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ISSN 0974-5904, Volume 08, No. 02

International Journal of Earth Sciences and Engineering

April 2015, P.P.471-476

Experimental Investigation on Performance of Sugarcane Bagasse Ash Concrete in Acidic Environment

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Abstract: With the increasing demand and more consumption of cement in construction and improper waste management, researchers are always in search of different cement replacing materials. Due to the vast production of sugar cane in India, huge amount of sugarcane bagasse is being produced and which is a waste product coming out of sugar industries. Sugarcane bagasse ash is a byproduct of sugar factories found after burning sugarcane bagasse. Sugarcane bagasse is a fibrous waste product of sugar refining industry along with ethanol vapor. The utilization of industrial and agricultural waste produced by industrial process has been focus to waste reduction. The present study has been focused on assessing performance of SCBA concrete in different curing environments by the partial replacement of ordinary Portland cement with different weight percentages of SCBA (0%, 5%, 10%, 15%, 20% and 25%). The tests were conducted on cubes and cylinders and prisms at various ages of concrete i.e., 7, 28 and 56 days to assess the strength aspects of SCBA concrete. From the present study it is evident that, utilization of waste material sugar cane bagasse ash can be advantageously used as a replacement of cement up to 5% without reduction in strength of concrete. Also, it can be observed that, SCBA concrete performed better even in aggressive environments when compared to ordinary concrete even at later stages.

Keywords: *Sugarcane Bagasse Ash, Mechanical Properties*

1. Introduction

With increasing demand and consumption of cement, researchers and scientist are in search of developing alternate binders that are eco-friendly and contribute towards waste management. The utilization of industrial and agricultural waste produced by industrial processes has been the focus on waste reduction.

Recently sugarcane bagasse ash, which is a byproduct of sugar factories found after burning sugarcane bagasse which in turn is found after the extraction of all economical sugar from sugarcane, has been tested in some parts of the world for its pozzolanic property and has been found to improve some of the properties of the paste, mortar and concrete like compressive strength and water tightness in certain replacement percentages and fineness [5, 6]. The pozzolanic property of sugarcane bagasse ash came from the silicate content of the ash. This silicate under goes a pozzolanic reaction with the hydration products of the cement and results a reduction of the free lime in the concrete [1].

The use of different cement replacing materials has become a common practice in the construction industry. Most of these cement replacement materials are byproducts of different industries and agricultural wastes. Blast furnace slag, silica fume, fly ash and rice husk can be sited as an example. Sugarcane bagasse ash has also been found to have such pozzolanic property.

Bagasse is a cellulose fiber remaining after the extraction of the sugar-bearing juice from sugarcane [8]. Bagasse ash is one of the biomass sources and valuable byproducts in sugar milling that often uses bagasse as a primary fuel source to supply all the needs of energy to move the plants [4]. The bagasse ash is about 8-10% of the bagasse and contains unburned matter, silica and alumina [2].

Sugarcane production in India is over 300 million tons/year leaving about 10 million tons of as unutilized and, hence, wastes material. Due to the vast production of sugar cane in India, large amount of sugarcane bagasse is being produced and which is a waste product of industry. In the present study, partial replacement of cement with different weight percentages (0%, 5%, 10%, 15%, 20% & 25%) of sugarcane bagasse ash (SCBA) concrete subjected to different curing environments and predicted the strength parameters of concrete.

2. Properties of Ingredients

In the present investigation, sugarcane bagasse ash has been used as a partial replacement of cement in concrete mixes. On replacing cement with different percentages of SCBA, the strength properties are studied at different ages of concrete cured in different environments like fresh water and acidic curing.

2.1. Cement

Ultratech-OPC43 grade cement was used throughout the investigation. The cements were tested according to BIS standard conforming to (8112-1989) to determine various physical properties. The overall quality of cement required for the investigation was procured in the single lot and stored in the appropriate manner.

Table 1: *Properties of ordinary Portland cement*

Particulars	Test Results	Requirements as per IS: 8112-1989
Normal consistency (%)	31	35%>
Initial setting time (min)	35	Should not be less than 30
Final Setting time (min)	200	Should not be more than 600
Specific gravity Fineness (%)	3.10 4	3.15 10%>
Soundness (mm)	6.1 6.0 6.3	10>
Cube Compressive Strength		
3 days (N/mm^2)	24.5	23
7 days (N/mm^2)	35.6	33
28 days(N/mm^2)	44.8	43

2.2. Sugarcane Bagasse Ash

Sugar cane bagasseash consistsof approximately 50% of cellulose, 25% of hemicelluloses of lignin. Each ton of sugar cane generates approximately 26% of bagasse (at a moisture content of 50%) and 0.62% of residual ash. Sugarcane bagasse ash used for replacement was obtained from Bannari Amman Sugar's Ltd, Nanjangud, Karnataka. It is a by-product of sugarcane bagasse. It is mixed in different proportions in concrete. The physical properties and chemical composition of SCBA are given in the table 2 and 3.

Table 2: *Physical Properties of SCBA*

Property	Test Results
Particle Shape	Spherical
Mean Particle Size	0.1-0.2µm
Minimum Specific Surface Area	250 m /kg
Specific gravity	2.18
Density	573 kg/m^3

Table 3: *Chemical Properties of SCBA*

Component	Chemical Composition	Quantity
Silica	SiO_2	68.5
Alumina	Al_2O_3	7.1
Ferric oxide	Fe_2O_3	6.97
Calcium oxide	CaO	4.35
Magnesium oxide	MgO	3
Sulphur trioxide	SO_3	0.95
Chloride	Cl	0.02
Sodium oxide	Na_2O	0.2
Potassium oxide	K_2O	4
Loss of Ignition	LOI	5

2.3. Fine Aggregate

In the present study, locally available river sand confirming to zone II of IS: 383-1970 was used as fine aggregate. The sand is free from clay, silt and other organic impurities. The aggregate was tested for its physical requirements such as gradation, fineness modulus, specific gravity and bulk modulus in accordance with IS: 2386-1963. The fineness modulus of the fine aggregate used in this work is 2.89 which fall under the category of medium sand as per IS: 383-1970.

Specific gravity of fine aggregate used in this investigation is 2.67.

2.4. Coarse Aggregate

Crushed coarse aggregate of 20mm size procured from the local crushing plant was used throughout the investigation. The aggregate was tested for its physical requirements such as gradation, fineness modulus, specific gravity and bulk density in accordance with IS: 383-1970 and IS: 2386-1963.

2.5. Water

Fresh potable water with pH value less than 7 free from organic matter which is available in the college campus was used.

3. Experimental Programme

3.1. Concrete

Trial mix was done with a given set of constituent materials i.e., ordinary Portland cement, sand, 20mm graded coarse aggregate mixed with potable water. The mix proportions were arrived after carrying out trial mix, final mix proportions are mentioned in table 4.

Table 4: *Mix Proportions by Weight*

Cement	Fine Aggregate	Coarse Aggregate	W/C Ratio
1	1.59	2.63	0.4

3.2. Details of the Standard Specimens

Mixing of ingredients of concrete was done for the mix proportion mentioned in table 4 by adding SCBA with different percentages 0%, 5%, 10%, 15%, 20% and 25%. The standard dimension of the specimens for various tests and the total number of specimens casted and cured in specified manner are mentioned in table 5 and table 6.

Table 5: *Dimensions of specimens for different strength aspects*

Type of Test	Type of Specimen	Dimensions(mm)
Compression Test	Cubes	150x150x150
Split Tensile Test	Cylinders	150x300
Flexural Test	Prisms	100x100x500

Table 6: *Proposed number of specimens casted for various percentages of replacements of SCBA for different curing regime*

Curing Type	Ratio/Days	Cubes			Cylinders			Prisms		
		7	28	56	7	28	56	7	28	56
Conventional	0%	3	3	3	3	3	3	3	3	3
	5%	3	3	3	3	3	3	3	3	3
	10%	3	3	3	3	3	3	3	3	3
	15%	3	3	3	3	3	3	3	3	3
	20%	3	3	3	3	3	3	3	3	3
	25%	3	3	3	3	3	3	3	3	3
$2NH_2SO_4$	0%	3	3	3	3	3	3	3	3	3
	5%	3	3	3	3	3	3	3	3	3
	10%	3	3	3	3	3	3	3	3	3
	15%	3	3	3	3	3	3	3	3	3
	20%	3	3	3	3	3	3	3	3	3
	25%	3	3	3	3	3	3	3	3	3
$2NMGSO_4$	0%	3	3	3	3	3	3	3	3	3
	5%	3	3	3	3	3	3	3	3	3
	10%	3	3	3	3	3	3	3	3	3
	15%	3	3	3	3	3	3	3	3	3
	20%	3	3	3	3	3	3	3	3	3
	25%	3	3	3	3	3	3	3	3	3
Total no. of Specimens		162			162			162		

4. Results and Discussions

This section summarizes the test results obtained through different experimental set up in predicting the various strength aspects of SCBA concrete.

Figure 1, 2 and 3 shows the variation in compressive strength of concrete at all percentage of replacement of cement by sugarcane bagasse ash for different ages of curing in conventional as well as 2N sulphuric acid and 2N magnesium sulphate solution.

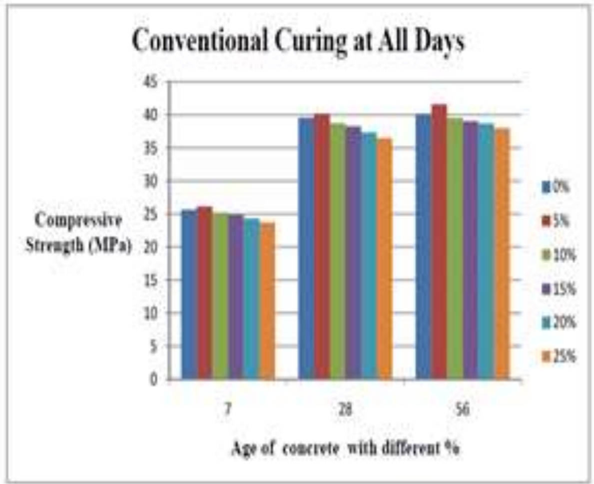

Figure 1 *Compression strength of cubes with partial replacement of SCBA at all ages - conventional curing*

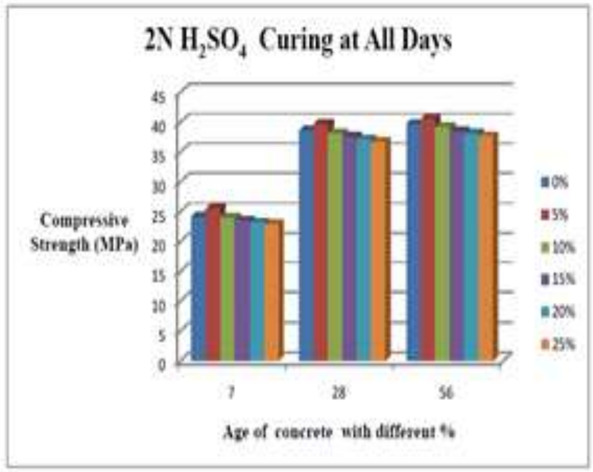

Figure 2 *Compression strength of cubes with partial replacement of SCBA at all ages –*$2NH_2SO_4$ *curing*

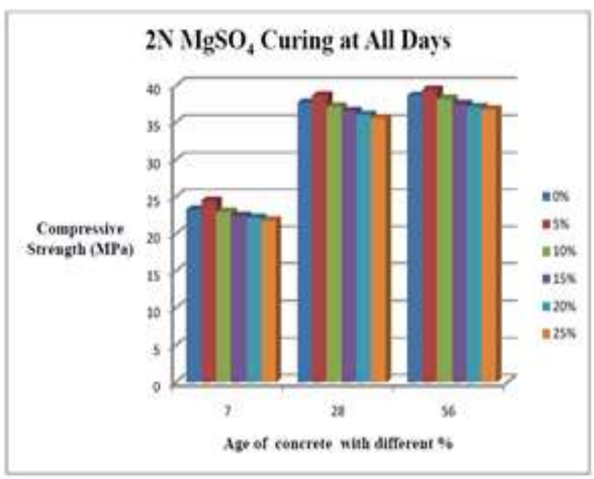

Figure 3 *Compression strength of cubes with partial replacement of SCBA at all ages –* $2NH_2SO_4$ *curing*

Figure 4, 5 and 6 shows the variation in splitting tensile strength of concrete at all percentage of replacement of cement by sugarcane bagasse ash for different ages of curing in conventional as well as 2N sulphuric acid and 2N magnesium sulphate solution.

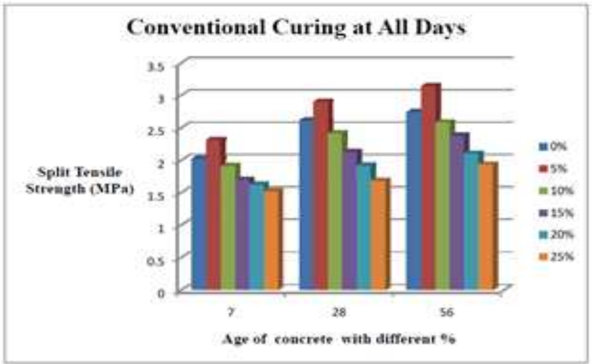

Figure 4 *Splitting Tensile strength of cylinders with partial replacement of SCBA at all ages - conventional curing*

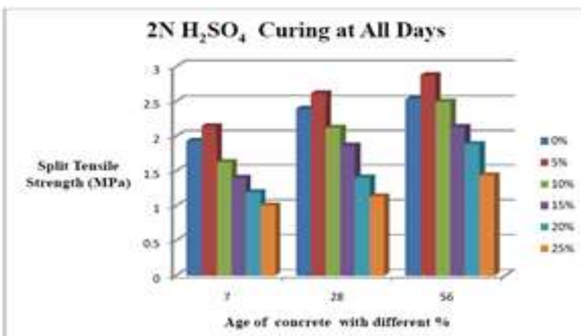

Figure 5 *Splitting Tensile strength of cylinders with partial replacement of SCBA at all ages - 2N H2SO4 curing*

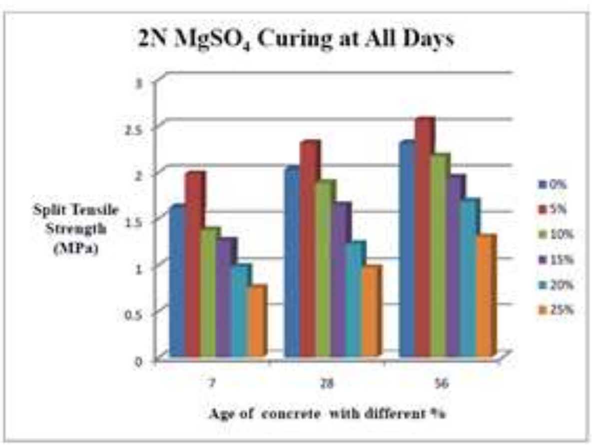

Figure 6 *Splitting Tensile strength of cylinders with partial replacement of SCBA at all ages - 2N MgSO4 curing*

Similarly, figure 7, 8 and 9 shows the variation in flexural strength of concrete prisms at all percentage of replacement of cement by sugarcane bagasse ash for different ages of curing in conventional as well as 2N sulphuric acid and2N magnesium sulphate solution.

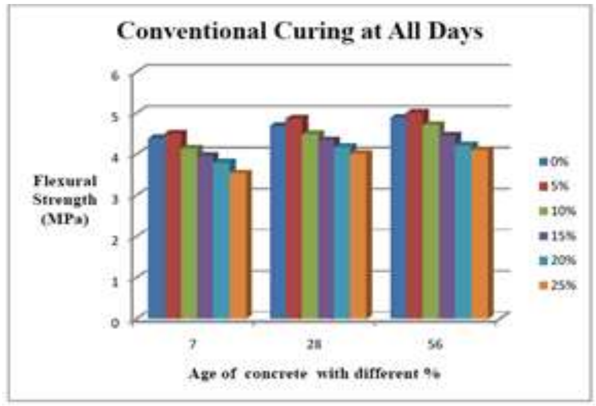

Figure 7 *Flexural strength of Prisms with partial replacement of SCBA at all ages - conventional curing*

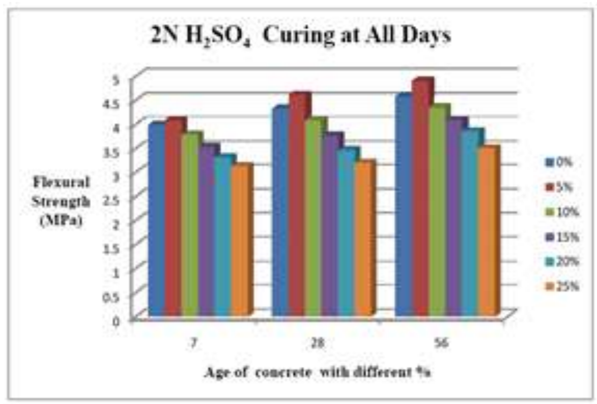

Figure 8 *Flexural strength of Prisms with partial replacement of SCBA at all ages - 2N H2SO4 curing*

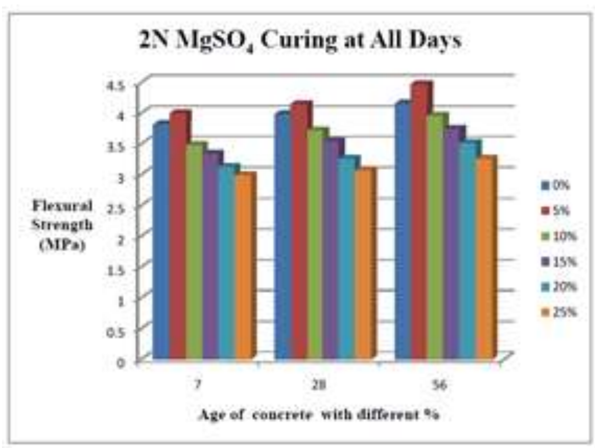

Figure 9 *Flexural strength of Prisms with partial replacement of SCBA at all ages - 2N MgSO4 curing*

4.1. Workability

The workability of SCBA concrete has decreased in comparison with ordinary concrete with the increase in replacements of SCBA in the range of 0% to 15%. The decrease in workability of concrete may be due to the large surface area of SCBA resulting in reduction of fluidity of concrete.

4.2. Strength Aspects

The compressive strengths of concrete with 0%, 5%, 10% & 15% weight replacement of cement with SCBA cured conventionally have reached the target mean strength.

Concrete with 5% replacement of SCBA shows an increase in compressive strength. At higher percentages of (15%) replacement of cement he reduction in workability resulted in lowering the strength.

It can also be seen from the experimental results that strength attainment of concrete at later stages is equal to or even more than that of concrete with SCBA. This may be due to the slow pozzolanic reaction of SCBA concrete which is responsible for significant improvement in strength at later stages.

Split tensile strength as well as flexural strength characteristics also have followed the same pattern i.e., the strength of controlled concrete is nearly same for SCBA concrete at 5% replacement of cement by SCBA whereas the test results were found to be decreased at 15% and 25% replacement.

5. Conclusions

a) The workability of mortar and concrete containing bagasse ash decreases slightly as the bagasse ash content increases which is due to the higher water demand of bagasse ash.
b) Sugar cane bagasse ash concrete performed better when compared to ordinary concrete up to 5% replacement of SCBA. At lower replacements the SCBA concrete performed better than ordinary concrete.
c) SCBA concrete performed better even in acidic curing regime compared to ordinary concrete at later ages.
d) The compressive strength results of the concrete have revealed that the concrete with 5% cement replacement by bagasse ash have shown a 5% compressive strength improvement at 28 days over the control concrete with 100% ordinary Portland cement. The 15% and 25% replacements have shown 3.4% and 12.6% reduction at 28 days of the control concrete.
e) The flexural strength of the concrete has decreased as the replacement percentage of the bagasse ash increased. At 28 days the control concrete and the concrete containing 5% bagasse ash have shown the same flexural strength whereas the 15% and 25% replacements have shown a lower flexural strength value.
f) Since bagasse ash is a by-product material, its use as a cement replacing material reduces the levels of CO_2 emission by the cement industry. In addition its use resolves the disposal problems associated with it in the sugar industries.

6. Acknowledgements

Authors kindly acknowledge all the teaching and non-teaching staff of civil engineering department, Adi Chunchanagiri Institute of Technology, Chikmagalur, Visvesvaraya Technological University, Belagavi for their needful support.

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