To Study the Performance of Bagasse Ash on the Strength of Concrete

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ABSTRACT - Utilization of Sugarcane Bagasse ash as a supplementary cementations material adds sustainability to concrete by reducing the CO2 emission of cement production. The positive effects of bagasse ash as a partial replacement of cement on the mechanical properties of concrete are recognized through numerous researches; however, the extent of improvement depends on the durability properties of bagasse ash. In this study, durability properties of conventional concrete utilizing bagasse ash sourced from Sugar factory have been investigated. Concrete mixtures with Bagasse ash as 0, 5, 10, 15, 20, 25 and 30% total binder were used to cast the test specimens.
The compressive strength, loss in mass of the bagasse ash and control concrete specimens were determined before and after exposure to elevated temperature and chemical attack. The 56-day compressive strength of the concrete mixtures varied from 3 to 26 MPa at elevated temperature conditions. The bagasse ash concrete samples showed less strength than the control concrete samples when designed for the same 56-day compressive strength of the control concrete. Inclusion of bagasse ash reduced the chemical attack significantly at 28 days and reduced further at 56days. In general, incorporation of bagasse ash as partial replacement of cement improved the durability properties of concrete.

Key Words: Sugar Cane Bagasse Ash, Compressive Strength of Concrete, % content of SCBA

I. INTRODUCTION

Utilization of agricultural, industrial and agro-industrial by-products in concrete production has become an attractive area to the researchers worldwide. Utilization of such wastes as cement replacement materials also as mineral admixture can reduce the cost of concrete and also minimize the negative environmental effects associated with the disposal of these wastes. Silica fume, rice husk ash, fly ash, metakaolin and ground granulated blast furnace slag are well established pozzolans because of high silica contents in their chemical composition. The calcium hydroxide (unfavorable product from the cement hydration) released during the hydration of Portland cement reacts with the silica content present in the pozzolanas and water to form additional calcium silicate hydrate which is responsible for the improvement in strength in cementations mediums. Bagasse is the waste produced after juice extraction in sugar industry, which is usually used as a fuel for boilers in the sugar mills and alcohol factories which produce high amounts of ash annually.

Previously the sugar cane bagasse (SCB) was burnt as a means of solid waste disposal, with increasing of the cost of natural gas, electricity, and fuel oil and with calorific properties of these wastes, since last decade the SCB has been used as the principal fuel in sugar factory boilers to produce heat and in cogeneration plants to produce electric power.

Sugarcane Bagasse Ash (SCBA) is usually obtained under uncontrolled burning conditions in boilers, thus the ash may contain black particles due to the presence of carbon and crystalline silica when burning occurs under high temperature (above 800 °C) or for a prolonged time. The quality of the ash can be improved by controlling parameters such as temperature, rate of heating. When the SCB is burnt under controlled conditions it may produce ash with high amorphous silica, which has the pozzolanic properties.

Since last few years tremendous efforts have been made to increase the use of cement replacement materials in concrete production because the cement production consumes high energy and is responsible for 5 to 7% of global anthropogenic CO2 emission (each ton of cement produces about 900 kg of CO2) and their use can also improve the properties of concrete.

Study of using SCB as a pozzolanic material is not well-known and its uses are limited and most of SCBA is disposed in the landfills, and "only a few studies have been reported on the use of SCBA as a pozzolanic material in respect of the cement paste". There is a continuous increase in the production of sugar and alcohol worldwide using sugarcane as raw material. Approximately 1850 Million tons of sugarcane is annually produced all over the world which leave about 40-45 % bagasse after juice crushing for sugar industry giving an average annual production of 675 Million tons of bagasse as a waste material. Bagasse is used as a fuel for generating steam in sugar industries as well as co-generation producing approximately 17 million tones of A waste i.e. about 3 to5% of bagasse. This waste is an agro-industrial by-product and there are many environmental problems associated with its disposal for instance: landfill volumes, underground water pollution, global warming and methane emission which cause degradation of Ozone layer. Utilization of such agro-industrial by-products as cement replacement materials in cementitious system (i.e. mortar and concrete) will not only save the environment; but also reduce the cement production and consequently the high energy consumption, reduce the CO2 emission, improve the mechanical properties and durability of the produced concrete and reduce the cost of concrete. This report aims to study the performance of SCBA.

The present study deals with effect of use of SCBA as cement replacement material on properties of concrete subjected to elevated temperatures and effect of different chemical attack on the concrete.

Therefore, in present attempt is made to use the bagasse ash produced in India mainly in state of Maharashtra as a pozzolanic material to replace cement. Chemical and physical composition of SCBA is found out. An experimental investigation is carried out to examine the impact of replacing cement by bagasse ash to the mechanical and physical properties of concrete subjected to elevated temperatures and different chemical attack on the concrete.

II. MATERIAL PROPERTIES

A) SUGARCANE BAGASSE ASH (SCBA):

Image: (Bagasse) Dirk India Ltd. Research Laboratory, Nasik.

Factory ash was burnt at controlled temperature 650oc for 1 hour, was ground, and termed as Processed Bagasse Ash (PBA). PBA was used as cement replacement material. The present study aims at checking the effect of replacing cement by PBA on properties of concrete for which study of physical and chemical properties of PBA is required. Physical and chemical properties of PBA are as shown in table below.

Table No. 1: Physical and Chemical Properties of PBA

1)Specific surface area(m^2/kg)	380
2) Fineness passing 45 µm	58.02
3) Specific gravity	1.70
4) Material	PBA
5) SiO_2	71.54
6) Al_2O_3	9.90
7) Fe_2O_3	8.7
8) CaO	3.18
9) MgO	5.68
10) SO_3	0.34
11) Na_2O	0.53
12) K_2O	-
13) LOI	0.25

B) CEMENT

The most common cement used is an ordinary Portland cement. The Ordinary Portland cement (Brand-Ultratech cement) of 53 grade is being used. Many tests were conducted on cement; some of them are consistency tests, setting tests, etc.

Table No-2: PROPERTIES OF CEMENT

Sr. No	Physical Requirement	Ultratech OPC 53 grade	I.S. 12629-1989
1	Specific surface m^2/Kg	330	225 Min
2	Soundness (Le-Chatelier Method)	0.8	10.0 Max
3	Auto Clave (%)	0.062	0.8 Max
4	Initial Setting Time	120	30 min
5	Final Setting time	225	600 min
6	Compressive Strength 3days 7 days 28 days	 38.0 47.6 63.6	 27 MPa 37 MPa 53 MPa

C) AGGREGATE

1) FINE AGGREGATE (SAND)

Aggregates are the important constitute of concrete. They give body to the concrete, reduce shrinkage and effect economy. Strength is dependent on the bond between the cement pastes and aggregate.

If either the strength of the paste or the bond between the paste and aggregate is low a concrete of poor quality will be obtained irrespective of strength of the aggregate, for making strong concrete, strong aggregate is an essential requirement. By and large naturally available mineral aggregate are strong enough for making normal strength concrete.

Table No-3: Physical properties of Fine Aggregate (sand)

Sr. No	Property	Results
1.	Particle Shape, Size	Round, Below 4.75mm
2.	Fineness Modulus	3.45
3.	Silt content	3%
4.	Specific Gravity	2.60
5.	Surface moisture	Nil

2) COURSE AGGREGATE

The size of aggregate greater than 4.75 mm is considered as coarse aggregate. The nominal maximum size of coarse aggregate should as large as possible within the specified limits but in no case greater than one fourth of the minimum thickness of the member, provided that the concrete can be placed without difficulty so as to surround all reinforcement thoroughly and fill the corners of the form. Locally available crushed stone with 20mm size aggregates confirming to IS 383:1970 are used. The test results are as follows:

Table No-4: Physical Properties of Coarse Aggregate.

Sr. No	Property	Results
1	Particle shape and max size	Angular, 20mm
2	Fineness Modulus of coarse aggregates	6.78
3	Specific Gravity	2.77
4	Surface moisture	Nil

D) WATER

Water is an important ingredient of concrete as it actively participates in hydration of cement for desired strength. Cement an anhydrous material when mixed with water reacts to form C-S-H gel, which is responsible for strength. The strength of cement medium is mainly due to the binding action of the hydrated cement gel i.e. C-H-S gel. Water plays a very important role in this process.

III. DESIGN MIX

A concrete mix of M 25 grade was designed as per Indian Standard method and the same was used to prepare the test samples. The design mix proportion is done in Table-5

Table No-5: Design Mix Proportion For (M 25)

Grade of Concrete	Cement	Fine Aggregate	Coarse Aggregate	Water
M 25	395kg/m^3	588kg/m^3	1177kg/m^3	184.6 kg/m^3
	1	1.49	2.98	0.47

IV. EXPERIMENTAL METHODOLOGY

1) High Temperature Test on SCBA Concrete

In this experimental investigation, the effects of elevated temperatures on the loss in mass, the compressive strength and Ultrasonic pulse velocity of concrete with and without SCBA were investigated. The concrete specimens were exposed to different elevated temperatures of 100, 200, 400 , 600ºC and 800ºC for 3 hrs. After exposure, the properties of SCBA concrete were measured and compared with the concrete without SCBA.

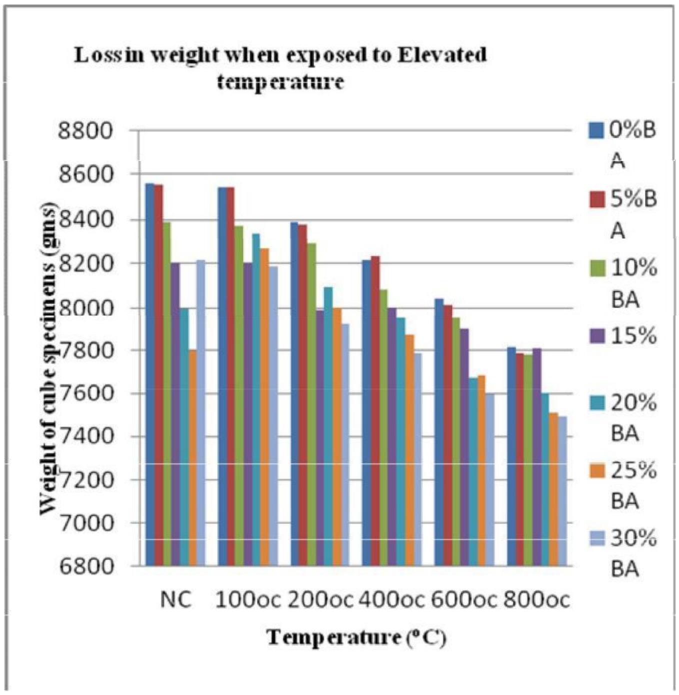
2) Exposure to elevated temperature

i) Loss of Weight under elevated temperature

The variation of Decrease in Weight with respect to increase in temperature for various % of bagasse ash is shown in the table no-7 and graph no-1 With increase in temperature the weight of concrete cubes is found to be decreasing. The percentage reduction in weight compared to weight of specimens at controlled concrete can define the effect of elevated temperature on weight loss. The percentage reduction in weight of each specimen at elevated temperature are shown below so as to understand the effect of elevated temperature on concrete.

Table No-6: Weight of concrete exposed to elevated temperature

% BA	Weight of cube specimens (gms) exposed to elevated temperatures.					
	Normal Concrete (NC)	100°c	200°c	400°c	600°c	800°c
0	8558	8541	8387	8216	8045	7814
5	8556	8540	8376	8231	8017	7790
10	8506	8480	8285	8132	7953	7780
15	8418	8391	8157	8014	7812	7760
20	8540	8376	8231	7950	7766	7675
25	8296	8267	8006	7871	7686	7510
30	8214	8185	7923	7789	7594	7490

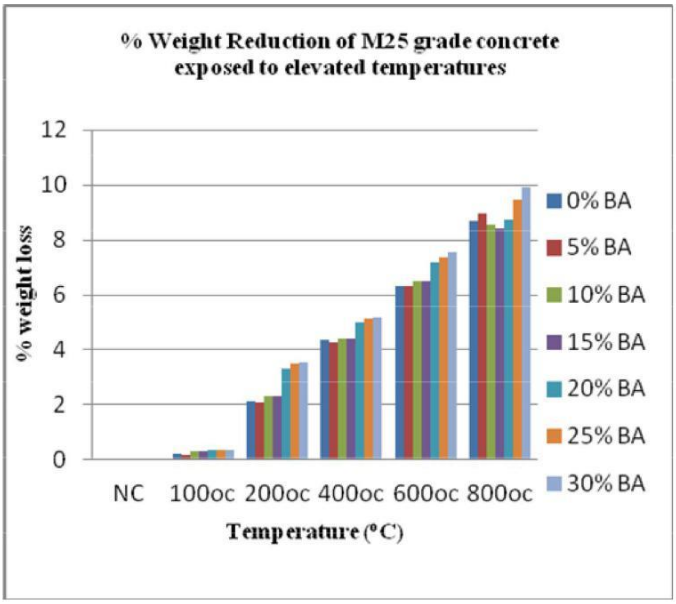


Graph no-1 % Weight loss of concrete exposed to Elevated temperatures

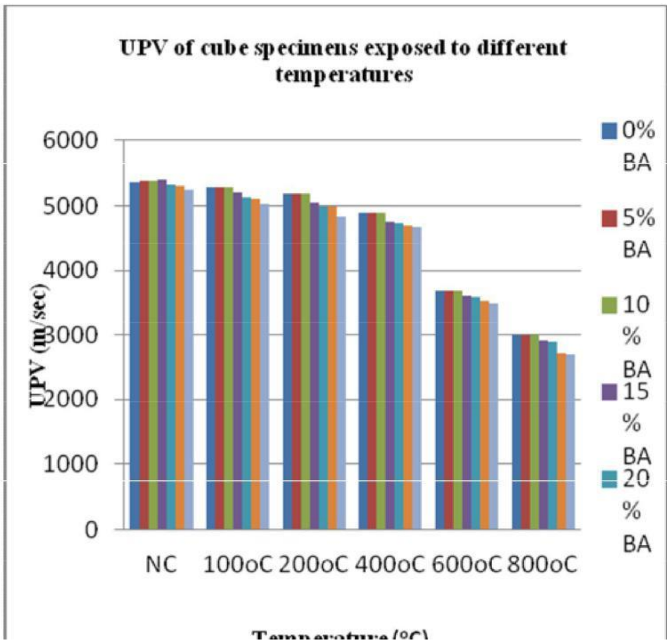
Table No-7: % Weight loss of cube specimens (gms) exposed to elevated temperatures.

% BA	% Weight loss of cube specimens (gms) exposed to elevated temperatures.					
	Normal Concrete (NC)	100°c	200°c	400°c	600°c	800°c
0	00	0.199	2.121	4.341	6.321	8.694
5	00	0.187	2.104	4.271	6.3	8.953
10	00	0.306	2.321	4.397	6.501	8.535
15	00	0.321	2.313	4.389	6.5	8.435
20	00	0.335	3.298	4.995	7.194	8.735
25	00	0.35	3.496	5.123	7.353	9.474
30	00	0.353	3.543	5.174	7.548	9.897

The percentage weight reduction of M25 grade of concrete is found to be between 0.199 % to 9.897 % when compared with controlled concrete (CC). The reduction of weight is found to be gradual upto400°C with increase in temperature, which can be understood clearly from the graph 2



Graph No. 2 %Weight loss Vs Temperature (°C Days)



Graph No.3 UPV Vs Temperature (°C)

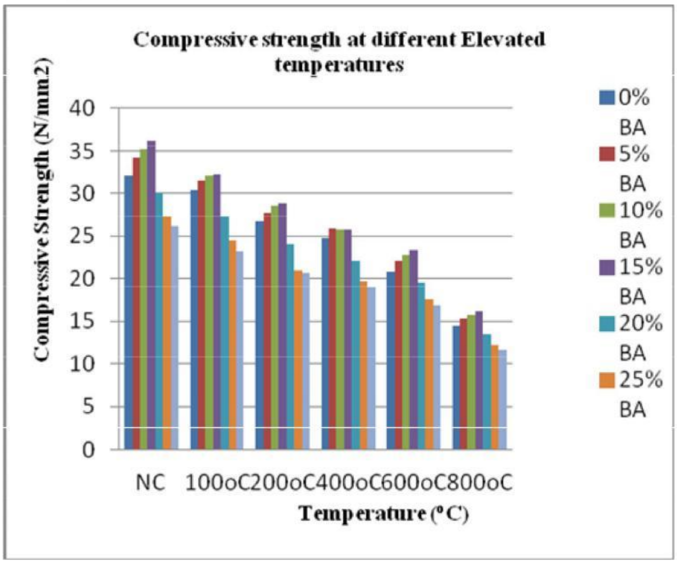
3) Ultrasonic Pulse Velocity Test (UPV)

The UPV test of these cooled cubes was conducted. In UPV test the time measuring device displayed the time for the wave to travel through specimen in microsecond. The length for propagation of wave cube specimen was 0.150 m. The results were obtained with basic relation as explained earlier. The results of UPV test in m/s are as shown in table 8.

Table No-8: basic relation as explained earlier. The results of UPV test in m/s are as shown in:

Table No. 8: UPV of concrete exposed to elevated temperatures

% BA	Ultrasonic Pulse Velocity (m/sec) of cube specimens exposed to different temperatures					
	Normal Concrete (NC)	100°C	200°C	400°C	600°C	800°C
0	5376	5282	5190	4890	3679	2990
5	5378	5280	5195	4889	3678	2989
10	5389	5286	5188	4891	3680	2985
15	5398	5208	5051	4752	3610	2910
20	5319	5137	5000	4734	3578	2888
25	5300	5102	4983	4700	3523	2711
30	5245	5034	4839	4680	3479	2691



Graph No.4 Compressive Strength Vs Temperature (^{o}C)

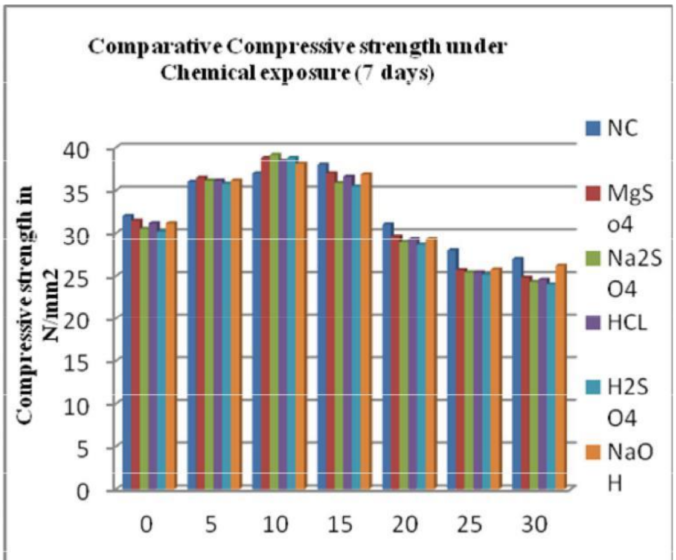
4) Compressive Strength

After UPV test the cubes were placed and crushed under compression testing machine and the compressive strength was determined of each cube specimen. The results of compressive strength test are as shown in table no-9.

Table No-9: Compressive Strength of concrete exposed to elevated temperatures.

% BA	Compressive Strength (N/mm2) at different temperatures					
	NC	100°C	200°C	400°C	600°C	800°C
0	32.12	30.44	26.8	24.72	20.8	14.4
5	34.21	31.48	27.7	25.88	22.1	15.3
10	35.19	32.1	28.62	25.72	22.75	15.75
15	36.23	32.21	28.8	25.79	23.4	16.2
20	30.11	27.36	24	22.08	19.5	13.5
25	27.32	24.48	21	19.65	17.55	12.15
30	26.18	23.2	20.6	19	16.9	11.7

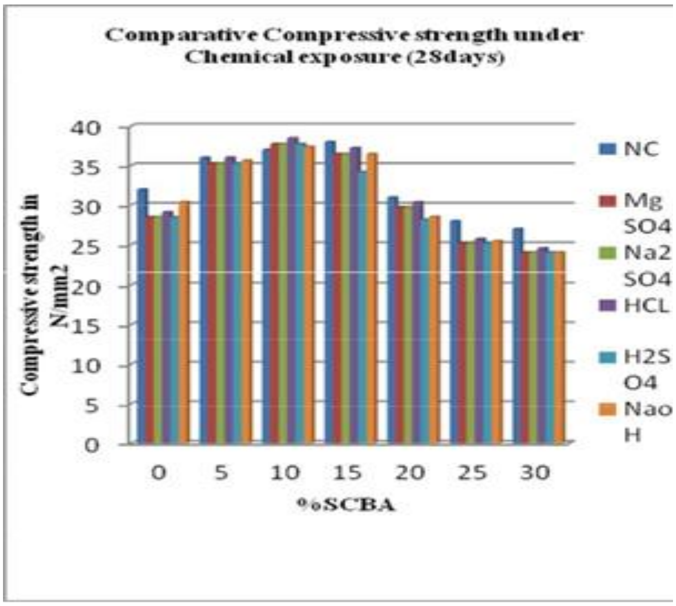
The compressive strength of concrete cubes was found to be decreasing with increase in the temperature. The graph no.4 explains the reduction of strength in detail.



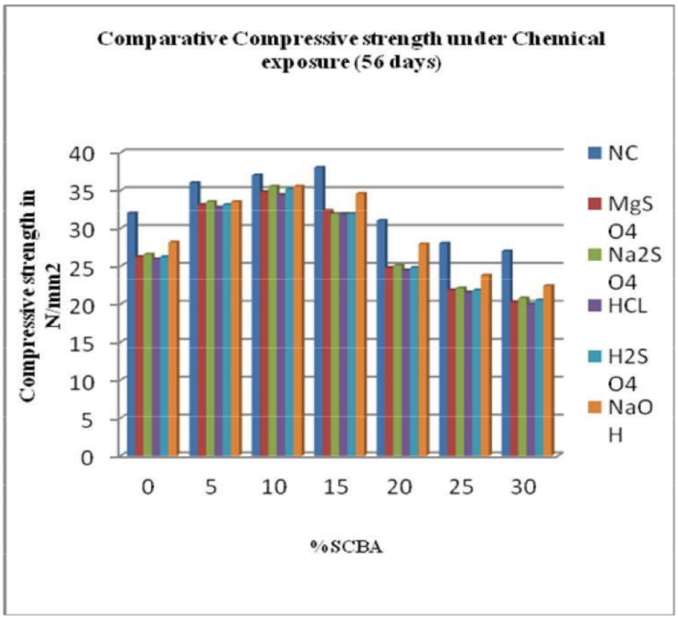
Graph No.5 Compressive Strength Vs % SCBA under chemical exposure (7 days)

5) Chemical Attack Results.

The experimental results indicate that the compressive strength of concrete at 7 days exposure to sulphates, acids and alkalis were found to be increasing upto 15% BA content. Above this content the strength was observed to be reducing. At 28 days chemical curing the strength of concrete for SCBA content as compared to normal concrete were found to be reducing. At 56 days chemical curing a large amount of strength loss is observed in the specimens. The rate of reduction in compressive strength was observed to be gradual. The acid attack has reduced the compressive strength in large amount as compared to the sulphates and alkalis attack.



Graph No-6 Compressive Strength Vs % SCBA under chemical exposure (28days)



Graph No-7 Compressive Strength Vs % SCBA under chemical exposure (56 days)

V. CONCLUSION

The experimental results indicate that with increase in temperature the loss in weight of specimen goes on The increasing. The maximum reduction in weight occurs at 800ºC temperature.

Ultrasonic pulse velocity values goes on decreasing with the increase in temperature, the maximum reduction in UPV values are observed above 600ºC temperature.

With the increase in temperature the compressive strength goes on decreasing, the rate in reduction is gradual upto 400oC, whereas the maximum reduction in compressive strength occurs above 600º C temperature.

Upto 15% SCBA content the reduction in compressive strength, weight loss and UPV values determined were less as compared to normal concrete and higher SCBA content.

The residue compressive strength at 200ºC was found to be about 80 percent whereas at around 600ºC to 800ºC residue strength was about 50 % compared to normal concrete.

Weight of concrete reduces with increase in exposure time (days) to the chemicals attack.

Compressive strength reduces with the exposure time to the chemicals, maximum reduction in compressive strength occurs with Acids as compared with sulphates and alkalis. It was observed to be in range to 0.34 to 10.29 for 7 days to 56 days respectively.

Exposure to alkalies showed minimum 0.14 % loss in weight and compressive strength as compared to sulphates and acids.

Mostly 15% SCBA content specimens has shown good output under chemical exposure conditions.

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