugar cane bagasse ash cement, Figure 4 was used to show graphically the relationships between these two strengths.

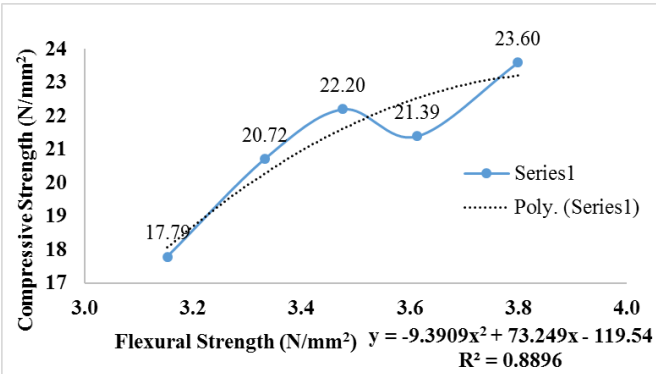

Figure 4: Relationship between compressive strength and flexural strength of glass concrete made using sugar cane bagasse ash cement

From the trend observed in Figure 4, a mathematical relationship between the compressive strength ($F_{cu}28$) and flexural strength (F_f28) of glass concrete made using sugar cane bagasse ash cement can be represented in the polynomial equation below with R^2 values of 0.89.

$$Fcu28 = -9.39Ff28^2 + 73.251Ff28 - 119.54$$

The usual relationship between compressive strength and flexural strength of concrete is that the compressive strength is approximately 8-10 times the flexural strength, hence the estimated values of equation 2 were within the required range.

4. Conclusions

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

1) The mathematical relationship between the compressive strength ($F_{cu}28$) at 28 days and the corresponding cylinder tensile split strength (F_t28) at 28 days of glass concrete made using sugar cane bagasse ash cement obeys the relationship represented in the polynomial equation $Fcu28 = -13.366Ft28^2 + 76.601Ft28 - 86.188$ with R^2 value of 0.93. The values of tensile strength of concrete are usually 10-15% of compressive strength but not more than 20%. From the equation, the estimated values were within the range of 10-15%.
2) The mathematical relationship between the 28 days' flexural strength (F_f28) and the compressive strength ($F_{cu}28$) of glass concrete made using sugar cane bagasse ash cement obeys the relationship represented in the polynomial equation $Fcu28 = -9.39Ff28^2 + 73.251Ff28 - 119.54$ with R^2 value of 0.89. The usual relationship between compressive strength and flexural strength of concrete is that the compressive strength is approximately 8-10 times the flexural strength, hence the estimated values of equation were within the required range.

5. Recommendations

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

a) All the mixes were weak in taking up flexural or bending stresses, hence not recommended unless these stresses are taken up by reinforcements in structural members.
b) 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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