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Investigation into Utilization of Sugarcane Bagasse Ash as Supplementary Cementitious Material in Concrete

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ABSTRACT

This paper presents the use of sugarcane bagasse ash (SCBA) as a pozzolanic material for producing high-strength concrete. The utilization of industrial and agricultural waste produced by industrial processes has been the focus on waste reduction. Ordinary Portland cement (OPC) is partially replaced with finely sugarcane bagasse ash. In this research physical characteristics, chemical combination (XRF test), TG-DTA were investigated and compared with cement.The concrete mixtures, in part, are replaced with 0%, 10%,15%, 20%,25% and 30% of BA respectively. In addition, the compressive strength, the flexural strength, the split tensile tests were determined. The bagasse ash was sieved through No. 600 sieve. The mix design used for making the concrete specimens was based on previous research work from literature. The water –cement ratios varied from 0.44 to 0.63. The tests were performed at 7, 28,56 and 90 days of age in order to evaluate the effects of the addition SCBA on the concrete. The test result indicate that the strength of concrete increase up to 15% SCBA replacement with cement.

Keywords: SCBA, Pozzolan, XRF test, Compressive strength test.

INTRODUCTION

Agro wastes are used in construction material. Agro wastes such as rice husk ash, wheat straw ash, hazel nutshell and sugarcane bagasse ash are used as pozzolanic materials for the development of concrete [1]. Sugarcane is major crop grown in over 110 countries and its total production is over 1500 million tons. Sugarcane production in India is over 300 million tonnes per year. The processing of it in sugar-mill generates about 10 million tonnes of SCBA as a waste material. One tonne of sugarcane can generate approximate 26% of bagasse and 0.62% of residual ash. The residue after combustion presents a chemical composition dominates by silicon dioxide [2-3]. In 2009, the total production of sugarcane in the world was estimated to be approximately 1661 million tons. The largest producer of sugarcane is Brazil and Thailand is the fourth largest [4-7]. Bagasse is often used as a primary fuel source for sugar mills; when burned in quantity, it produces sufficient heat energy to supply all the needs of a typical sugar mill. The dumping of these industrial wastes in open land poses a serious threat to the society by polluting the air and waste bodies. This also adds the no availability of land for public use [8-12]. After the extraction of all economical sugar from sugarcane, about 40-45% fibrous residue was obtained, which is reused in the same industry as fuel in boilers for heat generation leaving behind 8 -10 % ash as waste, known as sugarcane bagasse ash (SCBA). The SCBA contains high amounts of un-burnt matter, silicon, aluminum and calcium oxides [13,14].

DESCRIPTION OF MATERIALS

Cement: The most common OPC 53 grade Cement was used with fineness 6%and standard consistency 32%.

Fine Aggregate: Basalt stone crushed sand is used as fine aggregate. The specific gravity of sand is 2.6 and fineness modulus is 3.35. Those fractions from 4.75 mm to 50 micron are termed as fine aggregate, and the bulk density of fine aggregate is 1593.16kg/m^3.

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Table2.1. *Sieve Analysis of Fine Aggregate*

Passing through IS sieve (mm)	Wt On Each Sieve (gm)	Cumulative wt retained	Cumulative wt retained %	%Passing
10	0	0	0	100
4.75	70	70	3.5	96.5
2.36	120	190	9.5	90.5
1.18	300	490	24.5	75.5
0.6	530	1020	51	49
0.3	750	1770	88.5	11.5
0.15	160	1930	96.5	3.5

Coarse Aggregates: The crushed aggregates used were 10mm and 20mm nominal size and are tested as per Indian standards and results are within the permissible limit. The specific gravity and bulk density of 10 mm and 20mm aggregate are 2.8 and 2.85 and 1687 kg/ m^3 and 1792.31kg/m^3 respectively and fineness modulus is 6.260 and 6.734. 02 kg sample has been tested and following results obtained.

Table2.2. *Sieve Analysis of 20 mm Coarse Aggregate*

Passing through IS sieve (mm)	Wt on each sieve (gm)	Cumulative Wt. Retained(gm)	Cumulative %retained	%Passing
40	0	0	0	100
20	200	200	10	90
10	1590	1790	89.5	10.5
4.75	210	2000	100	0

Table2.3. *Sieve Analysis of 10 mm Coarse Aggregate*

Passing through IS sieve (mm)	Wt on each sieve (gm)	Cumulative Wt. Retained(gm)	Cumulative %retained	%Passing
40	0	0	0	100
20	0	0	0	100
10	750	750	37.5	62.5
4.75	1240	1990	99.5	0.5
2.36	7	1997	99.85	0.15
1.18	3	2000	100	0

Table2.4. *Physical Properties of Coarse and Fine Aggregate*

Properties	Coarse Aggregate		Fine Aggregate
	20mm	**10mm**	
Specific Gravity	2.8	2.85	2.6
Fineness Modulas	6.260	6.734	3.35
Bulk Density(Kg/m^3)	1687	1792.31	1593.16

Water: Water available in the site campus conforming to the requirements of water for concreting and curing as per IS: 456-2000[16].

Sugarcane Bagasse Ash: The bagasse ash was sieved through No. 600 sieve**.** The sugarcane bagasse consists of approximately 50% of cellulose, 25% of hemicellulose & 25% of lignin. Each ton of sugarcane produces approximately 26% 0f bagasse. In this, sugarcane bagasse ash was collected during the cleaning operation of a boiler operating in the Siddhi Sugar & allied industries, Ujana located in the city of Latur, Maharashtra.

Table2.5. *Chemical Compositions of Raw Material (SCBA)*

COMPONENT	MASS%
SiO_2	**87.59**
K_2O	3.64

CaO	2.59
MgO	1.65
P_2O_5	1.65
Fe_2O_3	0.67
Al_2O_3	0.51
Na_2O	0.17
TiO_2	0.07
MnO	0.05
SO_3	0.03
ZrO_2	0.02
Cl	0.02
SrO	0.01
CuO	0.01
Cr_2O_3	0.009
Rb_2O	0.002

The TG-DTA study was carried out, using SETRAM instrument under constant atmospheric condition at a heating rate of 10^0C/min. The heating was carried out from ambient to 1000^0C. The thermograph shows the decompositional characteristics in the form of TG and DTA curves. The weight loss determined from the TG curve in the temperature range of around 100^0C to 700^0C is about 1.22%.

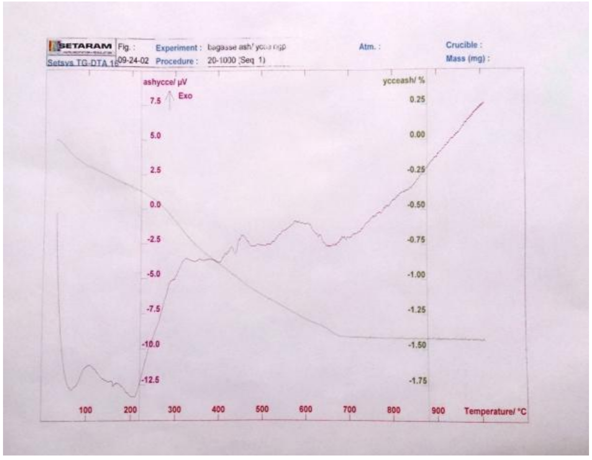

Figure2.1. *TG-DTA Test on SCBA*

Fineness test on SCBA was carried out on the raw sample of SCBA which is procured from the sugar industry.

Table2.6. *Fineness Test on SCBA*

Sieve Size	Passing Wt %	Retained Weight (gm)	Cumulative Weight
2.36mm	97	30	1000
1.18mm	89	60	970
600µ	80	110	910
300µ	50	300	800
150µ	5	450	500
90µ	1	40	50
Pan	0	10	10

EXPERIMENTAL INVESTIGATION

In this experimental work, a total of 192 numbers of concrete specimens were casted. The specimens considered in this study consisted of 144 numbers of 150mm side cubes, 24 numbers of 150mm diameter and 300mm long cylinders, and 24 numbers of 50mm x 150mm x 150mm size beams. The mix design of concrete was done according to Indian Standard guidelines for M 25 & m 35 grade for the 20 & 10 mm aggregates and the water cement ratio ranges between 0.44-0.63. Based upon the quantities of ingredient of the mixes, the quantities of SCBA for 0, 10, 15, 20,25 and 30% replacement by weight were estimated. In this project work no plasticizer was used. The ingredients of concrete were thoroughly mixed in mixer machine till uniform thoroughly consistency was achieved. Before casting, machine oil was smeared on the inner surfaces of the cast iron mould. Concrete was poured into the mould and compacted thoroughly using table vibrator. The top surface was finished by means of a trowel. The specimens were removed from the mould after 24 hour and then cured under water for a period of 7, 28, 56 and 90 days. The specimens were taken out from the curing tank just prior to the test. The tests for compressive, split tensile strength and flexural strength test were conducted using a 2000kN compression testing machine. These tests were conducted as per the relevant Indian Standard specifications.

Also some tests were conducted outer to concrete laboratory such as XRF test, TG-DTA test in Indian Bureau of Mines, Nagpur and fineness test in Geo-tech Services Nagpur. These tests were also conducted as per the relevant Indian Standard specifications.

EXPERIMENTAL RESULTS

The results obtained from the experimental investigations are showed in tables. All the values are the average of the three readings in each case in the testing work of this study. To determine the compressive strength of concrete is very important, because the compressive strength shows concrete quality. This strength will help us to arrive the optimal proportion for replacement. The compressive strength was performed according to IS:516-1959.The compressive strength for 7 day, 14 day,56 day and 90 day of various mixes with twelve w/c ratio ranges between 0.44-0.63 were determined and given in tables below. The results are discussed as follows.

Table4.1a. *Compressive Strength 7 and 28 Days*

Mix	**% of SCBA**	**7 Day** (MPa)	**28 Day** (MPa)
M25 A0	0	20	24.45
A1	10	21.33	24.45
A2	15	21.55	24.89
A3	20	18.66	20
A4	25	17.77	19.12
A5	30	16.44	18.67
M35 B0	0	26.67	31.12
B1	10	27.11	32
B2	15	27.11	32
B3	20	24.44	31.12
B4	25	22.22	29.78
B5	30	18.22	26.67

Table4.1b. *Compressive Strength 56 and 90 Days*

Mix	**% of SCBA**	**56 Day** (MPa)	**90 Day** (MPa)
M25 A0	0	33.34	42.22
A1	10	34.67	44.45
A2	15	36	46.67
A3	20	33.78	40
A4	25	31.11	38.22
A5	30	28.44	35.56
M35 B0	0	37.44	51.12
B1	10	38.67	53.34
B2	15	37.78	53.78
B3	20	36.88	48.89
B4	25	33.34	44.45
B5	30	28.89	41.78

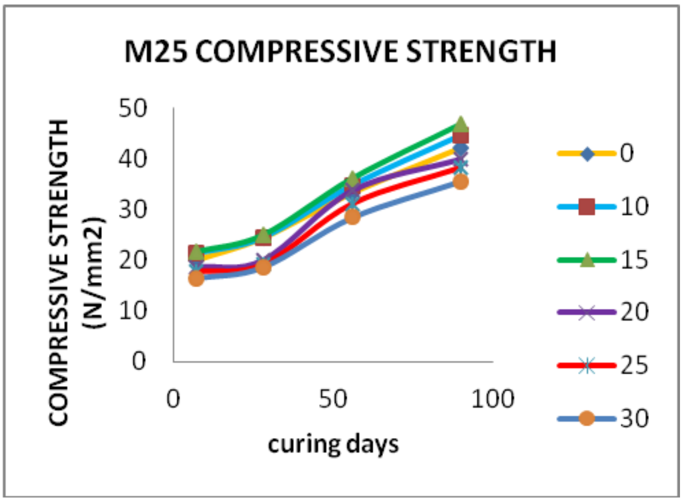

Figure4.1. *Compressive Strength of 7,28,56,90 Days for M25 Grade of Concrete.*

By comparing the above results, the 7,28,56,90 day compressive strength of control concrete was found to be 20, 24.45, 33.34, 42.22 N/mm2 respectively. For the 10 % replacement of cement with SCBA the compressive strength increases to 21.23, 24.45, 34.67, 42.22 N/mm2 and at 15% replacement the compressive strength increases to 21.55,24.89,36,46.67N/mm2 respectively which is higher than value of control concrete. Further increase in replacement causes decrease in compressive strength of concrete.

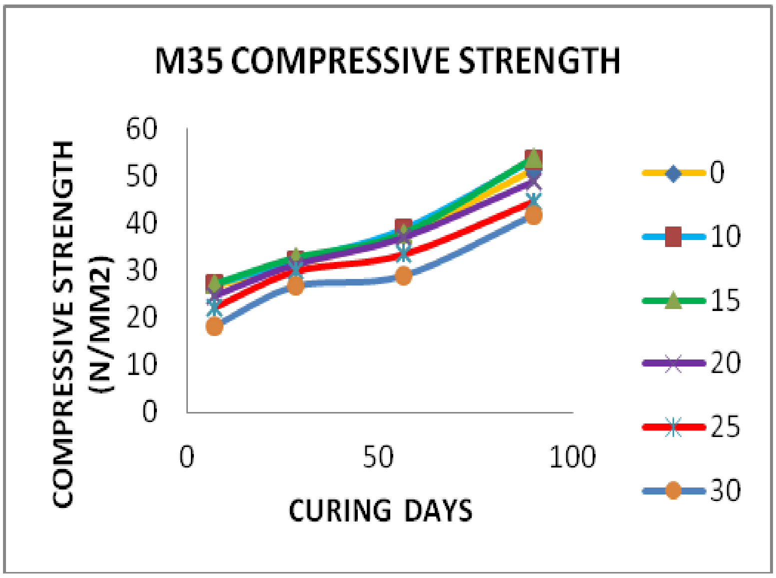

Figure4.2. *Compressive Strength of 7,28,56,90 Days for M35 Grade of Concrete.*

By comparing the above results, the 7,28,56,90 day compressive strength of control concrete was found to be 26.67, 31.12, 37.44, 51.12 N/mm2 respectively. For the 10 % replacement of cement with SCBA the compressive strength increases to 27.11, 32, 38.67, 53.34 N/mm2 and at 15% replacement the compressive strength increases to 27.11, 32, 37.78, 53.78 N/mm2 respectively which is higher than value of control concrete. Further increase in replacement causes decrease in compressive strength of concrete.

The strength test results obtained for concrete cubes, beams and cylinders with partial replacement of SCBA shown in Table 4.2. From the table 4.2, it is clear that the addition of SCBA in control concrete increases its strength under tension and flexure up to 15% of replacement after that strength results was decreases.

Comparison of the results from the 7, 28,56,90 days samples shows that the compressive strength, tensile strength and also flexure increases with SCBA up to 15% replacement and then it decreases, though the results of 20% replacement was sometime found higher than those of the control concrete .

It was shown that the use of 20% SCBA decreases the compressive strength to a value which is near to the control concrete.

Table4.2. *Flexural and Split Tensile Strength of SCBA Concrete at 28 Days*

Mix	% of SCBA	**Flexural Strength** (MPa)	**Split Tensile Strength** (MPa)
M25 A0	0	4.1	2.82
A1	10	5.4	3.11
A2	15	6.3	2.97
A3	20	4.2	1.55
A4	25	3.6	1.41
A5	30	2.5	1.13
M35 B0	0	5.1	3.25
B1	10	6	3.25
B2	15	6.5	3.39
B3	20	4.45	2.68
B4	25	3.9	2.12
B5	30	2.55	1.69

Specific heat capacity of concrete was recorded by thermometer gun. The maximum specific heat for concrete at 20% replacement of SCBA was found to be 338.59 J/Kg.^{o}K & 339.04 J/Kg.K for M25 and M35 grade of concrete respectively. As the nature of the graph is erratic we cannot make the relationship but value for specific heat of concrete found to be ranges between 325-341 (J/Kg.^{o}K).

Table4.3a. *Specific Heat Capacity of Concrete*

% of SCBA	Initial Temperature (°C)	Final Temperature (°C)
M25 0	22.6	44.28
10	22.7	32.88
15	22.8	36.71
20	22.8	34.78
25	22.9	43.01
30	22.7	44.46
M35 0	22.6	42.58
10	22.7	40.67
15	22.7	49.41
20	23.1	34.7
25	23	36.61
30	22.8	40.40

Table4.3b. *Specific Heat Capacity of Concrete*

% of SCBA	ΔT(°K)	C (J/Kg· ^{o}K)	Average Weight (Kg)
M25 0	294.83 ^{o}K	332.20	8.27
10	283.33 ^{o}K	341.15	8.38
15	287.06 ^{o}K	334.72	8.43
20	285.13 ^{o}K	338.59	8.39
25	293.26 ^{o}K	329.6	8.38
30	294.91 ^{o}K	325.04	8.45
M35 0	293.13 ^{o}K	334.53	8.26
10	291.12 ^{o}K	330.05	8.43
15	299.86 ^{o}K	329.42	8.20
20	284.75 ^{o}K	339.04	8.39
25	286.76 ^{o}K	336.26	8.40
30	290.75 ^{o}K	334.44	8.33

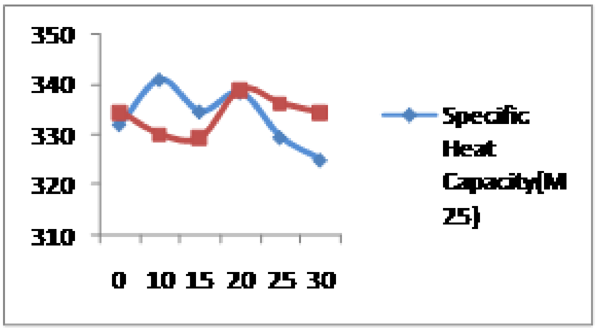

Figure4.3. *Specific Heat Capacity*

CONCLUSION

Based on the conducted experiment and according to the result obtained, it can be concluded that:

- The SCBA concrete gives higher compressive strength than that control concrete.
- The maximum compressive strength obtained in M25 grade concrete is at 15% SCBA replacement for 7, 28, 56 and 90 days curing while in case of M35 grade concrete it is at 10% for 7 and 56 days curing.
- The result shows that the addition of SCBA improves the compressive strength up to 20% addition of SCBA after that no considerable improvement is observed.
- The maximum flexural strength obtained is at 15% SCBA replacement in both M25 and M35grade of concrete for 28 days curing.
- The maximum split tensile strength obtained is at 10% SCBA replacement in M25 and in case of M35 it is at 10% SCBA replacement for 28 days curing.
- The maximum value for specific heat capacity is obtained at the 10% SCBA replacement for M25 grade of concrete and in case of M35 it is obtained at 20% SCBA replacement.
- The nature of the specific heat capacity graph is not giving any relationship as it is erratic.
- It is clearly seen that the 20% cost of cement can be save with better strength than control concrete.
- Partial replacement of cement by SCBA increases workability of fresh concrete; therefore use of super plasticizer is not essential.
- The utilization of bagasse ash in concrete solves the problem of its disposal thus keeping the environment free from pollution.

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