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Experimental Study of Sugarcane Bagasse Ash as a supplementary Cementitious Material in Concrete

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ABSTRACT

The co-generation of the sugar industries produces a lot of unwanted waste, which when disposed in large quantities in the open environment (landfill) has a hazardous effect on the environment and on living organisms. The utilisation of these unwanted wastes produced by industrial strategies has been the focus of waste reduction management for economical, environmental and technical reasons. This experimental and analytical study investigates the potential use of sugarcane bagasse ash (SCBA) as a cement replacing material in the production of concrete. This paper puts forward the use of bagasse ash at 0%, 5%, 10% and 15% for a water/cement ratio of 0.53 in the concrete mix. The slump test and compressive strength test are carried and results are compared with that of reference concrete.

Keywords: Cement, Concrete, Compressive Strength Test, Sugarcane Bagasse Ash, Workability

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1. INTRODUCTION

Concrete is widely used as a construction material for different types of structures due to its structural stability and strength. The three main components of concrete are cement, aggregates (coarse & fine) and water. During the production of cement, one of the greenhouse gas called carbon dioxide is emitted, which is the main cause of global warming. In order, to reduce the greenhouse effect, alternative materials for cement have been considered. A number of researchers are focusing on ways of utilising industrial and agricultural wastes as a new source of raw materials for the cement industry. Various agro wastes such as straw ash, rice husk ash, sugarcane bagasse ash and fly ash are being used as supplementary cementitious materials due to their pozzolanic properties (Patil et al. 2017). According to Srinivasan and Sathiya (2010) waste utilisation would not only be economical, but may also result in foreign exchange earnings and environmental pollution control.

Sugarcane bagasse ash is an agricultural waste which is used worldwide as fuel in the sugar cane industry. Bagasse ash is a cellulose fiber residual after extraction of the sugar bearing juice from sugarcane. It is an inestimable by-product in sugar milling that is often used as a vital fuel source due to its high calorific value required to supply energy to the factory. The residue after combustion presents a chemical composition dominated by Silicon Dioxide, which exhibits pozzolanic property and has been found to improve some of the characteristics of paste, mortar and concrete like compressive strength and water tightness in certain replacement percentages and finesse (BirukHailu et al.2012).

The SCBA is often disposed as landfills, spread over farms or dumped in ash ponds. Soobadar and Kwong (2009) stated that loading of ash to soils increases the salt content whose solubility may cause salinity problems in soils, resulting in increase of electrical conductivity which may retard plant establishment and growth but also affect the soil

and groundwater quality. Castledenand Hamilon-Patterson (1942) stated that people exposured to these dust particles are prone to serious lung illness known as bagassosis. To limit the impact of SCBA in our environment, various studies have been carried out and the results showed that an optimum amount of SCBA can be used to replace cement in concrete, depending on the quality of bagasse ash being used.

Many researchers from various countries have made experimentation on the utilisation of SCBA as replacement to cement in concrete.

Bhurudeen et al. (2014) stated that the increase of bagasse ash in concrete showed better strength performance than controlled concrete. He further stated that with increasing percentage of bagasse ash, the concrete is more resistant to chloride and gas penetration. Malyadri and Supriya (2015) studied the replacement of SCBA at 5%, 10%, 15% and 25 % in concrete. They concluded that the SCBA can be replaced by an optimum level of 15%. Manojkumar et al. (2017) examined the effect of SCBA on the mechanical properties of concrete. The latter concluded that at 15% of SCBA, the compressive strength and flexural strength increase significantly compared to control concrete. Gawande et al. (2017) studied the replacement ratio of cement by SCBA at 10%, 20%, 30% and 40% for an M40 Grade concrete. He concluded that the workability, compressive strength and flexural strength of the concrete increases with addition of SCBA. The latter stated that 10% of SCBA can be used to replace cement in concrete. Jha et al. (2018) investigated on the use of bagasse ash as replacement to cement in the ratio ranging from 0% to 20%, and the latter inferred that the slump values decreases as percentage of SCBA is increased, and the compressive strength and split tensile strength was found to be maximum at 10% replacement of SCBA.

This research put forward the use of SCBA as an promising component in the composition of green concrete, and this can be achieved by reducing the deposit of SCBA in the environment with alternative methods of re-use. This paper aims in elaborating an optimum SCBA content in concrete and any eventual use in the future.

2. MATERIALS AND METHODOLOGY

In thepresent experimental investigation, sugar cane bagasse ash has been partially replaced in the concrete mixes. The effect of replacing different percentages of sugar cane bagasse ash as a supplementary material in the concrete mixes was studied. The details of the experimental investigations are as follows.

The materials used in this research are as follows:

Cement

The Ordinary Portland Cement (OPC) used in this research is of type CEM II 42.5 which is available from the local market is represented in Table 1.

Table 1: Chemical & Physical Properties of Cement

Components/Test	Results
SiO_2 (%)	20.24
CaO (%)	62.73
Al_2O_3 (%)	5.22
Fe_2O_3(%)	3.08
MgO (%)	3.43
Loss of Ignition (%)	1.20
Specific Gravity (g/cm^3)	3.04
Initial setting time (min)	130
Final setting time (min)	195
Colour	Grey

Natural Coarse Aggregates

The natural coarse aggregates (NCA) were obtained from our local plant and consist of crushed basaltic rocks. The specific gravity was found to be 2.65 g/cm^3 and water absorption 2.18%.

Natural Fine Aggregates

The natural fine aggregates (NFA) were obtained from the same plant as for the coarse aggregates. The source of the fine aggregate are from crushed basaltic rocks. The size of NFA ranges from 0-4 mm. Its specific gravity is 2.90 g/cm^3, fineness modulus 3.24% and water absorption 1.84%.

Sugarcane Bagasse Ash (SCBA)

The sugarcane bagasse ash was collected from Medine Ltd depot at Bambous located in the west of Mauritius. The SCBA is obtained from the burning of sugar cane bagasse which is used for co-generation of electricity in the Medine Ltd sugar cane factory. For the purpose of this research and on an experimental basis, the black colour bagasse ash was further burnt in an oven in the laboratory at a temperature of 240ºC for 12 hours. The material obtained is of a brownish colour and much finer than the raw SCBA, as part of the fibers have been burned into ashes. The treated SCBA is then sieved as per BS 812 Part 103.1: 1985 with sieve size aperture 75 µm. All materials passing through the 75 µm size was collected for the use in this experiment. The SCBA was used as replacement to cement and their properties were shown in Table 2.

Table 2: Chemical &Physical Properties of SCBA

Components	**Mass (%)**
SiO2	30.27
CaO	1.69
Al2O3	23.80
Fe2O3	4.87
MgO	1.37
Loss of Ignition (%)	5.43
Specific Gravity (g/cm^3)	2.05
Colour	Light Brown

Water

Water from tap was utilised for this experiment.

Concrete Mix Design as per DOE Method

For this research 4 Nos. of concrete mixes were prepared, with B0 as the control mix containing 100% of Ordinary Portland Cement (OPC). The variation of replacement of cement with SCBA was experimented using 5%, 10% and 15% of treated SCBA in each mix. The DOE Method was used for the mix design process, which consist of tables and charts available at the Building Research Establishment (BRE). The concrete was designed for a compressive strength of 35 MPa with slump value ranging from 30 - 60 mm.

The following data were used for the mix design:

- Characteristic Compressive Strength at 28 days : 35 MPa
- Target mean strength : 45 MPa
- Cement : OPC CEM II 42.5
- Design Slump : 30 - 60 mm
- Natural Fine Aggregate : Crushed rock sand with 48.13% passing 600 µm sieve size aperture
- Natural Coarse Aggregate : Crushed Basaltic rock with maximum size of 20 mm
- Relative density of Natural Aggregates (SSD) : 2.70

The table below shows the mix proportion of materials in the concrete mix on Saturated Surface Dry Condition (SSD).

Table 3: Mix Proportion of Materials

		Materials(Kg)				
Specimen Type	**% of SCBA**	**Cement Content (Kg)**	**SCBA Content (Kg)**	**Fine Aggregates (Kg)**	**Coarse Aggregates (Kg)**	**Free Water Content (Kg)**
B0	0	396.00	0.00	655.0	759.0	210.0
B1	5	376.20	19.80	655.0	759.0	210.0
B2	10	356.40	39.60	655.0	759.0	210.0
B3	15	336.60	59.40	655.0	759.0	210.0

The concrete was mixed according to BS 1881: Part 125: 1986 with a drum mixer in the laboratory. Half of the coarse aggregates are added, followed by fine aggregates and then the remaining half coarse aggregates are added in the drum mixer. The materials are mixed in the drum for 15 secs to 30 secs. The mixing is continued and half of the water content is added during the next 15 secs. The whole batch is mixed for a total of 2 mins to 3 mins and then stopped and the content in the mixer is covered and left for 5 mins to 15 mins. The cement and bagasse ash is mixed separately in a container and added to the wet batch in the mixer, and the whole is mixed for another 30 secs. The remaining water is added over the next 30 secs and mixing is continued for at least 2 mins and not more than 3 mins.

3. EXPERIMENTAL INVESTIGATION

Slump Test

The workability of a fresh concrete was determined by the Slump Test pertaining to BS 1881: Part 102: 1983. The fresh concrete was laid in three layers in a cone with lower diameter of 200 mm, upper diameter of 100 mm and height 300 mm. The fresh concrete was poured into the cone with the first layer being 100 mm and using a tampered rod of diameter 16 mm^2, 25 strokes were applied to the layer. Same procedures were performed for the second and third layer. The excess concrete on top was strike off and the cone was carefully removed by raising vertically and placed beside the sample. The height of drop of the sample is measured compared with the inverted cone height.

Compressive Strength Test

The Compressive strength test was conducted on 9 numbers of 150 mm x 150 mm x 150 mm cubes samples tested at respectively on 7, 28 and 56 days and according to BS 1881: Part 116: 1983. The cube samples were centered on a compressive strength testing machine plate and was ensured that load were uniformly applied on two opposite flat surfaces. The load was gradually increased on the lower surface of the cube at a nominal rate of 0.2 N/(mm2·s) to 0.4 N/(mm2·s) until no greater load can be sustained by the cube. As failure of the cube is approached the rate will decrease and the sample was removed and verified for unsatisfactory or satisfactory failure. The compressive strength machine recorded the load at the failure point of the cube.

4. RESULTS AND DISCUSSION

Slump Test

The slump test was important as it determines the workability of the fresh concrete, and this was measured with the height of drop of the sample and this was illustrated in fig.1.

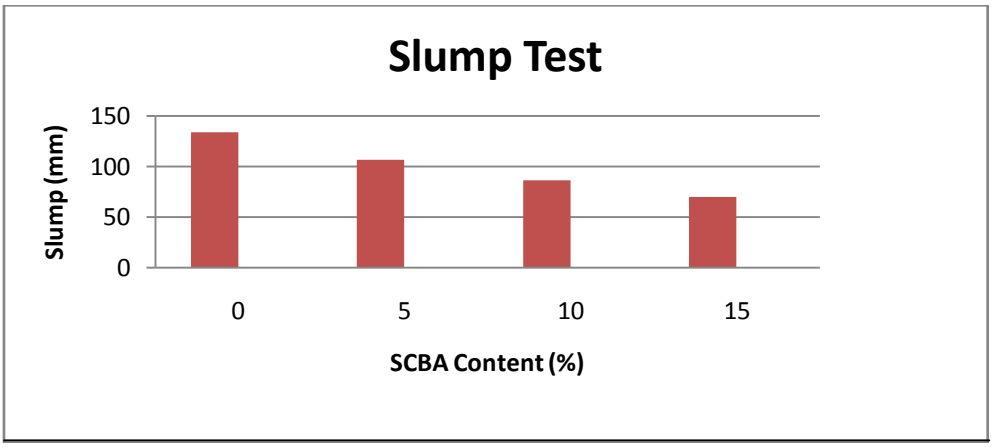

Figure 1.Workability of Sugarcane Bagasse Ash in concrete

From the results, it was observed that as the SCBA content was increased, the slump values decreases. The drop in height of the slump for 5%, 10% and 15% addition of SCBA to the concrete, the values decreased by 20.15%, 35.07% and 47.76%. This was attributed due to the high absorption nature of the particle of SCBA which has the ability to retain water.

Compressive Strength Test

The compressive strength test of the concrete samples containing SCBA at different proportion and days was illustration in Figure 2.

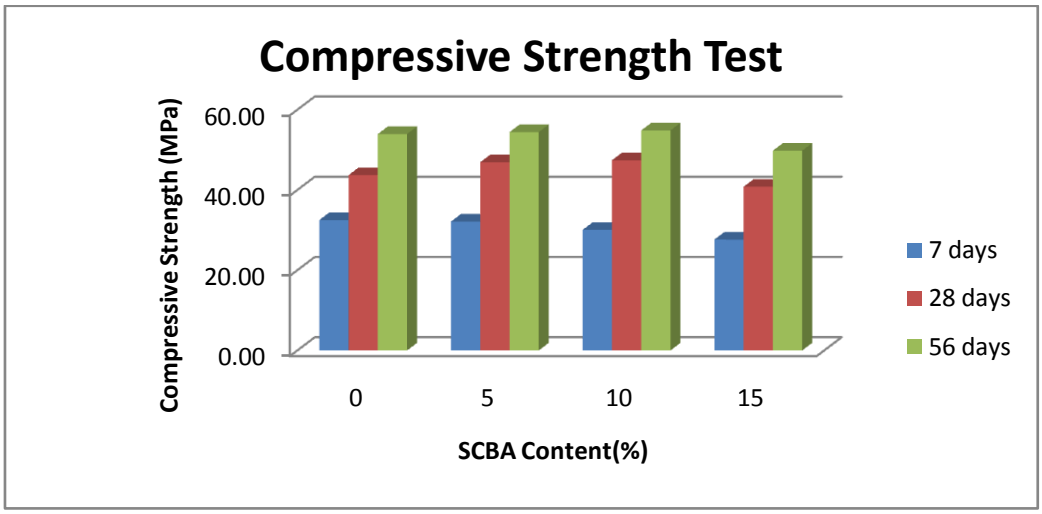

Figure 2.Compressive strength of Sugarcane Bagasse Ash in Concrete

From the results above, it was observed that the compressive strength increased as the concrete age increases, however it was also noted that the maximum strength was obtained at 10% of SCBA. At 7 days, the strength of the concrete was lower compared to reference concrete, however, at 28 days the strength for 5% and 10 % addition of SCBA showed an increase of 7.34% and 8.47%. At 15% addition, the strength decreases by 6.63%. At 56 days of curing, it was observed that with addition of 5% and 10% of SCBA, the strength increased by 0.87% and 1.65% and, a decrease of 7.69% was observed for 15% addition of SCBA to the concrete. The increase in strength was due to the pozzolanic properties of the SCBA. However, the decrease at 15% addition of SCBA showed to be in excess of silica which could lead to leaching out and causing deficiency in strength as it replaced part of the cementitious materials (M. Sachin Raj et al. 2017)

5. CONCLUSION

In the above study, an experiment was carried out where cement was replaced by SCBA at 5%, 10% and 15%, and to evaluate the effect of SCBA on the strength of the concrete. The main conclusions were as follows:

a) The experiment showed that SCBA materials have a high absorption value, which will affect the workability of the concrete. The use of a super plasticizer will have to be used to improve the workability.
b) The compressive strength of the concrete at 28 and 56 days were observed to increase for 5% and 10% addition of SCBA, however at 15 % addition the strength decreases. The maximum strength of the concrete sample was noted at 10% addition of SCBA.

From the results obtained, it can be concluded that the SCBA can be used at an optimum content of 10% mixed with 90% of Ordinary Portland Cement (OPC) and can be beneficial for the environment as well as for the human health, and contribute towards a more sustainable industry.

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