

# Effect of Sugarcane Bagasse Fibre on the Behavior of Geopolymer Concrete under Sulphate Attack

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**Abstract.** The use of various fibres such as steel, glass, sugarcane bagasse, and others has a considerable impact on the fresh and hardened properties of concrete. Sugarcane bagasse fibre is a byproduct from the sugarcane industry that can be reused as a concrete fibre. This paper objective is to work on the behaviour of sugarcane bagasse fibre on low calcium fly ash and slag based geopolymer concrete of G40 which is equivalent to M40 grade, when it is exposed to 5% sulphate attack with the help of experiments. The specimens were casted, GPC and GPCF Cured in an oven at 60 ° C for 24 hours, then let to cure in the atmosphere until the test is complete. After 28 days, the specimens were immersed in sulphates such as Na<sub>2</sub>SO<sub>4</sub> and MgSO<sub>4</sub> for 15, 45, and 75 days, and then tested according to codal standards on 15, 45, and 75 days. The comparisons were made in a controlled concrete environment (CC), controlled concrete with sugarcane bagasse fibre (CCF), geopolymer concrete (GPC) and geopolymer concrete with sugarcane bagasse fibre (GPCF). From the results it is observed that CCF and GPCF showed more resistant than CC and GPC when it is subjected to sulphate attack.

## 1 Introduction

Construction field is the fastest growing field in worldwide. Cement is the main constituent in the controlled concrete and behaves as a binder material. For production of OPC requires large amount of raw materials. During the production of OPC it emits large amounts of carbon dioxide into the atmosphere. For manufacturing of 1ton of cement about 1.5 tonnes of raw materials are used. Each tonne of cement produced releases about one tonne of CO<sub>2</sub>. It is the most important issue from a long-term perspective. OPC also emits heat during hydration process. In this case geopolymer concrete is the best alternative. Geopolymer concrete is made by reacting aluminate and silicate-bearing materials with a caustic activator. Iron and metal production produces byproducts such as flyash or slag used in concrete helps to lead a cleaner environment. By use of these byproducts produced from various industries results in environmental and economic benefit. Geopolymer concrete does not produce heat during polymerisation. By use of geopolymer concrete we can reduce the usage of ordinary Portland cement hence the production of cement decreases and also green house gases releasing into the atmosphere decreases. Utilization of various fibres like steel, glass, sugarcane bagasse etc, significantly influences fresh and hardened

properties of concrete. Sugarcane bagasse fibre is a by-product from sugar industries and can be used as a fibre in concrete.

## 2 Materials

### 2.1. Ordinary Portland Cement

Ordinary Portland cement with a grade of 53 was implemented in this research. A range of tests were performed on physical properties. The specific gravity of cement is measured to be 3.16.

## 2.2. Fine Aggregate (FA)

Local sources are used to obtain the fine aggregate. It is free of contaminants such as silt, clay, and organic materials. Physical properties of fine aggregate such as fineness modulus, gradation, bulk density, and specific gravity were tested in line with IS:2836. Zone-II of IS: 383-1970 has been confirmed in the sand. Fine aggregate has a specific gravity of 2.64.

## 2.3. Coarse Aggregate

In this experiment, coarse aggregate particles with a diameter of 20 mm were utilised. The parameters of coarse aggregate are determined using the IS:2386-1963 standard. It is found that coarse aggregate has a specific gravity of 2.60.

## 2.4. Fly Ash

In this experiment low calcium class F flyash is used.

## 2.5. GGBS (ground granulated blast furnace slag):

It's a byproduct from the steel industry. GGBS is a molten mixture of calcium silicates and other bases generated simultaneously with Fe in a blast furnace.

## 2.6. Water:

According to IS 456:2000, water should be free of pollutants and other compounds, and oils should be used for concrete mixing.

## 2.7. Sodium hydroxide:

It's most widely utilized as a geopolymerization activator, which is one of the main ingredients in geopolymer concrete. White solids are the physical appearance of sodium hydroxide pellets.

**Table 1.** Physical properties of NaOH

Molar mass	40 gm/mol
Appearance	White solid
Density	2.1 gr/cc
Melting point	318 <sup>0</sup> c
Boiling point	1390 <sup>0</sup> cc
Amount of heat liberated when dissolved in water	266 cal/gr

## 2.8. Sodium silicate solution:

Sodium silicate solution is an alkaline liquid that plays an important function as an activator in the

geopolymerisation process. Porosity is also reduced. If there is more calcium hydroxide in concrete, it bonds to the surface, enhancing durability and water resistance.

**Table 2.** Properties of Na<sub>2</sub>SiO<sub>3</sub> solution

Specific gravity	1.57
Molar mass	123.06 gm/mol
Na <sub>2</sub> O (by mass)	15.35%
SiO <sub>2</sub> (by mass)	30.00%
Water (by mass)	56.00%
Weight ratio (SiO <sub>2</sub> to Na <sub>2</sub> O)	2.09
Molarity ratio	0.98

## 2.9. Constituents of geopolymer

### 2.9.1. Source materials

Material containing primarily silicon and aluminium in amorphous form is a viable source for geopolymer production. In the past, several minerals and industrial byproducts were studied.

### 2.9.2. Alkaline activators

A mixture of sodium silicate and sodium hydroxide is the most frequent alkaline activator used in geopolymerisation.

### 2.9.3. Super plasticizer

Super plasticizer (sulphonated naphthalene formaldehyde) is used as admixture which reduces water content and increases the workability of concrete. It is added in 2% to the binder.

## 2.10 Sugarcane bagasse fibre

Sugarcane bagasse is a byproduct from sugarcane industry. After sugarcane stalks are crushed to obtain juice, it leaves a dry pulpy fibrous residue. Fiber has a 66.7 aspect ratio.

## 3 Experimental investigation

### 3.1 General

The behaviour of sugarcane bagasse fibre on low calcium flyash and slag based geopolymer concrete exposed to 5% sulphate solutions for up to 2.5 months of CC, CCF, and GPCF correspondingly is presented in this work. Alkaline solution is made up of sodium hydroxide and sodium silicate. The compressive strength is highest when the ratio of Na<sub>2</sub>SiO<sub>3</sub> to NaOH is 2.5, and when the ratio of

SiO<sub>2</sub> to Na<sub>2</sub>O is 2. After a one-day rest period, 100mmX100mmX100mm cubes of sugarcane bagasse fibre reinforced geopolymer concrete were cast. The specimens were oven cured for 24 hours at 60 degrees Celsius and then ambient cured for the rest of the time. For controlled concrete, a traditional approach of casting the same size cubes and keeping them under water for curing was used. After 28 days, the specimens were immersed in sulphates such as MgSO<sub>4</sub> and Na<sub>2</sub>SO<sub>4</sub> for 15, 45, and 75 days, and then the sulphate attack resistance of CC, CCF, GPC, and sugarcane bagasse fibre reinforced geopolymer concretes exposed to a 5% concentration of Na<sub>2</sub>SO<sub>4</sub> and MgSO<sub>4</sub> sulphates was measured in terms of weight loss and compressive strength. The Acid Attack Factors (AAFs) and Acid Durability Factors (ADFs) of controlled and sugarcane bagasse fibre reinforced geopolymer concrete exposed to 5% concentrations of various sulphates are also investigated to determine their resistance to sulphate attack, and the results are compared.

### 3.2 Mixing and Casting of Geopolymer Concrete

The traditional concrete processes can be used to make geopolymer concrete. In laboratory flyash, GGBS, sugarcane bagasse fibre and aggregates were mixed for 3minutes when in dry condition. Superplasticizer is mixed with alkaline liquid and extra water if any.

The liquid component was mixed in with the dry ingredients, and the mixing took around four minutes. The new concrete was cast and compacted using the same processes as Portland cement concrete. Conventional slump test is done for evaluating the workability of fresh concrete.

## 4 Test Results

### 4.1. Loss of weight and compressive strength

When exposed to a 5% concentration of MgSO<sub>4</sub> and Na<sub>2</sub>SO<sub>4</sub> solutions, the weight and compressive strength of CC, CCF, GPC, and sugarcane bagasse fibre reinforced geopolymer concrete is lost in percentage.

### 4.2. Acid Durability Factors (ADFs) and Acid Attack Factors (AAFs)

#### 4.2.1. Acid Durability Factors (ADFs)

The Acid durability factors can be calculated as follows

$$\text{Acid Durability Factors} = Sr (N/M)$$

Where

Sr = relative strength over a duration of N days (percent)

M = Number of days till the exposure is to be ended.

N is the number of days that the durability factor is required.

The Acid Attack test was stopped after 60 days. So M is equal to 60.

#### 4.2.2. Acid Attack Factors (AAFs)

For each of two cubes, the surface degradation of each corner of the affected face and the opposite face is measured in millimetres, and the acid attack factors per face are determined as follows:

Acid Attack Factors (AAFs) and Acid Durability Factors (ADFs) of CC, CCF, GPC, and sugarcane bagasse fibre reinforced geopolymer concrete specimens exposed to 5% MgSO<sub>4</sub> and Na<sub>2</sub>SO<sub>4</sub> solutions are shown in the figures.

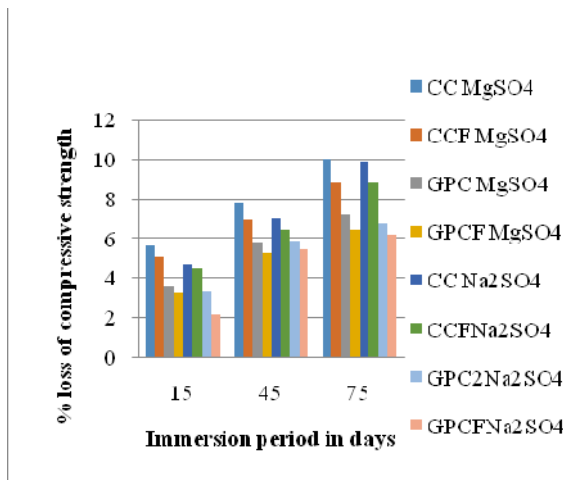
**Table 3.** The %loss of compressive strength when immersed in 5% MgSO<sub>4</sub> solution.

	Strength before immersion	strength after immersion		
		15	45	75
CC	49.2	46.45	45.38	44.28
% of strength loss		5.58	7.76	9.98
CCF	55.30	52.78	51.63	50.57
% of strength loss		5.03	6.96	8.76
GPC	50.5	48.70	47.58	46.88
% of strength loss		3.56	5.78	7.16
GPCF	56.80	55.23	54.00	53.28
% of strength loss		3.24	5.24	6.41

**Table 4.** The %loss of compressive strength when immersed in 5% Na<sub>2</sub>SO<sub>4</sub> solution.

	Strength before immersion	strength after immersion		
		15	45	75
CC	49.2	46.9	45.76	44.34
% strength loss		4.67	6.99	9.86
CCF	55.30	52.83	51.77	50.43
% strength loss		4.45	6.37	8.80
GPC	50.5	48.84	47.54	47.09
% strength loss		3.29	5.86	6.75
GPCF	56.80	55.59	53.73	53.31
% strength loss		2.12	5.40	6.13

	Weights before immersion	Weights after immersion		
		15	45	75
CC	2.49	2.50	2.50	2.51
% weight loss		-0.41	-0.41	-0.42
CCF	2.44	2.44	2.44	2.45
% weight loss		-0.4	-0.4	-0.41
GPC	2.29	2.30	2.31	2.32
% weight loss		-0.44	-0.89	-0.9
GPCF	2.34	2.34	2.35	2.36
% weight loss		-0.26	-0.82	-0.84

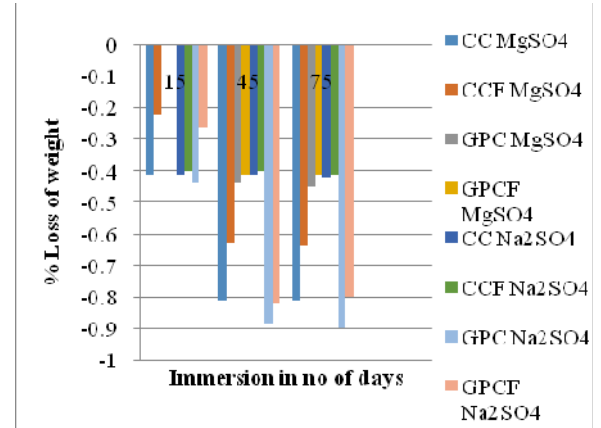


**Fig.1.** Percentage loss of compressive when immersed in MgSO<sub>4</sub> and Na<sub>2</sub>SO<sub>4</sub> solutions

**Table 5.** % loss of weight when immersed in MgSO<sub>4</sub> solution

	Weights before immersion	Weights after immersion		
		15	45	75
CC	2.46	2.47	2.48	2.48
% of weight loss		-0.41	-0.81	-0.81
CCF	2.32	2.33	2.34	2.34
% of weight loss		-0.22	-0.63	-0.64
GPC	2.27	2.27	2.28	2.28
% of weight loss		0	-0.44	-0.45
GPCF	2.38	2.38	2.39	2.39
% of weight loss		0	-0.41	-0.41

**Table 6.** % loss of weight when immersed in Na<sub>2</sub>SO<sub>4</sub> solution



**Fig.2.** Percentage loss of weight when immersed in MgSO<sub>4</sub> and Na<sub>2</sub>SO<sub>4</sub> solutions

**Table 7.** Acid durability factors when immersed in MgSO<sub>4</sub> solution

	Acid durability factors		
	MgSO <sub>4</sub>		
	15	45	75
CC	18.89	55.34	90.02
CCF	19.08	56.01	91.44
GPC	19.28	56.53	92.83
GPCF	19.44	57.04	93.80

**Table 8.** Acid attack factors when immersed in MgSO<sub>4</sub> solution

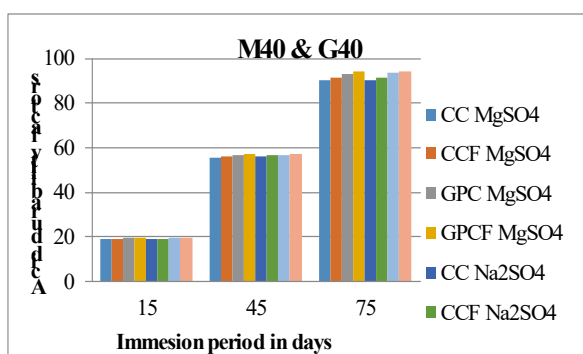
	Acid attack factors		
	MgSO <sub>4</sub>		
	15	45	75
CC	0.135	0.459	0.685
CCF	0.067	0.292	0.343
GPC	0.015	0.125	0.220
GPCF	0.011	0.015	0.018

**Table 9.** Acid durability factors when immersed in Na<sub>2</sub>SO<sub>4</sub> solution

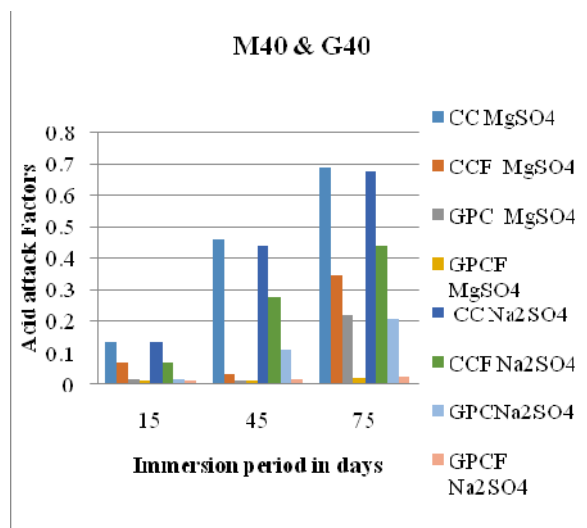
	Acid durability factor		
	Na <sub>2</sub> SO <sub>4</sub>		
	15	45	75
CC	19.06	55.80	90.12
CCF	19.11	56.16	91.19
GPC	19.34	56.48	93.24
GPCF	19.57	56.75	93.85

**Table 10.** Acid Attack factors when immersed in NaSO<sub>4</sub> solution

	Acid attack factor		
	Na <sub>2</sub> SO <sub>4</sub>		
	15	45	75
CC	0.135	0.439	0.675
CCF	0.068	0.274	0.440
GPC	0.015	0.110	0.205
GPCF	0.012	0.017	0.0201



**Fig.3.** Acid durability factors when immersed in MgSO<sub>4</sub> and Na<sub>2</sub>SO<sub>4</sub> solutions



**Fig.4.** Acid Attack factors when immersed in MgSO<sub>4</sub> and Na<sub>2</sub>SO<sub>4</sub> solutions

### 5 Conclusions

From the experimental investigations, following specific conclusions have been drawn:

1. The percentage of loss of compressive strength and weights are increased when specimens are exposed to magnesium and sodium sulphates. Loss of compressive strength and weights are increased as the immersion period increases for CC, CCF, GPC and GPCF.
2. The loss of compressive strength of CCF and GPCF decreased by 10.75% and 9.18% respectively when it is compared with CC and GPC under sodium sulphate attack for a period 75 days.
3. The loss of compressive strength of CCF and GPCF decreased by 12.22% and 10.48% respectively when it is compared with CC and GPC under magnesium sulphate attack for a period 75 days
4. Due to its alkalinity of concrete mass and high impermeability, sugarcane bagasse fibre geopolymer concrete is more durable in terms of 'Acid Durability Factors' and less attacked in terms of 'Acid Attack Factors' than CC, CCF, and GPC at all ages and can perform better in severe aggressive environments.
5. Since the weight and strength loss are more, it may be deduced that magnesium sulphate is more harsh than sodium sulphate environment. White deposits were seen on the specimens' surfaces, which gradually transform from soft and flaky shape to hard and round shape when exposed to magnesium sulphate compared to sodium sulphate solution.

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