

# **An Experimental Study on Concrete with Sugarcane Bagasse Ash as a Partial Replacement of Cement under Sulphate Attack Using $MgSO_4$ Solution**

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**ABSTRACT:** Sugarcane bagasse is a fibrous waste product of sugar refining industry. This product causes severe environmental pollution, which calls for urgent ways of handling the waste. Bagasse ash mainly contains aluminum ion silica, iron & calcium oxides. The ash therefore becomes an industrial waste and poses disposal problems. So few studies have been reported that sugarcane bagasse ash as good pozzolanic material in partial replacement of cement.

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  $MgSO_4$  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%  $MgSO_4$  solution. Bagasse ash has been chemically & physically characterized & partially replaced in the ratio of 0%, 5%, 10%, 15%, and 20% by weight.

**KEYWORDS:** Portland cement, Concrete, Sugar Cane Bagasse Ash (SCBA), Specimen Preparation, Testing,  $MgSO_4$

## **I.INTRODUCTION**

Portland cement is the major construction material throughout the world. Today researchers are focusing on utilizing industrial or agricultural waste, as a source of raw materials for industry which results in foreign exchange earning and environmental pollution. Industrial wastes, such as blast furnace slag, fly ash and silica fumes are being used as supplementary cement materials. The utilization of bagasse ash is more, the residue from an in-line sugar industry and the bagasse-biomassfuel in electric generation industry. When this waste is burned under controlled conditions, it also gives ash having amorphous silica, which has pozzolanic properties. The study of pozzolanic activity and their suitability as binders, have been carried out on the ashes in replacing cement..There is a possibility in using sugarcane bagasse ash as cement material to improve quality and reduce the cost of construction materials such as mortar, concrete pavers, concrete roof tiles and cement interlocking block.

Concrete is the most common construction material in the world because it combines very good mechanical and durability properties, workability and relative low cost. cement production emits greenhouse gases, mainly  $CO_2$ , being responsible for about 5% of global anthropogenic  $CO_2$  emissions in the world. The use of low emission pozzolans as cement replacement is one of the possibilities to reduce greenhouse gases emissions

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The bagasse is an important by-product of the sugar cane industry and most of it is used to produce steam and electricity in a co-generation plant at the ethanol plant. After the bagasse combustion, a new by-product is the Sugar Cane Bagasse Ash (SCBA). It consists mainly of silica ( $\text{SiO}_2$ ), which indicates its potential as mineral admixture for use in concrete. The results of this research program indicated that SCBA can be used as a pozzolan and substitute cement. Since durability is a very important issue for implementing new construction materials, in this Thesis, the results of tests of sulphate attack on concrete cubes made with SCBA. These tests indicated that SCBA improves the durability of a reference

## II. METHODOLOGY

In the investigation sugar cane bagasse ash has been used as partial replacement of cement as an additional ingredient in concrete mixes. The effect of adding different percentages of sugar cane bagasse ash as additional material to concrete mixes on their compressive strength, resistance to sulphates, were studied.

1. Cement: Ordinary Portland cement available in the local market of standard brand was used in the investigation. The cement procured was tested for physical requirements in accordance with IS: 12269-1987 and for chemical requirements in accordance with IS: 4032-1977.
2. Sugar Cane Bagasse Ash: Sugarcane bagasse consists of approximately 50% of cellulose, 25% of hemicelluloses of lignin. Each ton of sugarcane generates approximately 26% of bagasse (at a moisture content of 50%) and 0.62% of residual ash. The residue after combustion presents a chemical composition dominated by silicon dioxide ( $\text{SiO}_2$ ).
3. Fine Aggregate: The locally available river sand is used as fine aggregate in the present investigation. The sand is free from clay, silt and organic impurities. The sand is tested for various properties like specific gravity, bulk density etc., and in accordance with IS 2386-1963.
4. Coarse Aggregate: Machine crushed angular granite metal of 20mm nominal size from the local source is used as coarse aggregate.
5. Water: The locally available potable water accepted for local construction is used in the experimental investigation after testing. The pH value should not be less than 6
6. Magnesium Sulphate ( $\text{MgSO}_4$ ): The magnesium Sulphate is obtained from locally and is manufactured in Molychem, Mumbai with minimum assay of 99.8%.

### Design requirements:

Characteristic compressive strength ( $F_{ck}$ )	- 35 N/mm <sup>2</sup>
Max. Size of aggregate	- 20 mm
Degree of workability	- 0.86 compacting factor
Degree of quality control	- Good
Type of exposure	- Moderate
Type of compaction	- Vibration

### Test data for materials:

Type of cement/ grade of cement	- OPC 53 grade
Specific gravity of cement	- 3.10
Specific gravity of sand	- 2.62
Specific gravity of coarse aggregate	- 2.68
Bulk density of sand	- 1600 kg/m <sup>3</sup>
Bulk density of coarse aggregate	- 1500 kg/m <sup>3</sup>
Fineness modulus of sand	- 2.72
Grading zone of sand	- Zone II

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Design of concrete mix:

Target mean strength (f)	- $F_{ck} + 1.65(s) = 35 + 1.65(5) = 43.25 \text{ N/mm}^2$
Water cement ratio	- 0.41
Water content	- 187.78 lits
Sand content ( $\rho$ )	- 31%
Cement content per m3 of concrete	- 450 kg
Percentage of entrapped air	- 2%
Fine aggregates required	- 523.68 kg
Coarse aggregates required	- 1229.86 kg

### III. RESULTS AND DISCUSSIONS

#### 1. MATERIALS AND PROPERTIES:

Table 1: Physical properties of Portland cement (53 grade)

S. No.	Properties/Characteristics	Test results	Requirements as per IS 12269-1987
1	Normal Consistency	32%	---
2	Setting time a) Initial Setting Time b) Final Setting Time	64 minutes 271 minutes	Not less than 30 minutes Not more than 600 minutes
3	Specific Gravity	3.10	---
4	Fineness of cement by sieving through sieve No.9 (90 microns) for a period of 15 min.	2.82%	<10%
5	Soundness (Le-Chatlier Exp.)	1.29 mm	Not more than 10mm
6	Compressive strength of cement (28 days)	53 MPa	53 MPa
7	Specific surface area	3200 $\text{cm}^2/\text{gm}$	---

Table 2: Physical Properties of scba:

S. No.	Property	Test Result
1.	Density	575Kg/m3
2.	Specific Gravity	2.2
3.	Mean particle size	0.1-0.2 $\mu\text{m}$
4.	Min specific surface area	250 $\text{m}^2/\text{kg}$
5.	Particle shape	Spherical

Table 2.1 Chemical Composition of sugarcane bagasse ash

S. No.	Characteristic	Test Results %
1	(SiO <sub>2</sub> ) + Al <sub>2</sub> O <sub>3</sub> Fe <sub>2</sub> O <sub>3</sub> % by mass	85.14
2	SiO <sub>2</sub> % by mass	60.20
3	MgO % by mass	2.48
4	Total sulphur as SO <sub>3</sub> % by mass	0.10

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5	Available alkali as sodium oxide (Na <sub>2</sub> O) % by mass	4.32
6	Loss of ignition % by mass	5.10

Table 3: Sieve Analysis (Fine Aggregate)

S. No.	I.S. Sieve No.	Weight retained (gm)	Percentage weight retained	Cumulative percentage retained	Percentage passing
1.	40mm	0	0	0	100
2.	20mm	0	0	0	100
3.	10mm	0	0	0	100
4.	4.75mm	21	2.10	2.10	97.90
5.	2.36mm	65	6.50	8.60	91.40
6.	1.18mm	180	18.00	26.06	73.94
7.	600μ	278	27.80	54.04	45.96
8.	300μ	280	28.00	82.04	17.96
9.	150μ	176	17.06	100.00	0
Total :				274.00	

Fineness modulus =  $274.1 / 100 = 2.74$

Table 4: Sieve Analysis (Coarse Aggregate)

S.No.	I.S. Sieve No.	Weight Retained (gms)	Percentage weight retained	Cumulative Percentage Retained	Percentage Passing
1.	40mm	0	0	0	100
2.	20mm	877	17.54	17.54	82.46
3.	10mm	4085	81.70	99.24	0.76
4.	4.75mm	38	0.76	100.00	0
5.	2.36mm	0	0	100.00	0
6.	1.18mm	0	0	100.00	0
7.	600μ	0	0	100.00	0
8.	300μ	0	0	100.00	0
9.	150μ	0	0	100.00	0

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Total :	716.78	
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$Fineness\ modulus = 716.78 / 100 = 7.17$

Table 5: Physical Properties of Fine And Coarse Aggregate

S. No.	Properties	Test results	
		Fine Aggregate	Coarse Aggregate
1.	Specific gravity	2.60	2.74
2.	Bulk Density (Kg/m <sup>3</sup> ) a) loose b) compacted	1600 kg/m <sup>3</sup> 1750 kg/m <sup>3</sup>	1400 Kg/m <sup>3</sup> 1580 Kg/m <sup>3</sup>
3.	Fineness Modulus	2.74	7.17

Table 6: Analysis of Water (Limitations As Per IS: 456-2000)

S. No.	Impurity	Max. Limit	Results
1	PH Value	6 to 8.5	7
2	Suspended matter mg/lit	2000	220
3	Organic matter mg/lit	200	20
4	Inorganic matter mg/lit	3000	150
5	Sulphate (SO <sub>4</sub> ) mg/lit	500	30
6	Chlorides (Cl) mg/lit	2000 for P.C.C. 1000 for R.C.C.	60

Table 7: Properties of MgSO<sub>4</sub>

Chemical	Volume (%)
pH (5% water)	6.3
Free Alkali sol. (as NaOH)	0.008
Free Acid (as H <sub>2</sub> SO <sub>4</sub> )	0.01
Chlorides	0.02
Heavy metals (Pb)	0.0005
Arsenic	0.0002
Iron (Fe)	0.01
Selenium (Se)	0.001
Loss of Drying (at 450°C)	50.4

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### 2. CONVENTIONAL CONCRETE MIX DESIGN (AS PER IS 10269: 1982)

Table 8: MIX PROPORTIONS BY WEIGHT

<i>Cement</i>	<i>Fine aggregate</i>	<i>Coarse aggregate</i>	<i>w/c ratio</i>
450	523.68	1229.86	187.78
1	1.16	2.73	0.41

Table 8.1: WORKABILITY STUDIES

<i>S. No.</i>	<i>% Replacement of cement with SCBA</i>	<i>Workability compaction factor</i>
1	0%	0.856
2	5%	0.838
3	10%	0.817
4	15%	0.807
5	20%	0.779

### 3. RESULTS OF STRENGTH PARAMETERS

Compressive strength of concrete:

Table 9: Compressive Strength results for cubes cured in water

<i>Sample Designation</i>	<i>% of SCBA</i>	<i>compressive strength at 7 days (<math>f_{cu}^1</math>)</i>	<i>compressive strength at 28 days (<math>f_{cu}^1</math>)</i>	<i>compressive strength at 60days (<math>f_{cu}^1</math>)</i>	<i>compressive strength at 90days (<math>f_{cu}^1</math>)</i>	<i>compressive strength at 180days (<math>f_{cu}^1</math>)</i>
W-0	0	38.24	46.19	56.82	59.99	62.00
W-05	5	38.95	47.08	57.54	60.18	62.20
W-10	10	39.69	48.145	57.86	61.16	63.16
W-15	15	37.30	45.61	55.28	58.12	60.12
W-20	20	35.76	44.14	54.01	57.81	59.81

### 4. DURABILITY STUDIES

Table 10.1: Compressive Strength results for cubes cured in 2% magnesium sulphate solution

<i>Sample Designation</i>	<i>% of SCBA</i>	<i>compressive strength at 7 days (<math>f_{cu}</math>)</i>	<i>compressive strength at 28 days (<math>f_{cu}</math>)</i>	<i>compressive strength at 60days (<math>f_{cu}</math>)</i>	<i>compressive strength at 90days (<math>f_{cu}</math>)</i>	<i>compressive strength at 180days (<math>f_{cu}</math>)</i>
M-21	0	35.84	43.3	53.71	57.18	59.20
M-22	5	36.92	44.66	55.52	58.68	60.70
M-23	10	38.32	46.64	56.44	59.88	61.80
M-24	15	35.86	43.78	53.52	56.54	58.55
M-25	20	35.23	42.32	52.04	55.98	57.99

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Table 11.1: Reduction in Compressive strength due to 2% MgSO<sub>4</sub> Cured for 7 days

Sample Designation	% of SCBA	( $f_{cu}^1$ )	( $f_{cu}$ )	% reduction
M-21	0	38.24	35.84	6.28
M-22	5	39.25	36.92	5.93
M-23	10	39.69	38.32	3.45
M-24	15	37.45	35.86	4.24
M-25	20	36.82	35.23	4.32

Table 11.2: Reduction in Compressive strength due to 2% MgSO<sub>4</sub> cured for 28 days

Sample Designation	% of SCBA	( $f_{cu}^1$ )	( $f_{cu}$ )	% reduction
M-21	0	46.19	43.3	6.26
M-22	5	47.08	44.66	5.14
M-23	10	48.145	46.64	3.13
M-24	15	45.61	43.78	4.01
M-25	20	44.14	42.32	4.12

Table 11.3: Reduction in Compressive strength due to 2% MgSO<sub>4</sub> cured for 60 days

Sample Designation	% of SCBA	( $f_{cu}^1$ )	( $f_{cu}$ )	% reduction
M-21	0	56.82	53.71	5.47
M-22	5	57.54	55.52	3.51
M-23	10	57.86	56.44	2.45
M-24	15	55.28	53.52	3.18
M-25	20	54.01	52.04	3.65

Table 11.4: Reduction in Compressive strength due to 2% MgSO<sub>4</sub> cured for 90 days

Sample Designation	% of SCBA	( $f_{cu}^1$ )	( $f_{cu}$ )	% reduction
M-21	0	59.99	57.18	4.68
M-22	5	60.18	58.68	2.5
M-23	10	61.16	59.88	2.1
M-24	15	58.12	56.54	2.72
M-25	20	57.81	55.98	3.17

Table 11.5: Reduction in Compressive strength due to 2% MgSO<sub>4</sub> cured for 180 days

Sample Designation	% of SCBA	( $f_{cu}^1$ )	( $f_{cu}$ )	% reduction
M-11	0	62.00	59.2	4.52

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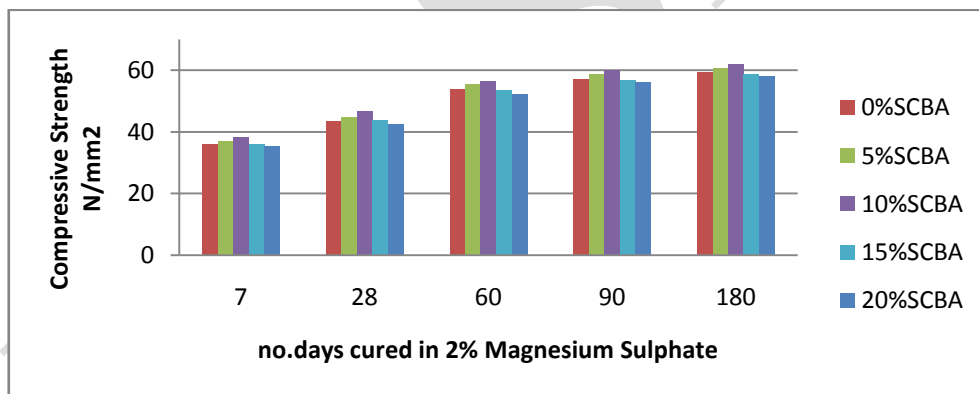
M-12	5	62.20	60.70	2.4
M-13	10	63.16	61.80	2.2
M-14	15	60.12	58.55	2.6
M-15	20	59.81	57.99	3.0

## IV. DISCUSSIONS

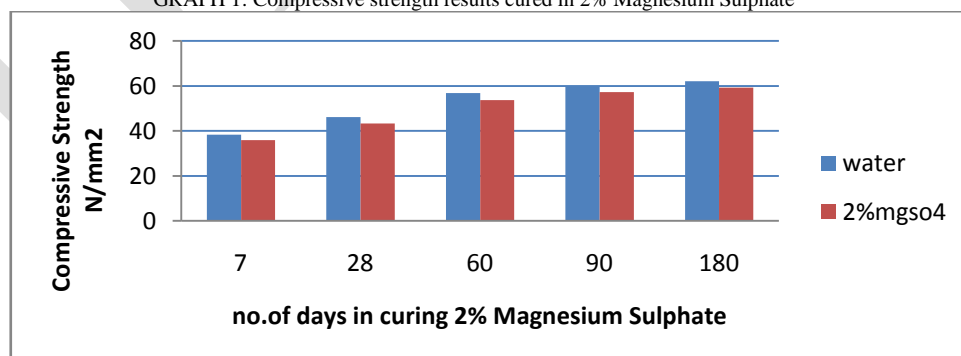
The physical property of ordinary Portland cement used in 28 days cube compressive strength of cement is 53 MPa. The SCBA contains 63% of Silica (SiO<sub>2</sub>), 31.5% of Alumina (Al<sub>2</sub>O<sub>3</sub>), 1.79% of Ferric Oxide, 0.48% of Calcium Oxide. The density of SCBA is 575 Kg/m<sup>3</sup> and specific surface area is 420 m<sup>2</sup>/kg greater than 330 m<sup>2</sup>/kg of cement. The fineness modulus of fine aggregate is 2.74. The fineness modulus of the 20mm coarse aggregate is 7.17. The compressive strengths of concrete (with 0%, 5%, 10%, 15% and 20% weight replacement of cement with SCBA) cured in different concentrations of (1%, 2%, 3%, 4%, 5%) Magnesium sulphate solution for 7, 28, 60, 90 and 180 days, indicate that at 5% replacement there is increase in strength and it extended in 10% replacement also and then decrease in strength is noticed at 15% and 20% replacements and here I shown the results Compressive strength due to 2% MgSO<sub>4</sub> cured for 7, 28, 60, 90, 120 days.

Due to slow pozzolanic reaction the Sugar Cane Bagasse Ash (SCBA) concrete achieves significant improvement in its mechanical properties at later ages. In concretes cement can be replaced with 20% SCBA without sacrificing strength.

## V. GRAPHS



GRAPH 1: Compressive strength results cured in 2% Magnesium Sulphate



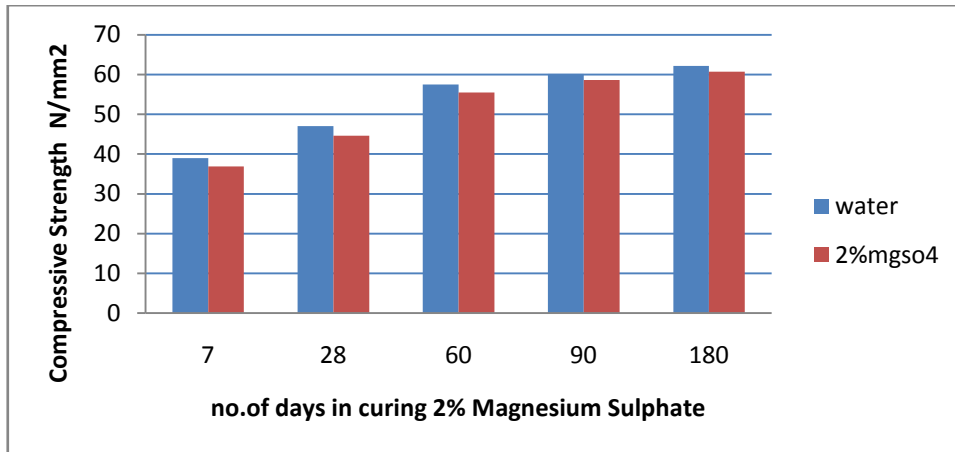
GRAPH 2 : Compressive strength results of 0% SCBA cubes days cured in water and 2% magnesium sulphate



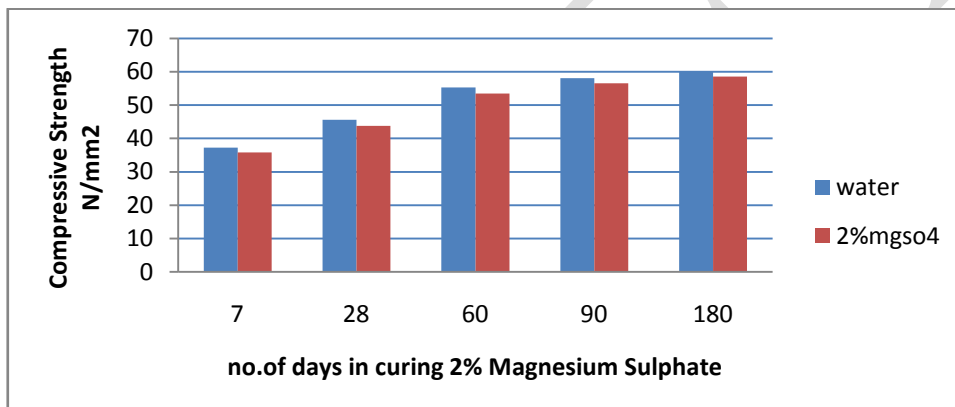
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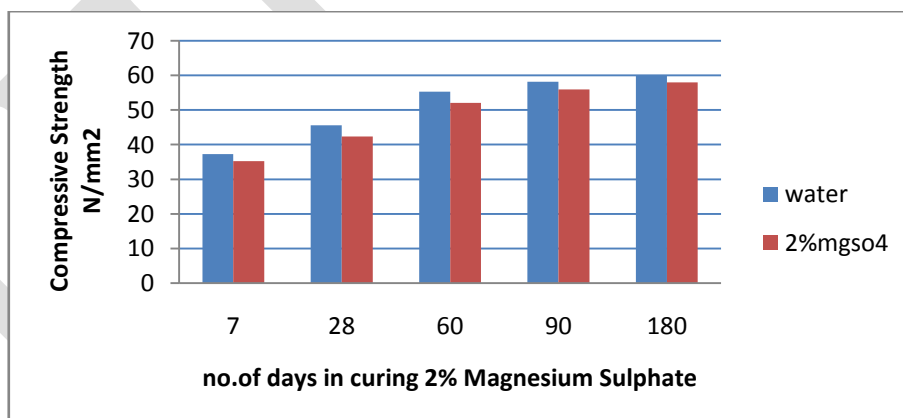
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Graph 3 : Compressive strength results of 10%SCBA cubes days cured in water and 2% magnesium sulphate



Graph 4 : Compressive strength results of 15%SCBA cubes days cured in water and 2% magnesium sulphate



Graph 5 : Compressive strength results of 20%SCBA cubes days cured in water and 2% magnesium sulphate

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