Durability Studies on Concrete Using Sugarcane Bagasse Ash

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***Abstract*— Sugarcane bagasse is a fibrous by-product of the sugar refining process. This by-product causes a high level of environmental pollution, necessitating the use of urgent waste disposal methods. The present study focuses on the use of Sugarcane Bagasse Ash in a concrete production as a substitute material for fine aggregate. The use of fine aggregate in concrete is increasing day by day. Sugarcane Bagasse ash contains a high amorphous silica and aluminium content. In the present analysis, agricultural waste product Sugar Cane Bagasse Ash (SBCA) is used as an alternative binding material. The aim of this project is to investigate the effects of partially replacing fine aggregate with sugarcane bagasse ash in concrete that has been exposed to various curing environments. The bagasse ash used for the research work is collected from Mahatma Sugar Factory, Wardha and used in concrete as a fine aggregate replacement in the ratio of 0 %, 5%, 10%, 15% & 20% by a weight. The influence of a fine aggregate replacement by bagasse ash on durability of concrete to Acid attack and Sulphate attack is determined in this paper. The concrete specimens were cured for 28 days in a solution of 3% sulphuric acid and hydrochloric acid. In this paper, we primarily focus on evaluating variation in compressive strength and weight reduction in five different M30 Grade mixes.**

***Index Terms*—Durability, Hydrochloric acid (HCL), Sugarcane Bagasse Ash, Sulphuric acid (H_2SO_4), Weight loss**

I. INTRODUCTION

For a long time, concrete was thought to be a very durable material that required little to no maintenance. This statement is correct except when it is exposed to extremely hostile conditions**.** Some concrete buildings are constructed in highly contaminated urban and industrial areas, hostile marine environments, toxic subsurface water in coastal areas, and a variety of other hostile environments where other building materials are found to be non-durable. Concrete is not completely resistant to acid and sulphates. Depending on the form and concentration of acid, most acid solutions can disintegrate Portland cement concrete slowly or quickly. Ca(OH)2 is the most fragile element of the cement hydrate, but C-S-H gel is also vulnerable. The use of pozzolanic admixtures to enhance the properties of concrete has been demonstrated by renowned researchers. Pozzolanic products have also been shown to improve the resistance of concrete to acid attack in studies.

Globally, programs are being developed to regulate and control the monitoring of by-products, residuals and an industrial waste in an order to protect the atmosphere from pollution. Burning them in a regulated atmosphere and using the ashes (waste) for more polite methods would be a successful solution to the issue of recycling an agro-industrial excess. The use of a waste such as cement and fine aggregate substitute materials will reduce the cost of the manufacture of concrete and mitigate the negative environmental impact of the disposal of such waste. Many researchers have recognized one such possible application in the agricultural waste known as sugarcane Bagasse from the sugar industry, which when burned produces sugarcane Bagasse ash (SCBA). Sugarcane is an essential agricultural plant that grows well in hot climates. India has a total sugar production capability of over 30 million tonnes per year. Sensitive amorphous silica is produced due to the combustion process when bagasse is burnt in the boiler of the cogeneration plant under controlled conditions and is present in the residual ashes known as a Sugarcane Bagasse Ash. Bagasse ash is a useful sand substitute material due to this amorphous silica content. If the concrete is exposed to acidic conditions, it can degrade. It is one of the most significant durability problems that affects the maintenance costs and life cycle performance of all concrete structures since sulphuric acid, hydrochloric acid, and other acids may be contained in chemical waste, ground water, and other locations. Acid rains, one of the main components of which is sulphuric acid, can cause concrete structures in industrial zones to deteriorate. Hence to study the effect of sugarcane bagasse ash on acid and sulphate resistance we used sugarcane bagasse ash as a substitute for 0%, 5%, 10%, 15% and 20% by weight of fine aggregate to increase consistency and lower construction costs. A study on acid and sulphate resistance of concrete using HCl and H_2SO_4 solutions respectively is observed. Concrete of grade M30 for a curing time of 28 days of the concrete specimens in 3% HCl and H_2SO_4 solutions were the component factors considered in this analysis. The effect of HCl and H2SO4 is measured by the loss in weight and loss in strength compared to the previously determined conventional concrete.

II. LITERATURE REVIEW

"An Experimental Study on Concrete with Sugarcane Bagasse Ash as a Partial Replacement of Cement under Sulphate Attack Using Mgso4 Solution", (December 2014) by Mohananganga Raju Puppala, M K M V Ratnam

In this project objective is to study the influence of partial replacement of Portland cement with sugarcane bagasse ash in concrete subjected to different curing environments. Experimental investigation on acid resistance of concrete in mgso4 solution. The variable factors considered in this study were concrete grade of M35 & curing periods of 7days, 28days, 60days, 90days, 180days of the concrete specimens in 1%, 2%, 3%, 4%, and 5% MgSO4 solution. Bagasse ash has been chemically & physically characterized & partially replaced in the ratio of 0%, 5%, 10%, 15%, and 20% by weight [1].

"Study on Bagasse Ash as Partial Replacement of Cement in Concrete", (January 2017) by Lathamaheswari, R., Kalaiyarasan, V and Mohankumar, G

This paper presents the attempt made in making concrete with partially replacing cement by 2.5, 5.0, 7.5,10 and 12.5 % of bagasse ash. Mix design is made for conventional M20 grade, conventional and ash based concrete prepared, the workability, strength and durability characteristics are determined through proper testing and the results are compared. The optimum level of cement replacement with bagasse ash is observed to be 7.5 percent [2].

"EFFECT ON M30 SCBA CONCRETE IN ACIDIC ENVIRONMENT", (December 2019) by P. V. RamBabu, V. Jahnavi Deepthi, G. V. Ramarao

In this experiment the impact of partial replacement of SCBA in ordinary Portland cement cured in various acidic environments is studied. Bagasse ash has been replaced by 0%, 5%, 10%, 15% and 20% by weight of cement. The concrete specimens were cured for 28, 60 and 90 days in water and in concentrations of 1%, 3 % and 5% sulphuric acid and hydrochloric acid solutions. The tests conducted are compressive strength. The ideal percentage of SCBA replacement is around 10%. The presence of SCBA in concrete developed resistivity towards Acidic attacks [3].

"Study on Concrete with Sugarcane Bagasse Ash as a Partial Replacement of Cement using HCL Solution", (June 2016) by S. NAGA BHARGAVI, Y. ANAND BABU

This investigation is focused on the partial replacements of Portland cement by Sugarcane Bagasse Ash in concrete. . In this paper the influence of partial cement replacement with Sugarcane Bagasse ash in concrete subjected to different curing environments has been studied by Experimental investigation on acid resistance of concrete in HCL solution. The variable factors considered in this study were concrete grade of M35 & curing periods of 7days, 28 days, 60 days, 90days, and 180 days of the concrete specimens. The parameter investigated was the time in days to cause strength deterioration factor of fully immersed concrete specimens in 1%, 2%, 3%, 4%, 5% HCL solution. Bagasse ash has been chemically & physically characterized & partially replaced in the ratio of 0%, 5%, 10%, 15%, and 20%. Fresh concrete tests like compaction factor test and hardened concrete tests like compressive strength at the age of 7days, 28 days, 90, 180 days was obtained [4].

"To Study the Properties of Concrete using Bagasse Ash on M-25 Grade of Concrete", (July 2018) by Amit and Sahil Goel

In this paper M25 grade of concrete was prepared to study the durability of concrete in terms of resistance of concrete specimens under the exposure of chloride and sulphate attack at exposure time of 7, 28 and 62 days after 28 days of water curing. The concrete specimens containing of bagasse ash as a partial replacement of cement subjected to chloride and sulphate attack had better resistance in comparison to the control mix [5].

III. MATERIALS

The materials used in the study are

Cement

The cement is used as a material which binds. The cement used is Portland-Pozzolana cement in this research is available from Birla Cement Company and complies with IS 1489 (Part 1): 1991.

Table 1. Physical Properties of Cement

Sr. No.	Property of cement	Value
1	Fineness	313 m^2/kg
2	Specific gravity	3.14
3	Initial setting time	55 mins
4	Final setting time	320 mins

Fine Aggregate

Aggregates were purchased from licensed suppliers in compliance with IS 383 - 1970 standards and were chemically inactive (inert), spotless and robust. The fine aggregate has been checked according to the limitations stated in IS: 383-1970. In this research, the specific gravity of sand is 2.64 and the sand corresponds to zone II as per the Indian standards

Coarse Aggregate

Machine-crushed coarse aggregates shall be one of black trap or similar black tough stone and shall be stiff, robust, thick, durable, and spotless or obtained from consultant licensed quarries. In this analysis, crushed aggregate is used in angular form with a maximum size of 20 mm and confirms to IS: 2386-1969. The specific gravity is 2.70.

Sugarcane Bagasse Ash (SCBA)

Approximately 50 % of cellulose, 25 % of hemicellulose and 25 % of lignin make up the Sugarcane Bagasse Ash. Each ton of sugarcane produces about 26 % of bagasse 0.620 % of residual ash. The chemical composition of the waste after incineration is dominated by Silicon Dioxide (SiO2). The ash is used on farms as a fertilizer in the Sugarcane Baggage Ash harvests, despite being a substance of an extreme degradation and that contains little nutrients.

Table 2. Properties of sugarcane bagasse ash

Property	Value
Fineness modulus	1.78
Specific gravity	1.44

Table 3. Chemical properties of sugarcane bagasse ash

Compound	Mass (%)
SiO_2	64.55
Al_2O_3	7.97
Fe_2O_3	4.53
CaO	6.4
K_2O	3.77
MgO	3.13
SO_3	0.86
Loss of Ignition	3.29

Water

Good potable water available in the site is used for the construction purpose which conforming to the requirements of water for concreting and curing as per IS: 456-2000.

IV. METHODOLOGY

IS 456:2000 was followed while creating the mix design. The fresh concrete was mixed by a hand until the consistency was achieved before mixing; the materials were spread in layers at the bottom of the pan, the rough aggregate first, followed by the cement and finally the fine aggregate. The components of the mixtures were mixed dry for 1.00 minute in order to homogenize the mixture; water was then added and mixed for another 3.00 minutes. The concrete was cast into the moulds in three layers, and each layer received 36.00 blows, using 16.00 mm diameter bar, to remove any air. The requisite number of cubes were cast for each mix. Sacking was used to protect the moulds for 24 hours at room temperature. After at least 24 hours, the specimens were de-moulded and poured into the curing tank. The cubes were removed from water, surface dried and weighed after 28 days and then immersed in 3% hydrochloric acid solution and 3% sulphuric acid solution for 28 days. After 28 days cubes were taken out from solution, surface dried and weighed. The acid attack test was carried out according to ASTM C 267-97 for a total of 28 days. For the acid resistance test, hydrochloric acid of 3%

concentration was used, and sulphuric acid of 3% concentration was used for the sulphate resistance test. Concrete specimens of size 150 mm were immersed in a solution of dilute HCl and H_2SO_4. Once every two weeks, the solution was replaced. Concrete specimens were subjected to two separate examinations. The compressive strength of concrete was checked to see if it changed as a result of acid and sulphate attack. After 28 days of immersion in dilute hydrochloric and sulphuric acid, the concrete specimens were tested for compressive strength. The specimens were also checked to see loss in weight.

V. RESULTS & DISCUSSION

After 28 days, specimens immersed in 3% hydrochloric acid and 3% sulphuric acid solution were removed form curing tank and tested for weight loss and compressive strength loss. After treating specimens with hydrochloric acid and sulphuric acid for 28 days of M30 grade concrete for replacement of natural sand by SCBA in proportions of 0%, 5%, 10%, 15%, and 20% by weight, the decrease in the compressive strength and loss in weight of the concrete are as follows:

Acid attack

The effect of bagasse ash on the weight and strength of concrete specimens exposed to 3% hydrochloric acid solution for 28 days has been investigated. The difference in weight and strength was studied and compared with the control mix and normal water curing.

1) Weight Loss

The weight loss of bagasse ash concrete cube specimens exposed to hydrochloric acid solution for days has been investigated. The impact of bagasse ash on weight loss is shown in Table 4 and illustrated in fig. 1

Table 4. Weight Loss of Concrete Specimens Subjected to Acid Attack

Mix Designation	Weight before acid attack (gm)	Weight after acid attack (gm)	% Loss in weight
M0	8192	7964	2.78
M5	8158	7988	2.08
M10	8141	7995	1.79
M15	8173	7991	2.23
M20	8169	7959	2.57

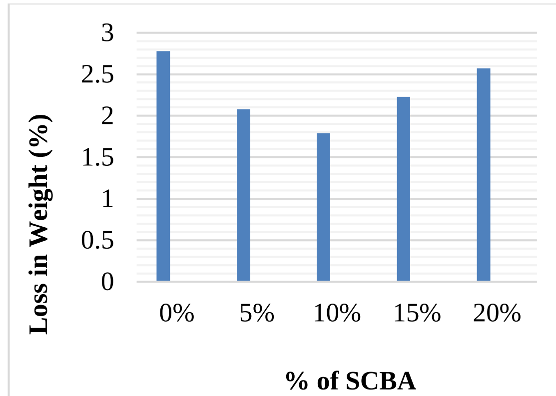

Fig. 1 Weight Loss of Concrete Specimens Subjected to Acid Attack

More amount of weight loss was observed in the control mix specimens and it was found decreasing up to 10% of SCBA content as sand replacement. It means that the control mix specimen have recorded maximum loss in weight that is 2.78% and the specimen with 10% SCBA have recorded the least loss in weight. The percentage loss in weight was 1.79% for the mix with 10% SCBA.

2) Compressive Strength Loss

Table 5 and fig. 2 shows the comparison of the compressive strength loss values of acid attacked specimens at 28 days.

Table 5. Compressive Strength Loss of Concrete Specimens Subjected to Acid Attack

Mix Designation	Compressive strength		% Loss in C.S.
	Before acid attack (N/mm^2)	After acid attack (N/mm^2)	
M0	31.6	30.03	4.96
M5	31.95	30.6	4.22
M10	33.82	32.66	3.43
M15	29.97	28.66	4.37
M20	28.89	27.53	4.70

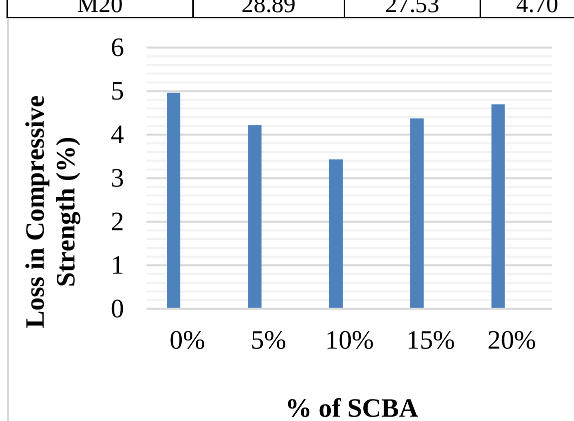

Fig. 2 Compressive Strength Loss of Concrete Specimens Subjected to Acid Attack

There was loss in compressive strength for the entire concrete specimens. In the case of concrete mixes with 0% SCBA more reduction in compressive strength was observed when exposed to hydrochloric acid solution. Also gradual reduction in the loss was observed with the increase in the percentage of SCBA in concrete up to 10%. The maximum loss in compressive strength (4.96%) was recorded for the control mix with 0% SCBA. The value was 3.43% for the mix with 10% SCBA. So the specimen with 10% SCBA have recorded the least loss in compressive strength.

Sulphate Attack

The effect of SCBA when used in concrete as a fine aggregate replacement in the ratio of 0 %, 5%, 10%, 15% & 20% by a weight on the weight and compressive strength of concrete specimens exposed to sulphuric acid (98% concentrated) solution with 3% concentration for 28 days has been studied. The difference in weight and strength was studied and compared with the control mix and normal water curing.

1) Weight Loss

The result of the weight loss of concrete specimens after the end of 28 days is illustrated in Table 6 and fig. 3

Table 6. Weight Loss of Concrete Specimens Subjected to Sulphate Attack

Mix Designation	Weight before sulphate attack (gm)	Weight after sulphate attack (gm)	% Loss in weight
M0	8145	7821	3.97
M5	8180	7900	3.42
M10	8163	7913	3.06
M15	8171	7870	3.68
M20	8128	7818	3.81

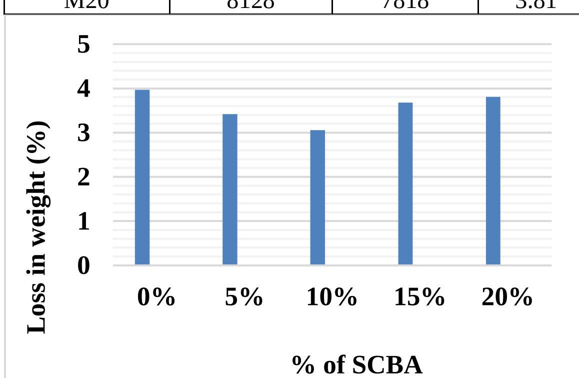

Fig. 3 Weight Loss of Concrete Specimens Subjected to Sulphate Attack

At the end of the immersion in a 3% sulphuric acid solution, the mixture that contained 10% SCBA showed lower weight loss (3.06%) than the other mixes and the mix with 5% SCBA had only lost 3.42% of its initial weight which is close to the weight loss of M10. Maximum amount of weight loss that is 3.97% was observed in the control mix specimens with 0% SCBA.

2) Compressive Strength Loss

Table 7 and fig. 4 shows the comparison of the compressive strength loss values of sulphate attacked specimens at 28 days.

Table 7. Compressive Strength Loss of Concrete Specimens Subjected to Sulphate Attack

Mix Designation	Compressive Strength		% Loss in C.S.
	Before sulphate attack (N/mm^2)	After sulphate attack (N/mm^2)	
M0	31.6	29.87	4.96
M5	31.95	30.36	4.22
M10	33.82	32.45	3.43
M15	29.97	28.47	4.37
M20	28.89	27.38	4.70

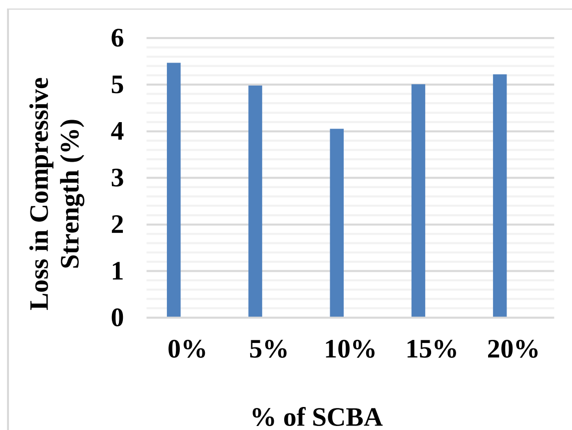

Fig. 4 Compressive Strength Loss of Concrete Specimens Subjected to Sulphate Attack

The initial compressive strength and strength loss of concrete specimens from different mixtures were measured to evaluate the performance of concrete specimens against sulphuric acid intrusion after 28 days of immersion. It can be seen from Table 7 that the concrete mixture with 10% SCBA showed minimum strength loss (4.05%) than the other mixes. The maximum loss in compressive strength (5.47%) was recorded for the control mix with 0% SCBA. So the specimen with 10% SCBA have recorded the least loss in compressive strength.

VI. CONCLUSION

In this study, concrete with SCBA in the ratio 0%, 5%, 10%, 15%, and 20% by weight of sand were studied for durability properties. The conclusion from the above examination are as per the following.

- In the weight loss test of acid attacked specimens, the maximum weight loss was observed in the control mix concrete and the minimum was observed in the mix with 10% SCBA.
- In case of acid resistance test, the compressive strength decreases for all mixes. The maximum compressive strength loss was recorded in the control mix concrete with 0% SCBA and the minimum was observed in the M10 mix with 10% SCBA.
- After sulphate attack, more losses in the weight and compressive strength were observed in control mix concrete than the concrete with SCBA. The weight loss is least at 10% replacement.
- In the compressive strength loss test of sulphate attacked specimens, the minimum compressive strength loss was observed in the mix with 10% SCBA.
- It was found that the 10% incorporation of sugarcane bagasse ash as partial sand replacement material is able to improve the resistance of concrete towards acid and sulphate attack.

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