Effect of alkali curing environment on M30 grade Sugarcane Bagasse Ash (SCBA) Concrete

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Abstract. The present paper deals with the replacement of Ordinary Portland Cement with SCBA at different percentages of 0%, 5%, 10%, 15% and 20% by weight of cement in M30 grade concrete, the mechanical properties of SCBA blended concrete were studied when subjected to alkali environment. The concrete specimens were cured in normal water, sodium sulphate solution (1%, 3% and 5%) and Magnesium Sulphate solution (1%, 3% and 5%) at ages of 28, 60 and 90 days and tested. From the experimental observation, the SCBA blended concrete provides resistance against sulphate attack.

1. Introduction
Ordinary Portland cement is the main constituent in the production of concrete. Replacement of cement with agricultural and industrial wastes such as sugar cane Bagasse ash, Rice husk ash, fly ash, blast furnace slag etc was the present trend in concrete technology [1-4]. A few studies were conducted on the ashes obtained directly from the Argo and other industries to study the pozzolanic activity and their suitability as binders, partially replacing cement [5-9]. Sulphate attack on marine Structures was major Concern in the durability aspect of structures [10-15]. Leaching of the calcium compounds was a major problem due to sulphate attack. Sulphate attack leads to loss of calcium silicate hydrate gel and results in deterioration of the cement constituents [16]. The sulphate attack depends on several factors [17]. Use of pozzolanic materials as a partial replacement of ordinary cement has been found to resist sulphate attack [18-20]. The sugar cane Bagasse ash as a partial replacement of cement was taken to study the performance of concrete. The main objective of this research was to study the durability Characteristics of Sugar cane Bagasse ash blended concrete Exposed to Alkali Environment (Sodium And magnesium Sulphates)

2. Materials
The materials utilised in this work were Ordinary Portland Cement of grade 53 (with setting time of 121minutes (initial) and setting of 242 minutes (final) and consistency of 31%), Fine aggregate (of Zone II, with water absorption 1% Specific gravity 2.6 and fineness modulus 2.99), Coarse aggregate (with water absorption0.5%, fineness modulus7.26and Specific gravity 2.8) and Water (suitable according to Indian standards for use in concrete: potable water). Sugar Cane Bagasse Ash (SCBA) was obtained from Sugar factory at Vuyurru (KCP Factory), Andhra Pradesh. Each 1000 kg of sugarcane generates approximately 0.60 % of residual Bagasse Ash. The major component of the residue was silicon dioxide. The specific gravity of SCBA was found to be 2.49. The physical properties of SCBA are presented in Table 1.
Table 1: Physical properties of Sugar Cane Bagasse Ash

| No | Property         | Test Results |
|----|------------------|--------------|
| 1  | Specific gravity | 2.49         |
| 2  | Particle shape   | Spherical    |
| 3  | Density          | 375 kg/m³    |
| 4  | Specific surface area | 420 m²/kg |

3. Experimental Investigation
Mixing: the cementations materials we remixed properly and aggregates (fine and coarse) were added and then mixed with water till consistency was achieved. The casting of specimen: Before placing concrete into moulds, the moulds were cleansed. The moulds were placed on the level ground and Compacted by vibrator. A total number of 126 cubes, 126 cylinders and 126 beams were caste Curing: After Casting the moulds were left for 24 hours and de moulded, de moulded specimens cured in water and sulphate solutions forth desired period. Durability: Here, the durability tests were conducted on SCBA concrete against salts such as Sodium and Magnesium Sulphate. The response of Na₂SO₄ and MgSO₄ attack on sugar cane Bagasse ash concrete for various percentages was studied by observations like the loss in mechanical properties.

4. Experimental Results
The graphs below show the various strength results of concrete specimens with 0%, 5%, 10%, 15% and 20% weight replacement of cement with SCBA cured in water and various percentages of Na₂SO₄ and MgSO₄ solutions for 28, 60 and 90 days.

4.1 Compressive strength of concrete cured in water:

![Figure 1](image-url)  
Figure 1. Compressive strength of concrete cured in water

From figure 1, it was noticed that, strength increase up to 2.99%, 1.4%, 2.3% at 28, 60, 90 days for 0% to 5%, the strength increase up to 2.3%, 2.8%, 2.7% at 28, 60, 90 days for 5% to 10%, strength decreases to 10.2%, 5.8%, 8.1% at 28, 60, 90 days for 10% to 15% and strength decreases to 3.04%, 2.4%, 2.9% at 28, 60, 90 days for 15% to 20%. The strength results of SCBA replaced concrete cubes cured in water was shown below graphically. The decline in compressive strength was noticed at fifteen and twenty percentage replacements and a surge in compressive strength was noticed at ten percentage replacements.
4.2 Compressive strength of concrete cured in 1% \( \text{Na}_2\text{SO}_4 \) solution:

From figure 2, it was noticed that, for 0% to 5% strength increase up to 3.21%, 2.95%, 3.49% at 28, 60, 90 days, for 5% to 10% the strength increase up to 3.03%, 4.76%, 5.28% at 28, 60, 90 days, for 10% to 15% strength decreases to 9.84%, 6.75%, 6.34% at 28, 60, 90 days and for 15% to 20% strength decreases to 3.23%, 3.63%, 2.4% at 28, 60, 90 days. The graph shows the results for SCBA cubes cured 1% \( \text{Na}_2\text{SO}_4 \) solution, for all curing periods. Decline in compressive strength was noticed at fifteen and twenty percentage replacements and surge in compressive strength was noticed at ten percentage replacements.

4.3 Compressive strength cured in 3% \( \text{Na}_2\text{SO}_4 \) solution:

From figure 3, it was noticed that, for 0% to 5% strength increase up to 5.91%, 1.04%, 1.33% at 28, 60, 90 days, for 5% to 10% the strength increase up to 3.91%, 2.71%, 3.11% at 28, 60, 90 days, for 10% to 15% strength decreases to 11.29%, 6.38%, 6.02% at 28, 60, 90 days and for 15% to 20% strength decreases to 3.04%, 3.41%, 2.37% at 28, 60, 90 days. The graph shows the results for SCBA cubes cured 3% \( \text{Na}_2\text{SO}_4 \) solution, for all curing periods. Decline in compressive strength was noticed at fifteen and twenty percentage replacements and surge in compressive strength was noticed at ten percentage replacements.
4.4 Compressive strength of concrete cured in 5% \( \text{Na}_2\text{SO}_4 \) solution:

![Graph 1](image1.png)

**Figure 4.** Compressive strength of concrete cured in 5% \( \text{Na}_2\text{SO}_4 \) solution

From figure 4, it was noticed that, for 0% to 5% strength increase up to 1.9%, 1.58%, 0.98% at 28, 60, 90 days, for 5% to 10% the strength increase up to 6%, 4.67%, 4.43% at 28, 60, 90 days, for 10% to 15% strength decreases to 9.51%, 6.4%, 6.54% at 28, 60, 90 days and for 15% to 20% strength decreases to 3%, 3.17%, 2.5% at 28, 60, 90 days. The graph shows the results for SCBA cubes cured 5% \( \text{Na}_2\text{SO}_4 \) solution, for all curing periods. Decline in compressive strength was noticed at fifteen and twenty percentage replacements and surge in compressive strength was noticed at ten percentage replacements.

4.5 Compressive strength of concrete cured in 1% \( \text{MgSO}_4 \) solution:

![Graph 2](image2.png)

**Figure 5.** Compressive strength of concrete cured in 1% \( \text{MgSO}_4 \) solution

From figure 5, it was noticed that, for 0% to 5% strength increase up to 1.22%, 2.9%, 1.44% at 28, 60, 90 days, for 5% to 10% the strength increase up to 3.04%, 1%, 2.8% at 28, 60, 90 days, for 10% to 15% strength decreases to 7.61%, 6.5%, 7.3% at 28, 60, 90 days and for 15% to 20% strength decreases to 2.5%, 2.6%, 1.36% at 28, 60, 90 days. The graph shows the results for SCBA cubes cured 1% \( \text{MgSO}_4 \) Solution, for all curing periods. Decline in compressive strength was noticed at fifteen and twenty percentage replacements and surge in compressive strength was noticed at ten percentage replacements.
4.6 Compressive strength of concrete cured in 3% MgSO₄ solution:

From figure 6, it was noticed that, for 0% to 5% strength increase up to 3.5%, 2.8%, 2.26% at 28, 60, 90 days, for 5% to 10% the strength increase up to 1.62%, 1.12%, 2.56% at 28, 60, 90 days, for 10% to 15% strength decreases to 6.4%, 5.4%, 5.8% at 28, 60, 90 days and for 15% to 20% strength decreases to 4.3%, 2.9%, 2.7% at 28, 60, 90 days. The graph shows the results for SCBA cubes cured 3% MgSO₄ solution, for all curing periods. Decline in compressive strength was noticed at fifteen and twenty percentage replacements and surge in compressive strength was noticed at ten percentage replacements.

4.7 Compressive strength of concrete cured in 5% MgSO₄ solution:

From figure 7, it was noticed that, for 0% to 5% strength increase up to 0.98%, 2.5%, 2.95% at 28, 60, 90 days, for 5% to 10% the strength increase up to 4.7%, 1.08%, 5.23% at 28, 60, 90 days, for 10% to 15% strength decreases to 9.8%, 9.4%, 10.4% at 28, 60, 90 days and for 15% to 20% strength decreases to 6.4%, 3.7%, 2.5% at 28, 60, 90 days. The graph shows the results for SCBA cubes cured 5% MgSO₄ solution, for all curing periods. Decline in compressive strength was noticed at fifteen and twenty percentage replacements and surge in compressive strength was noticed at ten percentage replacements.
4.8 Split tensile strength of concrete cured in water:

![Tensile Strength Graph](image)

**Figure 8.** Split tensile strength of concrete cured in water

From figure 8, it was noticed that, for 0% to 5% strength increase up to 2.8%, 1.4%, 2.3% at 28, 60, 90 days, for 5% to 10% the strength increase up to 2.43%, 2.9%, 2.7% at 28,60, 90 days, for 10% to 15% strength decreases to 10.1%, 5.9%, 8.13% at 28,60, 90 days and for 15% to 20% strength decreases to 3.03%, 2.5%, 2.9% at 28,60, 90 days. The graph shows the results for SCBA cylinders cured in water, for all curing periods. The decline in compressive strength was noticed at fifteen and twenty percentage replacements and a surge in compressive strength was noticed at ten percentage replacements.

4.9 Split tensile strength of concrete cured in 1% Na$_2$SO$_4$ solution

![Tensile Strength Graph](image)

**Figure 9.** Split tensile strength of concrete cured in 1% Na$_2$SO$_4$ solution

From figure 9, it was noticed that, for 0% to 5% strength increase up to 2.32%, 2.89%, 3.31% at 28,60, 90 days, for 5% to 10% the strength increase up to 2.92%, 4.92%, 5.34% at 28,60, 90 days, for 10% to 15% strength decreases to 8.8%, 6.7%, 6.28% at 28,60, 90 days and for 15% to 20% strength decreases to 3.11%, 3.83%, 2.38% at 28,60, 90 days. The graph shows the results for SCBA cylinders cured in 1% Na$_2$SO$_4$ solution, for all curing periods. Decline in compressive strength was noticed at fifteen and twenty percentage replacements and surge in compressive strength was noticed at ten percentage replacements.
4.10 Split tensile strength of concrete cured in 3% Na$_2$SO$_4$ solution:

![Figure 10](image1.png)

**Figure 10.** Split tensile strength of concrete cured in 3% Na$_2$SO$_4$ solution

From figure 10, it was noticed that, for 0% to 5% strength surges up to 5.91%, 0.87%, 1.2% at 28, 60, 90 days, for 5% to 10% the strength increase up to 3.72%, 2.82%, 3.18% at 28, 60, 90 days, for 10% to 15% strength decreases to 11.28%, 6.4%, 5.98% at 28, 60, 90 days and for 15% to 20% strength decreases to 2.89%, 3.8%, 2.46% at 28, 60, 90 days. The graph shows the results for SCBA cylinders cured in 3% Na$_2$SO$_4$ solution, for all curing periods Decline in compressive strength was noticed at fifteen and twenty percentage replacements and surge in compressive strength was noticed at ten percentage replacements.

4.11 Split tensile strength of concrete cured in 5% Na$_2$SO$_4$ solution:

![Figure 11](image2.png)

**Figure 11:** Split tensile strength of concrete cured in 5% Na$_2$SO$_4$ solution

From figure 11, it was noticed that, for 0% to 5% strength increase up to 1.86%, 1.46%, 0.88% at 28, 60, 90 days, for 5% to 10% the strength increase up to 6.11%, 4.8%, 4.44% at 28, 60, 90 days, for 10% to 15% strength decreases to 9.51%, 6.42%, 6.52% at 28, 60, 90 days and for 15% to 20% strength decreases to 3.18%, 3.2%, 2.47% at 28, 60, 90 days. The graph shows the results for SCBA cylinders cured in 5% Na$_2$SO$_4$ solution, for all curing periods. Decline in compressive strength was noticed at fifteen and twenty percentage replacements and surge in compressive strength was noticed at ten percentage replacement.
4.12 Split tensile strength of concrete cured in 1% MgSO₄ solution:

![Split tensile strength of concrete cured in 1% MgSO₄ solution](image)

**Figure 12.** Split tensile strength of concrete cured in 1% MgSO₄ solution

From figure 12, it was noticed that, for 0% to 5% the strength increase up to 1.16%, 2.9%, 1.5% at 28, 60, 90 days, for 5% to 10% the strength increase up to 3.16%, 0.89%, 2.76% at 28, 60, 90 days, for 10% to 15% strength decreases to 7.8%, 6.6%, 7.3% at 28, 60, 90 days and for 15% to 20% strength decreases to 2.46%, 2.6%, 1.35% at 28, 60, 90 days. The graph shows the results for SCBA cylinders cured in 1% MgSO₄ solution, for all curing periods. Decline in compressive strength was noticed at fifteen and twenty percentage replacements and surge in compressive strength was noticed at ten percentage replacements.

4.13 Split tensile strength of concrete cured in 3% MgSO₄ solution:

![Split tensile strength of concrete cured in 3% MgSO₄ solution](image)

**Figure 13.** Split tensile strength of concrete cured in 3% MgSO₄ solution

From figure 13, it was noticed that, for 0% to 5% strength increase up to 3.58%, 2.8%, 2.2% at 28, 60, 90 days, for 5% to 10% the strength increase up to 1.59%, 1.06%, 2.5% at 28, 60, 90 days, for 10% to 15% strength decreases to 6.4%, 5.5%, 5.8% at 28, 60, 90 days and for 15% to 20% strength decreases to 4.34%, 2.9%, 2.7% at 28, 60, 90 days. The graph shows the results for SCBA cylinders cured in 3% MgSO₄ solution, for all curing periods. Decline in compressive strength was noticed at fifteen and twenty percentage replacements and surge in compressive strength was noticed at ten percentage replacements.
4.14 Split tensile strength of concrete cured in 5% MgSO₄ solution:

![Split Tensile Strength Graph](image)

**Figure 14.** Split tensile strength of concrete cured in 5% MgSO₄ solution

From figure 14, it was noticed that, for 0% to 5% strength increase up to 1.79%, 1.61%, 0.99% at 28, 60, 90 days, for 5% to 10% the strength increase up to 5.94%, 4.57%, 4.42% at 28, 60, 90 days, for 10% to 15% strength decreases to 9.35%, 6.39%, 6.43% at 28, 60, 90 days, 10.3% and for 15% to 20% strength decreases to 3.21%, 3.05%, 2.52% at 28, 60, 90 days. The graph shows the results for SCBA cylinders cured in 5% MgSO₄ solution, for all curing periods. Decline in compressive strength was noticed at fifteen and twenty percentage replacements and surge in compressive strength was noticed at ten percentage replacements.

4.15 Flexural strength of concrete cured in water:

![Flexural Strength Graph](image)

**Figure 15.** Flexural strength of concrete cured in water

From figure 15, it was noticed that, for 0% to 5% strength increase up to 2.9%, 1.3%, 2.18% at 28, 60, 90 days, for 5% to 10% the strength increase up to 2.5%, 2.9%, 3.1% at 28, 60, 90 days, for 10% to 15% strength decreases to 9.65%, 9.4%, 10.3% at 28, 60, 90 days and for 15% to 20% strength decreases to 6.6%, 3.8%, 2.5% at 28, 60, 90 days. The graph shows the results for SCBA beams cured in water, for all curing periods. Decline in compressive strength was noticed at fifteen and twenty percentage replacements and surge in compressive strength was noticed at ten percentage replacements.
4.16 Flexural strength of concrete cured in 1% Na$_2$SO$_4$ solution:

![Graph showing flexural strength of concrete cured in 1% Na$_2$SO$_4$ solution](image)

*Figure 16.* Flexural strength of concrete cured in 1% Na$_2$SO$_4$ solution

From figure 16, it was noticed that, for 0% to 5% strength increase up to 3.26%, 2.83%, 3.45% at 28, 60, 90 days, for 5% to 10% the strength increase up to 2.94%, 4.81%, 5.25% at 28, 60, 90 days, for 10% to 15% strength decreases to 8.79%, 6.73%, 6.35% at 28, 60, 90 days and for 15% to 20% strength decreases to 3.36%, 3.7%, 2.42% at 28, 60, 90 days. The graph shows the results for SCBA beams cured in 1% Na$_2$SO$_4$ solution, for all curing periods. Decline in compressive strength was noticed at fifteen and twenty percentage replacements and surge in compressive strength was noticed at ten percentage replacements.

4.17 Flexural strength of concrete cured in 3% Na$_2$SO$_4$ solution:

![Graph showing flexural strength of concrete cured in 3% Na$_2$SO$_4$ solution](image)

*Figure 17* Flexural strength of concrete cured in 3% Na$_2$SO$_4$ solution

From figure 17, it was noticed that, for 0% to 5% strength increase up to 6.09%, 1.12%, 1.35% at 28, 60, 90 days, for 5% to 10% the strength increase up to 3.83%, 2.7%, 3.11% at 28, 60, 90 days, for 10% to 15% strength decreases to 11.25%, 6.35%, 6.04% at 28, 60, 90 days and for 15% to 20% strength decreases to 3.11%, 3.47%, 2.45% at 28, 60, 90 days. The graph shows the results for SCBA beams cured in 3% Na$_2$SO$_4$ solution, for all curing periods. Decline in compressive strength was noticed at fifteen and twenty percentage replacements and surge in compressive strength was noticed at ten percentage replacements.
4.18 Flexural strength of concrete cured in 5% Na$_2$SO$_4$ solution:

From figure 18, it was noticed that, for 0% to 5% strength increase up to 4.2%, 8.5%, 9.3% at 28, 60, 90 days, for 5% to 10% the strength increase up to 4.5%, 4.6%, 4.7% at 28, 60, 90 days, for 10% to 15% strength decreases to 22.6%, 28.3%, 29.2% at 28, 60, 90 days and for 15% to 20% strength decreases to 24.6%, 18.6%, 20.6% at 28, 60, 90 days. The graph shows the results for SCBA beams cured in 5% Na$_2$SO$_4$ solution, for all curing periods. Decline in compressive strength was noticed at fifteen and twenty percentage replacements and surge in compressive strength was noticed at ten percentage replacements.

4.19 Flexural strength of concrete cured in 1% MgSO$_4$ solution:

From figure 19, it was noticed that, for 0% to 5% strength increase up to 1.25%, 2.9%, 1.57% at 28, 60, 90 days, for 5% to 10% the strength increase up to 2.9%, 0.97%, 2.8% at 28, 60, 90 days, for 10% to 15% strength decreases to 7.5%, 6.6%, 7.4% at 28, 60, 90 days and for 15% to 20% strength decreases to 2.6%, 2.6%, 1.31% at 28, 60, 90 days. The graph shows the results for SCBA beams cured in 1% MgSO$_4$ solution, for all curing periods. Decline in compressive strength was noticed at fifteen and twenty percentage replacements and surge in compressive strength was noticed at ten percentage replacements.
4.20 Flexural strength of concrete cured in 3% MgSO₄ solution:

![Flexural strength of concrete cured in 3% MgSO₄ solution](image1)

**Figure 20.** Flexural strength of concrete cured in 3% MgSO₄ solution

From figure 20, it was noticed that, for 0% to 5% strength increase up to 3.5%, 2.8%, 2.6% at 28,60, 90 days, for 5% to 10% the strength increase up to 1.5%, 1.1%, 2.6% at 28,60, 90 days, for 10% to 15% strength decreases to 6.4%, 5.4%, 5.4% at 28,60, 90 days and for 15% to 20% strength decreases to 4.4%, 2.9%, 2.9% at 28,60, 90 days. The graph shows the results for SCBA beams cured in 3% MgSO₄ solution, for all curing periods. Decline in compressive strength was noticed at fifteen and twenty percentage replacements and surge in compressive strength was noticed at ten percentage replacements.

4.21 Flexural strength of concrete cured in 5% MgSO₄ solution:

![Flexural strength of concrete cured in 5% MgSO₄ solution](image2)

**Figure 21.** Flexural strength of concrete cured in 5% MgSO₄ solution

From figure 21, it was noticed that, for 0% to 5% strength increase up to 0.86%, 2.5%, 2.9% at 28,60, 90 days, for 5% to 10% the strength increase up to 4.9%, 1.15%, 5.3% at 28,60, 90 days, for 10% to 15% strength decreases to 10.1%, 9.4%, 10.4% at 28,60, 90 days and for 15% to 20% strength decreases to 6.4%, 3.6%, 2.5% at 28,60, 90 days. The graph shows the results for SCBA beams cured in 5% MgSO₄ solution, for all curing periods. Decline in compressive strength was noticed at fifteen and twenty percentage replacements and surge in compressive strength was noticed at ten percentage replacements.
5. Conclusions
The following are the conclusions from this study.
1. The mechanical properties of SCBA (sugarcane Bagasse ash) concrete specimens were improved when compared to concrete specimens without SCBA when cured in water.
2. SCBA blended concrete when cured in Sodium sulphate solution and Magnesium sulphate solution shows better results than normal concrete.
3. The increment in compressive strength of sugarcane Bagasse ash blended concrete was noticed up to replacement level of 10%. Further replacement of SCBA results in the decrement of strength.
4. Improvement in split tensile and flexural strength strengths of SCBA blended concrete was noticed at 10% replacement of SCBA.
5. SCBA concrete specimens provide sulphate resistance than specimens without SCBA.
Hence Ten percentage replacement of sugarcane Bagasse ash with cement in concrete is an optimum percentage and can be used in places vulnerable to sulphate environment.

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