# EXPERIMENTAL STUDY ON CONCRETE DURABILITY BY PARTIAL REPLACEMENT OF CEMENT WITH SUGARCANE BAGASSE ASH

**B. Ajay Deva Raj[1], Dr.V.Ravindra[2], J. Suma Sree[3]**

*[1]PG Student, Department of Civil Engineering, University college of Engineering JNTUK (A), Andhra Pradesh, Kakinada, India-533001*

*[2] Professor of Civil Engineering, Department of Civil Engineering, University college of Engineering JNTUK (A), Andhra Pradesh, Kakinada, India-533001*

*[3] PhD Student, Department of Civil Engineering, University college of Engineering JNTUK (A), Andhra Pradesh, Kakinada, India-533001*

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**Abstract -** W*e* are aware that the production of cement causes significant environmental harm involves carbon dioxide emissions along pollutants. There is an urgent need to restrict cement use since studies have revealed that each tonne of cement manufactured emits half a tonne of carbon dioxide. On the other hand, it might be difficult to dispose of material wastes like the bagasse ash from sugar cane, which is hazardous to the environment.

This study primarily focuses on substituting cement with analysis of the effects of hydrochloric acid and sodium sulphate on concrete with SCBA and bagasse ash in predetermined amounts. The cubes are cast and aged for 28, 56, and 90 days in standard water, 3% hydrochloric acid, and sodium sulphate solution. By varying the Bagasse ash amounts for 0%, 10%, the concrete mix is created. Additionally, findings from tests on fresh concrete, such as the slump cone test, and hardened concrete, such as the compressive strength, split tensile strength, and flexural test, were obtained at ages of 28, 56, and 90 days.

***Key Words***: Sugar Cane Bagasse Ash (SCBA), Fine Aggregate (FA), Coarse Aggregate (CA), Compressive Strength, Split Tensile Strength, Flexural Strength, Durability.

## 1. INTRODUCTION

A regulated mixture of calcium silicates, aluminates, and ferrate is used to make regular Portland cement. Gypsum and other minerals are used to grind the mixture into a fine powder. The common construction material that is truly accountable for between 5% and 8% of worldwide $CO_2$ emissions is ordinary Portland cement. Due to the exponential growth in demand for regular Portland cement, this environmental issue will undoubtedly get worse.

The most popular and essential material used in all kinds of construction projects is concrete. Cement, aggregates, water, and admixtures make up concrete. Over 10 billion tonnes of concrete are used worldwide each year. Concrete has strong mechanical strength and adequate durability performance. Out of concern for the environment and in support of sustainable development, cement companies are increasing their output by a number of means, such as by increasing the production of blended cements or using renewable fuels. According to the Danish Centre for Green Concrete, all of these precautions have helped to lower $CO_2$ emissions, which may be decreasing by up to 30%.

Around the world, scientists are exploring ways to utilise industrial or agricultural waste as a supply of raw materials for industry. Blast furnace slag, fly ash, and silica fumes are a few more types of industrial waste that can be used to substitute cement. Sugarcane is one of the most important crops farmed in over 110 countries, with an annual production of over 1500 million tonnes. With over 300 million tonnes of sugarcane produced in India alone each year, around 10 million tonnes of sugarcane bagasse ash is left behind as waste.

About 40–45 percent of the sugarcane's fibrous residue, which is utilised in the same sector as fuel for boilers to generate heat, remains after all economically viable sugar has been extracted, leaving 8–10 percent as waste material known as sugarcane bagasse ash (SCBA). Sugarcane bagasse ash contains high levels of unburned materials, silicon, aluminum, and calcium oxides. As a result, the ash becomes an industrial waste with disposal problems. Several studies have been undertaken in the past on the usage of bagasse ash obtained directly from industries to investigate the pozzolonic activity and usefulness as binders by partially substituting cement.

Because concrete is frequently exposed to ground or water with some acidity or alkalinity, the durability of the concrete is important information for extending the service life of concrete. This acidic or basic atmosphere will shorten the life of the concrete. The current study examines the strength and longevity of concrete that contains sugarcane bagasse ash (SCBA).

## 2. OBJECTIVE

1. The current study's goal is to mix-design M25 grade of concrete and identifies its necessary components.

2. To research the effects of using bagasse ash as a pozzolonic alternative for cement in concrete.
3. In order to compare the fresh properties of bagasse ash-based concrete with controlled concrete, it is necessary to determine the impact of bagasse ash as an alternative cementitious material with 10% of cement by weight.
4. To determine the impact of bagasse ash as an alternative cementitious material with 10% percentages of cement by weight of cement on hardened properties including compressive strength and split tensile strength, flexural strength of bagasse ash based on concrete to be compared with conventional concrete.
5. To determine the performance of bagasse ash blended concrete under various exposure situations, durability tests such as acid resistance tests and sulphate resistance tests are conducted.

## 3. MATERIAL PROPERTIES

### 3.1Cement

To ascertain its different qualities, the Ordinary Portland Cement is tested in accordance with IS standard (IS: 12269-1983). Cement is 53 grade in grade. Cement's physical characteristics are listed in table below.

**Table -1:** Physical properties of cement

| SNo | Tests | Values obtained | IS Code |
|---|---|---|---|
| 1 | Specific gravity | 3.13 | IS 4031:1988 |
| 2 | Normal Consistency | 30% | IS 4031(Part-4): 1988 |
| 3 | Initial Setting Time | 92mins | IS 4031(Part-5):1988 |
| 4 | Final Setting Time | 194mins | IS 4031(Part-5):1988 |
| 5 | Fineness | 7.5% | IS 4031 :1988 |

### 3.2 FINE AGGREGATE

Locally-purchased fine aggregate that complied with Indian Standard Specifications IS: 383-1970 to Zone II was employed in the experimental programme. Zone II is where the fine aggregate is located. Table 2 contains a summary of the fine aggregate's characteristics.

**Table -2:** Physical properties of Fine aggregate

| SNo | Tests | Values obtained | IS Code |
|---|---|---|---|
| 1 | Specific gravity | 2.62 | IS 2386 : 1963(Part 3) |
| 2 | Fineness | 2.83 | IS 2386 :1963(Part 1) |
| 3 | Bulk Density(Loose) | 1520kg/m$^3$ | IS 2386 :1963 (Part 3) |
| 4 | Bulk Density(Dense) | 1644 kg/m$^3$ | IS 2386 :1963 (Part 3) |
| 5 | Grading | Zone - II | IS 2386 :1963 (Part 3) |

### 3.3 COARSE AGGREGATE

The study followed IS 383:1970 testing procedures and employed locally available crushed granular aggregates with a maximum particle size of 20 mm. The physical properties of coarse aggregate are mentioned in Table 3 below.

**Table -3:** Physical properties of Coarse aggregate

| SNo | Tests | Values obtained | IS Code |
|---|---|---|---|
| 1 | Specific gravity | 2.76 | IS 2386 : 1963(Part 3) |
| 2 | Fineness | 7.12 | IS 2386 :1963(Part 1) |
| 3 | Bulk Density(Loose) | 1487 kg/m$^3$ | IS 2386 :1963 (Part 3) |
| 4 | Bulk Density(Dense) | 1603 kg/m$^3$ | IS 2386 :1963 (Part 3) |

### 3.4 SUGARCANE BAGASSE ASH

The ash from sugarcane bagasse is grey. The collected ash is run through a 90µm standard size IS sieve. SCBA has around 50% cellulose, 25% hemicellulose, and 25% lignin in it. For every tonne of sugarcane, approximately 26% of bagasse and 0.62% residual ash are generated. Table 4 lists the SCBA's physical characteristics.

**Table - 4:** Physical properties of Sugarcane bagasse ash

| SNo | Tests | Values obtained |
|---|---|---|
| 1 | Specific gravity | 2.2 |
| 2 | Fineness | 8% |
| 3 | Density(g/cm$^3$) | 2.53 |
| 4 | Color | Grey |
| 5 | Initial Setting Time | 32min |
| 6 | Fine Setting Time | 410min |

### 3.4 WATER

The concrete mix design has been made with potable water that is readily available on the college site. The following list table 5 includes water physical characteristics.

**Table - 5:** Physical properties of Water

| SNo | Tests | Values obtained |
|---|---|---|
| 1 | PH | 7.1 |
| 2 | Taste | Agreeable |
| 3 | Appearance | Clear |
| 4 | Turbidity | 1.75 |

### 3.5 HYDROCHLORIC ACID

**Table 6:** Physical properties of Hydrochloric acid

| | |
|---|---|
| Molecular formula | HCl in water($H_2O$) |
| Molar mass | 35.47 g/mol |
| Appearance | Clear colourless to light yellow liquid |
| Density | 1.8g/cm$^3$ |
| Melting point | 27.32$^0$c |
| Boiling point | 110$^0$c |
| Solubility in water | Miscible |
| Acidity | (pka)-8.1 |
| Viscosity | 1.9mpa at 25$^0$c |

### 3.6 SODIUM SULPHATE

**Table 7:** Physical properties of Sodium Sulphaate

| | |
|---|---|
| Molecular formula | $Na_2SO_4$ in water($H_2O$) |
| Molar mass | 142.04g/mol (anhydrous) |
| Appearance | White Crystalline Solid |
| Density | 2.66g/cm$^3$ |
| Melting point | 884$^0$c(anhydrous) |
| Boiling point | 1429$^0$c(anhydrous) |
| Solubility in water | Soluble in water , glycerol |
| Refractive index | 1.468(anhydrous) |

## 4. Preparation of Mix

For this investigation, cement , sugarcane bagasse ash fine aggregate and coarse aggregate, were all used. The mix ratio for the concrete mix was determined according to IS 10262:2019, and it is listed in table 9.

SCBA was used to replace cement in all combinations at replacement levels of 0% (control mix) and 10% for specimens, with a constant w/c ratio of 0.50 for M25 grade.

Table 8 shows the mix details for SCBA, cement, fine aggregate, and coarse aggregate, and cubes, cylinders, and prisms were cast, with compressive strength, split tensile strength, and flexural strength calculated at 28,56,90 days.

**Table-8** Proportions of all mixes

| S NO | Mix | Cement Kg/m$^3$ | SCBA kg/m$^3$ | F.A kg/m$^3$ | C.A Kg/m$^3$ | W/C |
|---|---|---|---|---|---|---|
| 1 | SCBA 0% | 330 | 0 | 716.83 | 1232.06 | 0.50 |
| 2 | SCBA10% | 297 | 33 | 716.83 | 1232.06 | 0.50 |

**Table-9** Mix proportions of M25

| Cement (kg/m$^3$) | Fine aggregate (kg/m$^3$) | Coarse aggregate (kg/m$^3$) | Water (kg/m$^3$) |
|---|---|---|---|
| 330 | 716.83 | 1232.06 | 165 litres |
| 1 | 2.17 | 3.73 | 0.50 |

## 4. RESULTS AND DISCUSSIONS

### 4.1 Tests on Fresh Concrete

### 4.1.1 Slump Cone Test

The slump cone test identifies workability of concrete. Table 10 displays the slump Cone test results for each mix.

**Table 10:** Slump for different mix

| SNO | Mix proportions | Slump value(mm) |
|---|---|---|
| 1 | SCBA 0% | 81 |
| 2 | SCBA 10% | 85 |

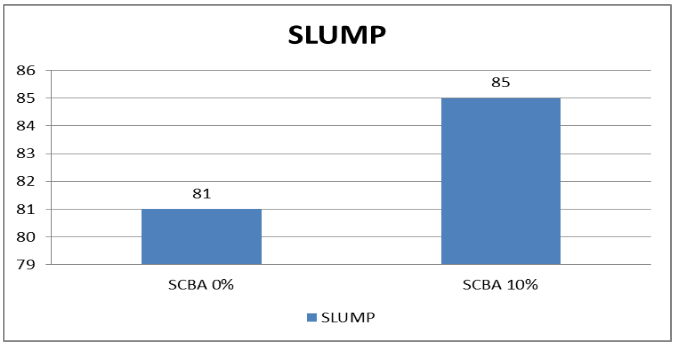


**Fig 1: Slump**

The slump values for SCBA 0% and SCBA 10% successively fluctuate regularly by 81mm and 85mm, according to the graph. The inclusion of sugar cane bagasse ash was assumed to have improved the mix's workability. When sugarcane bagasse ash is used in place of control mix, cementation mixtures require much more water. The decline was seen to be a true slump in the nature. For workability, no plasticizer was used.

## 4.2 Tests on Hardened Concrete

### 4.2.1 Compressive Strength

Table 11 shows the results of an experimental test on the compressive strength of M25 grade concrete at 28, 56, and 90 days.

**Table 11:** Compressive strength of M25

| | | Compressive strength(N/mm²) | | |
|---|---|---|---|---|
| **SNO** | **Mix proportions** | **28 days** | **56 days** | **90 days** |
| 1 | SCBA 0% | 31.9 | 36.11 | 43.26 |
| 2 | SCBA 10% | 34.39 | 37.58 | 44.24 |

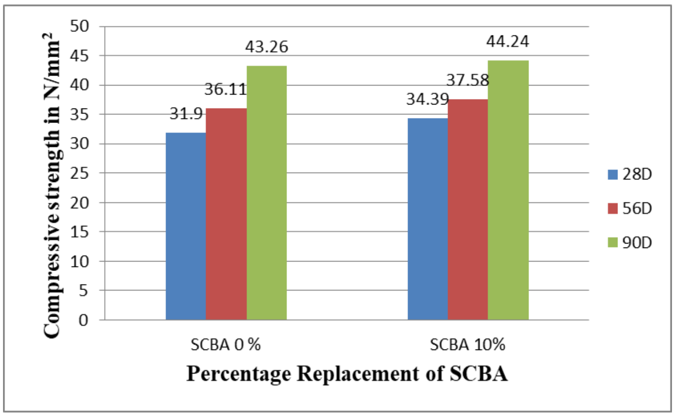


**Fig 2:** Compressive Strength vs Percentage Replacement of SCBA

According to the graph above, the compressive strength of SCBA 10% resulted in good compressive strength when compared to the conventional mix.. At 28, 56, and 90 days, partial replacement of SCBA 10% exhibits improved compressive strength trends. All of the mixtures are stronger than the target strength. When compared to standard mixes, the compressive strength of M25 SCBA 10% at 90 days is greater due to the inclusion of sugarcane bagasse ash as filler in the gaps or empty spaces.

### 4.2.2 Split tensile strength

Table 12 shows the results of an experimental test on the Split tensile strength of M25 grade concrete at 28, 56, and 90 days.

**Table 12:** Split tensile strength of M25

| | | Split Tensile Strength(Mpa) | | |
|---|---|---|---|---|
| **SNO** | **Mix proportions** | **28days** | **56days** | **90days** |
| 1 | SCBA 0% | 2.12 | 2.40 | 2.72 |
| 2 | SCBA 10% | 2.56 | 2.94 | 3.12 |

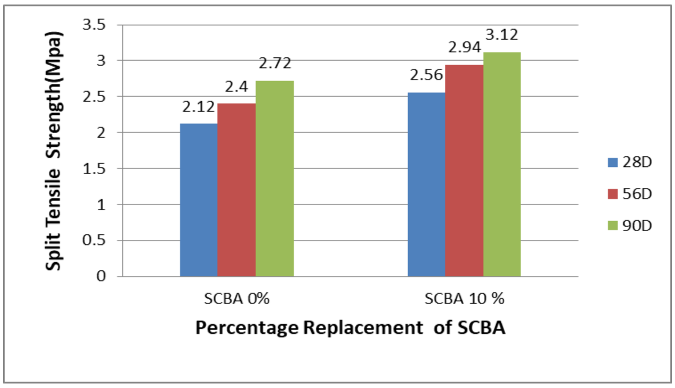


**Fig 3:** Split tensile Strength vs Percentage Replacement of SCBA

When compared to the conventional mix, the split tensile strength of SCBA 10% provided good split strength, according to the graph. At 28, 56 and 90 days, partial substitution of SCBA 10% shows improved split tensile strength trends. The combinations are all stronger than the desired strength. M25 SCBA 10% has a higher split tensile strength at 90 days than conventional mixes due to the inclusion of sugarcane bagasse ash as a filler in voids or empty areas.

### 4.2.3 Flexural Strength

Table 13 below shows the results of an experimental test on the Flexural Strength of M25 grade concrete at 28, 56, and 90 days.

**Table 13:** Flexural strength of M25

| | | Flexural Strength(Mpa) | | |
|---|---|---|---|---|
| **SNO** | **Mix proportions** | **28days** | **56days** | **90days** |
| 1 | SCBA 0% | 3.93 | 4.34 | 4.77 |
| 2 | SCBA 10% | 4.76 | 5.18 | 5.52 |

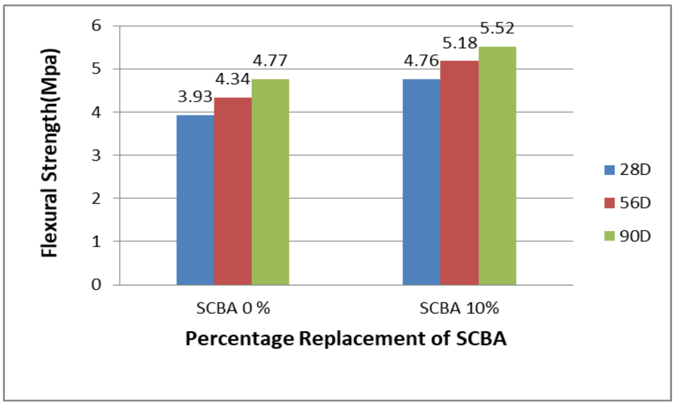


**Fig 4**: Flexural Strength vs Percentage Replacement of SCBA

From the graph, It was noted that the SCBA 10% test for flexural strength produced good flexural strength when compared to the normal mix. At 28, 56, 90 days partial substitution of SCBA 10% shows improved Flexural strength test trends. The combinations are all stronger than the desired strength. Due to the use of sugarcane bagasse ash as filler in the gaps or empty spaces, the flexural strength test of M25 SCBA 10% at the age of 90 days is greater than that of normal mixes.

### 4.3 Tests on Durability of Concrete

### 4.3.1 Acid Attack on the Concrete

Each specimen is cast and cured in a mould for 24 hours before being taken from the mould and maintained in a curing tank for 28 days. All specimens are weighed and immersed in a 3% hydrochloric acid solution for 28, 56, and 90 days. The specimens are removed from the hydrochloric acid solution after 28,56,90 days and washed in running water before being left in the atmosphere for two days to maintain weight .The specimens were then weighed, and the weight loss and compressive strength loss were determined as percentages.

### 4.3.1(a) Weight loss

Acid attack test was conducted on partial replacement of SCBA with cement (0, 10%) parameters such as loss in weight was evaluated after immersing the specimens in the 3 % acid at 28 ,56 ,90 days.

**Table 14** Loss of weight of cubes at different curing period

| | | Weight loss | | |
|---|---|---|---|---|
| **SNO** | **Mix proportions** | **28days** | **56days** | **90days** |
| 1 | SCBA 0% | 1.19% | 2.24% | 3.31% |
| 2 | SCBA 10% | 2.28% | 3.18% | 4.49% |

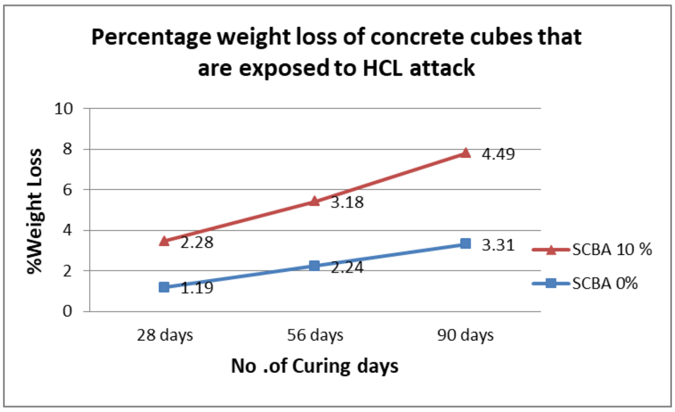


**Fig 5:** Loss of weight of cubes at different curing period

In this study, the values for weight loss of the cubes at the conclusion of the curing periods (28, 56 and 90 days) are reported for different replacement amounts of SCBA (0%, 10%). On a graph, these values are plotted. This illustrates the variance in weight loss of cubes containing SCBA at various curing ages. From our research, the loss of weight of cubes is increase in replacement of sugar cane bagasse ash compare to conventional concrete.

### 4.3.1(b) Compressive strength

Compressive strength of the specimen were evaluated after immersing them in acid for 28, 56 and 90 days and results are presented in following table 15,16,17.

**Table 15:** Comparison of Compressive strength of Normal and Acid attack Concrete at 28 days

| **Partial replacement in cement** | **Compressive Strength at 28 days in N/mm²** | | |
|---|---|---|---|
| | **Normal Concrete** | **Acid attack Concrete** | **%Decrease in Strength** |
| SCBA 0% | 31.96 | 29.53 | 7.60% |
| SCBA 10% | 34.39 | 32.68 | 4.97% |

**Table 16:** Comparison of Compressive strength of Normal and Acid attack Concrete at 56 days

| **Partial replacement in cement** | **Compressive Strength at 56 days in N/mm²** | | |
|---|---|---|---|
| | **Normal Concrete** | **Acid attack Concrete** | **%Decrease in Strength** |
| SCBA 0% | 36.11 | 34.45 | 4.59% |
| SCBA 10% | 37.58 | 34.81 | 7.37% |

**Table 17:** Comparison of Compressive strength of Normal and Acid attack Concrete at 90 days

| Partial replacement in cement | Compressive Strength at 90 days in N/mm² | | |
|---|---|---|---|
| | Normal Concrete | Acid attack Concrete | %Decrease in Strength |
| SCBA 0% | 43.26 | 39.88 | 7.81 % |
| SCBA 10% | 44.24 | 41.59 | 5.99% |

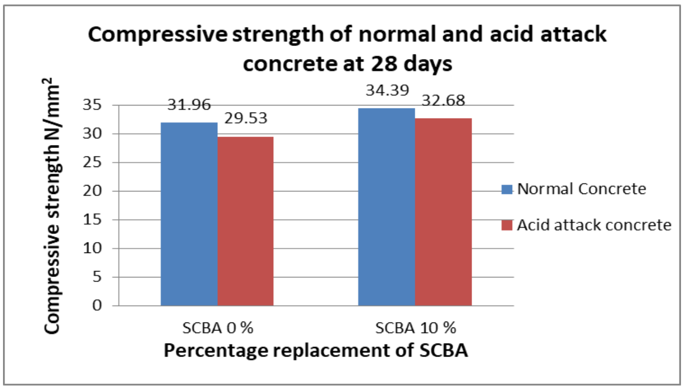


**Fig6:** Comparison of Compressive strength of Normal and Acid attack Concrete at 28 days

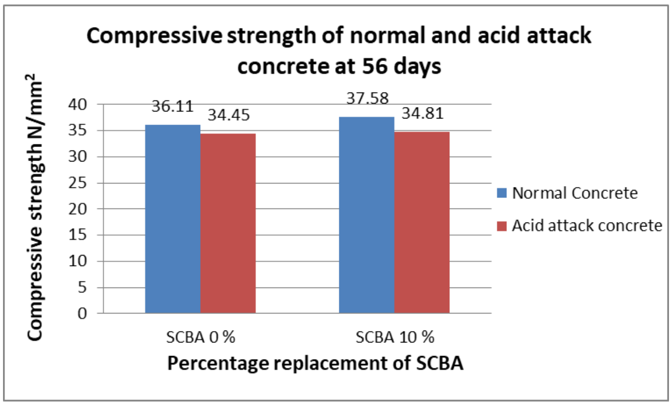


**Fig7:** Comparison of Compressive strength of Normal and Acid attack Concrete at 56 days

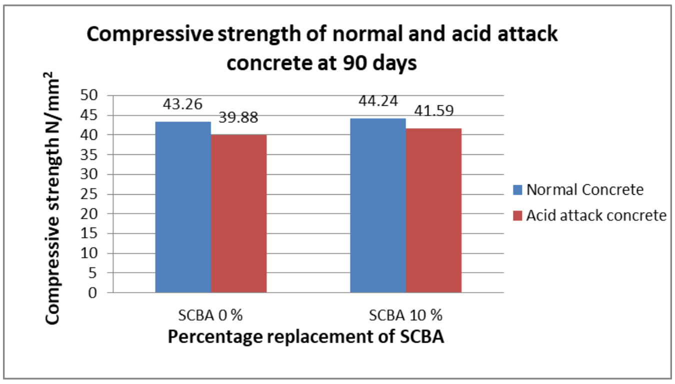


**Fig8:** Comparison of Compressive strength of Normal and Acid attack Concrete at 90 days

In this study, the value of Compressive strength of concrete for various level of SCBA replacement (0%, 10%) into water and hydrochloric acid during the Period of 28, 56, 90 days and given in the above table 15, 16, 17. The values are plotted in graph.

From our research, compressive strength of SCBA 0% is reduced due to hydrochloric acid attack at 28,56,90 days is 7.60%,4.59%,7.81% respectively compared to normal concrete and Compressive strength of SCBA 10% is reduced due to hydrochloric acid attack at 28,56,90 days is 4.97%,7.37%,5.99% respectively compared to normal concrete.

### 4.3.2 Sulphate attack on the concrete

Each specimen is cast and cured in a mould for 24 hours before being taken from the mould and maintained in a curing tank for 28 days. All specimens are weighed and submerged in a 3% Sodium sulphate solution for 28, 56, and 90 days The specimens are removed from the 3% Sodium sulphate solution after 28,56,90 days and washed in running water before being left in the atmosphere for two days to maintain weight. The specimens were then weighed, and the weight loss and compressive strength loss were determined as percentages.

### 4.3.2(a) Weight Loss

Sulphate attack was conducted on partial replacement of SCBA with cement (0, 10%) parameters such as loss in weight was evaluated after immersing the specimens in the 3 % sodium sulphate at 28 ,56 and 90 days.

**Table 18** Loss of weight of cubes at different curing period

| | | Weight loss | | |
|---|---|---|---|---|
| SNO | Mix proportions | 28days | 56days | 90days |
| 1 | SCBA 0% | 0.66% | 1.78% | 2.89% |
| 2 | SCBA 10% | 1.97% | 2.92% | 3.96% |

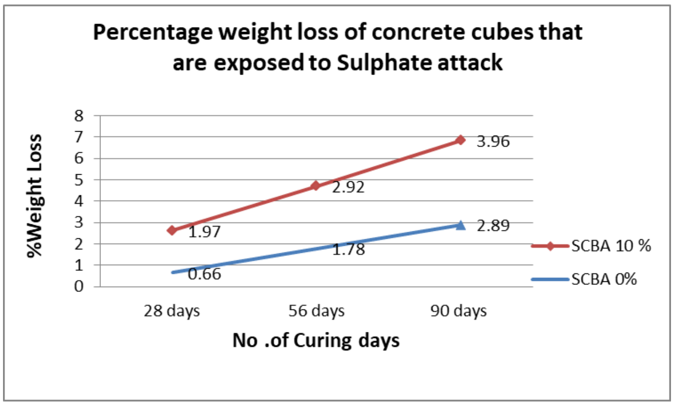


**Fig 9:** Loss of weight of cubes at different curing period

In this study, the values for weight loss of the cubes at the conclusion of the curing periods (28, 56 and 90 days) are reported for different replacement amounts of SCBA (0%, 10%). On a graph, these values are plotted. This illustrates the variance in weight loss of cubes containing SCBA at various curing ages. From our research, the loss of weight of cubes is increase in replacement of sugar cane bagasse ash compare to conventional concrete.

### 4.3.2(b) Compressive strength

Compressive strength of the specimen were evaluated after immersing them in 3 % sodium sulphate solution for 28, 56 and 90 days and results are presented in following table 19 ,20 ,21

**Table 19:** Comparison of Compressive strength of Normal and Sulphate attack Concrete at 28 days

| Partial replacement in cement | Compressive Strength at 28 days in $N/mm^2$ | | |
|---|---|---|---|
| | Normal Concrete | Sulphate attack Concrete | %Decrease in Strength |
| SCBA 0% | 31.96 | 30.12 | 5.75% |
| SCBA 10% | 34.39 | 33.24 | 3.37% |

**Table 20:** Comparison of Compressive strength of Normal and Sulphate attack Concrete at 56 days

| Partial replacement in cement | Compressive Strength at 56 days in $N/mm^2$ | | |
|---|---|---|---|
| | Normal Concrete | Sulphate attack Concrete | %Decrease in Strength |
| SCBA 0% | 36.11 | 35.03 | 2.99% |
| SCBA 10% | 37.58 | 34.61 | 7.90% |

**Table 21:** Comparison of Compressive strength of Normal and Sulphate attack Concrete at 90 days

| Partial replacemen t in cement | Compressive Strength at 90 days in $N/mm^2$ | | |
|---|---|---|---|
| | Normal Concrete | Sulphate attack Concrete | %Decrease in Strength |
| SCBA 0% | 43.26 | 41.19 | 4.78% |
| SCBA 10% | 44.24 | 40.38 | 8.72% |

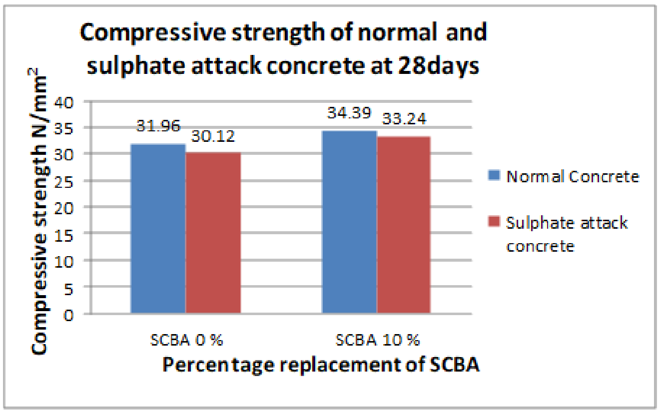


**Fig10:** Comparison of Compressive strength of Normal and Sulphate attack Concrete at 28 days

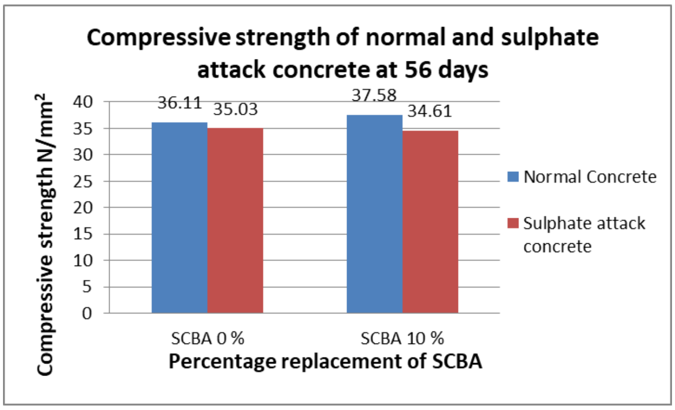


**Fig11:** Comparison of Compressive strength of Normal and Sulphate attack Concrete at 56 days

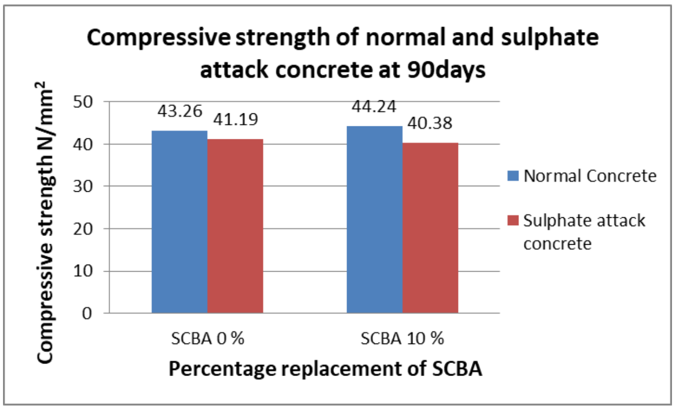


**Fig12:** Comparison of Compressive strength of Normal and Sulphate attack Concrete at 90 days

In this study, the value of Compressive strength of concrete for various level of SCBA replacement (0%, 10%) into water and sodium sulphate solution during the Period of 28, 56, 90 days and given in the above table19,20,21. The values are plotted in graph.

From our research, compressive strength of SCBA 0% is reduced due to sodium sulphate attack at 28,56,90 days is 5.75%,2.99%,4.78% respectively compared to normal concrete and compressive strength of SCBA 10% is reduced due to sodium sulphate attack at 28,56,90 days is 3.37%,7.90%,8.72% respectively compared to normal concrete.

## 5. CONCLUSIONS

The following conclusions shown below.

1. The use of bagasse ash in concrete and mortar eliminates the issue of its disposal, preventing contamination of the environment.
2. From the compressive strength results of cubes, it is found that 10% of bagasse ash replacement with cement yield increases in compressive strength 2.26% as compared to controlled concrete at 90 days of curing.
3. From the split tensile strength results, it is found that 10% of bagasse ash replacement with cement yield increases in tensile strength 14.7% as compared to controlled concrete at 90 days of curing.
4. From the Flexural strength test results, it is found that 10% of bagasse ash replacement with cement yield increase in flexural strength 15.72% as compared to controlled concrete at 90 days of curing.
5. From the total rate of percentage weight loss of the specimen subjected to acid exposure 10% SCBA blended concrete shows more reduction in weight lost 35.6% when compared to controlled concrete.
6. From the total rate of percentage weight loss of the specimen subjected to sulphate exposure 10% SCBA blended concrete shows more reduction in weight lost 37.02% when compared to controlled concrete.
7. Compressive strength of SCBA 0% is reduced due to hydrochloric acid attack at 28,56,90 days is 7.60%,4.59%,7.81% respectively compared to normal concrete and SCBA 10% is reduced due to hydrochloric acid attack at 28, 56 ,90 days is 4.83%,7.37%,5.99% respectively compared to normal concrete.
8. Compressive strength of SCBA 0% is reduced due to sodium sulphate attack at 28,56,90 days is 5.75%,2.99%,4.78% respectively compared to normal concrete and Compressive strength of SCBA 10% is reduced due to sodium sulphate attack at 28,56,90 days is 3.37%,7.90%,8.72% respectively compared to normal concrete.
9. Use of the waste materials It is advantageous to substitute sugar cane bagasse ash for cement when making concrete.

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