

Sustainable Materials In Concrete With Partial Replacement Of Cement : Bagasse Ash

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Abstract- *The demand for sustainable construction materials has accelerated research into the utilization of agro-industrial waste as supplementary cementitious materials. Sugarcane Bagasse Ash (SCBA), a by-product of sugar manufacturing, exhibits pozzolanic characteristics that can reduce cement consumption and environmental impact. This study evaluates the performance of concrete incorporating SCBA as a partial replacement of cement at levels of 0%, 10%, 15%, and 20%. Mechanical performance was assessed through compressive strength tests, while non-destructive testing methods were employed to evaluate concrete quality. Durability characteristics were examined using sulphate and chloride content analyses. Results indicate that the control mix achieved the highest compressive strength, with minor strength reductions observed at 10% and 15% SCBA replacement. At 20% replacement, a slight improvement in strength was noted due to enhanced pozzolanic activity. Cost analysis demonstrated a progressive reduction in concrete cost with increased SCBA content. The findings suggest that SCBA can be effectively utilized at lower replacement levels as a sustainable and economical cement substitute in concrete production..*

Keywords: Sugarcane Bagasse Ash, Sustainable Concrete Partial Cement Replacement, Compressive Strength, Cost Analysis.

I. INTRODUCTION

The growth of the construction industry has significantly increased cement consumption, making it an energy-intensive material with a high carbon footprint. Cement production generates substantial CO₂ emissions due to energy use and limestone calcination, creating a need for sustainable alternatives that partially replace cement without compromising concrete performance.

Agricultural and industrial by-products have emerged as viable supplementary cementitious materials because of their availability, low cost, and environmental benefits. Sugarcane Bagasse Ash (SCBA), a by-product of sugarcane combustion for energy, contains high amorphous silica, enabling pozzolanic reactions with calcium hydroxide during

cement hydration. This forms additional calcium silicate hydrate (C-S-H), enhancing concrete microstructure, durability, and long-term strength.

The effectiveness of SCBA depends on particle fineness, burning conditions, and replacement level. Excessive replacement can reduce strength due to cement dilution, highlighting the need to identify an optimal proportion.

This study investigates SCBA as a partial cement replacement in concrete by evaluating compressive strength, quality through non-destructive testing, and durability via chemical analysis. The results aim to promote SCBA as a sustainable, cost-effective material in concrete production.

II. IDENTIFY, RESEARCH AND COLLECT IDEA

The use of supplementary cementitious materials derived from agricultural waste has been widely investigated as a sustainable approach to reduce cement consumption and environmental impact. Among these materials, Sugarcane Bagasse Ash (SCBA) has attracted significant attention due to its pozzolanic properties and abundant availability in sugar-producing regions.

Ganesan et al. (2007) studied the performance of SCBA as a partial replacement of cement in concrete and reported that finely processed bagasse ash contributes to improved compressive strength at later ages due to its pozzolanic activity. The study highlighted the formation of additional calcium silicate hydrate (C-S-H) gel, which enhances the microstructure and durability of concrete.

Chusilpet al. (2009) investigated the influence of fineness of bagasse ash on its reactivity and observed that finely ground SCBA significantly improves strength development and resistance to sulphate attack. The authors emphasized that proper processing of SCBA is essential to achieve desirable performance in cementitious systems.

Srinivasan and Sathiya (2010) conducted experimental studies on concrete incorporating bagasse ash as a partial cement replacement. Their results showed that

replacement levels up to 10% yielded compressive strength comparable to conventional concrete, particularly at later curing stages. The study concluded that SCBA can be effectively used as a sustainable pozzolanic material when adequately processed.

Sata et al. (2007) examined the durability characteristics of bagasse ash concrete and reported reduced chloride permeability and improved resistance to shrinkage. The findings indicated that SCBA enhances durability by refining the pore structure and reducing calcium hydroxide content.

Ramezaniapour (2012) highlighted the environmental benefits of using bagasse ash in concrete, including reduced heat of hydration and improved microstructural properties. These characteristics make SCBA particularly suitable for mass concreting applications where thermal cracking is a concern.

More recent studies by Raju et al. (2016) focused on the economic and environmental impacts of SCBA utilization. Their research demonstrated that partial replacement of cement with SCBA significantly reduces carbon emissions and overall concrete cost, reinforcing its suitability for sustainable construction practices.

From the reviewed literature, it is evident that SCBA has considerable potential as a supplementary cementitious material. However, variations in ash quality, fineness, and replacement levels greatly influence concrete performance. This highlights the need for experimental evaluation to identify optimal replacement percentages that ensure strength, durability, and cost efficiency.

III. BACKGROUND STUDY

The use of sustainable materials in concrete has evolved as a response to the growing environmental concerns associated with rapid industrialization and urban development. Traditionally, concrete relied entirely on ordinary Portland cement as the binding material. However, by the mid-20th century, researchers began recognizing that cement production consumed large amounts of natural resources and released significant carbon dioxide into the atmosphere. This led to early investigations into supplementary cementitious materials such as fly ash and silica fume, which demonstrated that industrial by-products could partially replace cement while maintaining concrete performance.

The idea of using agricultural waste in concrete emerged later, particularly in countries with strong agricultural

and sugar industries. Sugarcane bagasse, the fibrous residue obtained after extracting juice from sugarcane, has long been used as a fuel in sugar mills. When bagasse is burned, it produces bagasse ash, which was historically considered a waste material and disposed of in open landfills, causing environmental and disposal problems. In the late 20th century, researchers began studying the chemical composition of bagasse ash and discovered that it contained a high percentage of silica, similar to other known pozzolanic materials.

Early experimental studies in the 1990s and early 2000s focused on evaluating the feasibility of using bagasse ash as a partial replacement for cement in concrete and mortar. These studies showed that, when properly processed and finely ground, bagasse ash could exhibit pozzolanic behavior by reacting with calcium hydroxide released during cement hydration. This reaction contributed to the formation of additional cementitious compounds, improving long-term strength and durability. As a result, bagasse ash started gaining attention as a potential supplementary cementitious material, especially in developing countries where sugarcane production is high.

In recent years, with the global emphasis on sustainable construction and green building practices, research on bagasse ash has expanded significantly. Studies have explored its effects on mechanical properties, workability, durability, and environmental performance of concrete. The historical development of bagasse ash usage in concrete reflects a gradual shift from waste disposal to resource utilization, highlighting its role in reducing cement

III. MATERIALS AND METHODOLOGY

A. Materials Used

Ordinary Portland Cement (OPC) conforming to relevant Indian Standard specifications was used as the primary binding material. Natural river sand was used as fine aggregate, while crushed stone of nominal maximum size 20 mm served as coarse aggregate. Clean potable water was used for mixing and curing of concrete specimens.

Sugarcane Bagasse Ash (SCBA) was obtained from locally collected sugarcane bagasse, which was dried and subjected to controlled combustion. The resulting ash was sieved through a 90-micron sieve to improve fineness and pozzolanic reactivity. The processed SCBA was stored in airtight containers to prevent moisture absorption before use.

B. Processing of Sugarcane Bagasse Ash

Fresh sugarcane bagasse was collected from local sources and cleaned to remove impurities. The bagasse was pre-dried to eliminate excess moisture and then burned under controlled conditions to obtain ash with minimal unburnt carbon. After cooling, the ash was sieved using a 90-micron sieve to obtain fine particles suitable for use as a supplementary cementitious material. Basic physical properties such as bulk density and specific gravity were determined for mix design considerations.

C. Mix Proportions

Concrete mixes were prepared by partially replacing cement with SCBA at four different replacement levels: 0% (control mix), 10%, 15%, and 20% by weight of cement. All other constituents and the water–cement ratio were kept constant to ensure uniformity across mixes. The control mix was used as a reference for evaluating the performance of SCBA-modified concrete.

D. Casting and Curing of Specimens

Concrete cubes of size 150 mm × 150 mm × 150 mm were cast for each mix proportion. The concrete was mixed thoroughly to achieve a uniform consistency and placed into moulds in layers with adequate compaction to eliminate air voids. After 24 hours, the specimens were demoulded and cured in clean water for a period of 28 days.

E. Testing Program

After the curing period, compressive strength tests were conducted using a compression testing machine in accordance with standard testing procedures. Non-destructive testing was also carried out to assess the quality and uniformity of concrete. Additionally, chemical tests such as sulphate and chloride content analysis were performed on SCBA to evaluate its suitability and durability aspects when used in concrete.

SCBA Replacement (%)	Cement (kg)	SCBA (kg)
0	5	0
10	4.5	0.5
15	4.25	0.75
20	4	1

IV. RESULTS AND DISCUSSION

A. Compressive Strength Analysis

The compressive strength results obtained from testing concrete cubes after 28 days of curing are presented and compared for different levels of Sugarcane Bagasse Ash (SCBA) replacement. The control mix with 0% SCBA exhibited the highest compressive strength, serving as a benchmark for evaluating the performance of modified mixes. Concrete with 10% SCBA replacement showed a slight reduction in compressive strength compared to the control mix. However, the decrease was marginal and remained within acceptable limits for structural applications. This behavior can be attributed to the partial replacement of cement, which initially reduces the availability of clinker compounds responsible for early strength development. At 15% SCBA replacement, a more noticeable reduction in compressive strength was observed. The higher replacement level led to a dilution effect, where the reduction in cement content outweighed the pozzolanic contribution of SCBA. Despite this reduction, the concrete maintained adequate strength for non-structural and moderate-load applications. Interestingly, at 20% SCBA replacement, a slight recovery in compressive strength was recorded when compared to the 15% mix. This improvement is associated with enhanced pozzolanic reactions at later ages, where reactive silica present in SCBA reacts with calcium hydroxide to form additional calcium silicate hydrate (C–S–H) gel, contributing to strength gain.

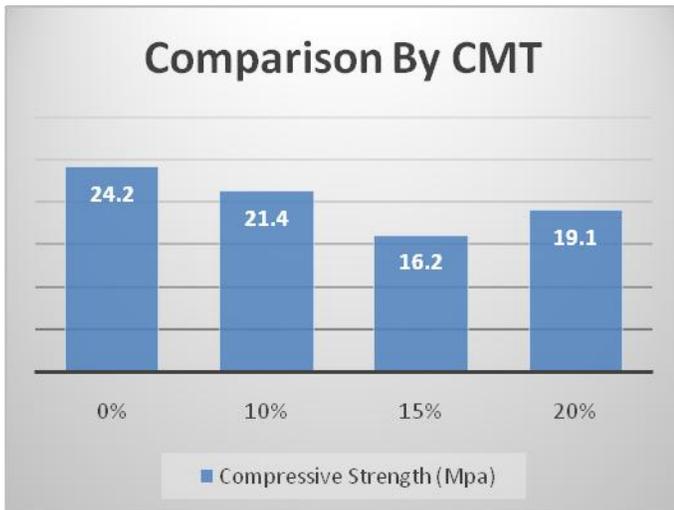


Table 1: Variation in Compressive Strength of concrete measured by Conventional Method Test

B. Non-Destructive Testing Results

Non-destructive testing methods were employed to assess the overall quality and uniformity of concrete. The results indicated good correlation with the compressive strength values obtained from destructive testing. The control mix exhibited excellent quality, while mixes with 10% and 15% SCBA showed satisfactory quality with minor variations. Concrete with 20% SCBA replacement demonstrated acceptable quality, confirming that SCBA incorporation did not adversely affect the internal integrity of concrete.

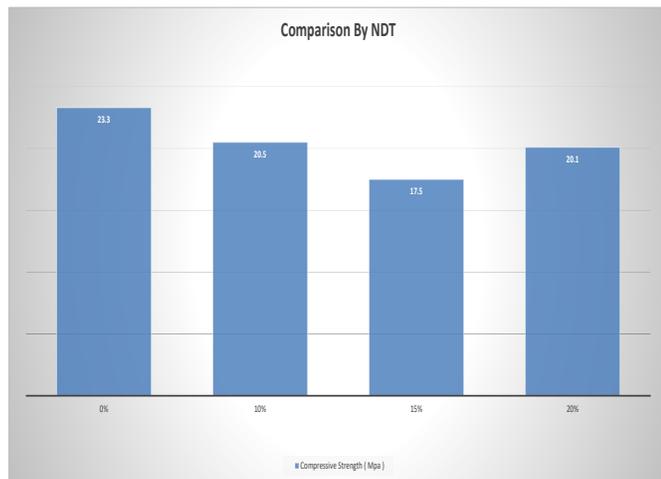


Table 2: Variation in Compressive Strength of concrete measured by Non-Destructive Test

C. Durability and Chemical Test Observations

Chemical analysis of SCBA revealed that sulphate and chloride contents were within permissible limits specified by relevant standards. This confirms the suitability of SCBA

as a partial cement replacement material with respect to durability considerations. Reduced calcium hydroxide content due to pozzolanic reactions also contributes to improved resistance against chemical attacks, enhancing long-term durability.

Replacement Levels	CMT (Mpa)	NDT (Mpa)
0 %	24.2	23.3
10 %	21.4	20.5
15 %	16.2	17.5
20 %	19.1	20.1

D. Cost Analysis

The cost analysis demonstrated a consistent reduction in the overall cost of concrete with increasing SCBA content. Since SCBA is significantly cheaper than cement, partial replacement resulted in direct material cost savings. Concrete mixes with 10% and 15% SCBA replacement offered an optimal balance between strength performance and economic benefits, making them suitable for sustainable construction applications.

Material Quantities per m³ of Concrete

Material	Quantity
cement	400 kg
Fine aggregate	0.50 m ³
Coarse aggregate	0.80 m ³
water	200 liter

SCBA Replacement (%)	Total Cost (₹/m ³)	Cost Saving Compared to Control (₹)
0	5,100	—
10	4,940	160
15	4,860	240
20	4,780	320

V. CONCLUSION

This study investigated the feasibility of using Sugarcane Bagasse Ash (SCBA) as a partial replacement of cement in concrete to promote sustainable and economical construction practices. Based on the experimental results, it is evident that SCBA can be effectively utilized as a supplementary cementitious material when used in controlled proportions.

The compressive strength results showed that the control mix achieved the highest strength, while concrete with 10% SCBA replacement exhibited only a marginal reduction in strength, remaining suitable for structural applications. Higher replacement levels led to a reduction in strength due to cement dilution; however, a slight improvement at 20% replacement was observed, attributed to the pozzolanic activity of SCBA at later curing stages.

Non-destructive testing confirmed satisfactory concrete quality across all mixes, and chemical analysis indicated that sulphate and chloride contents were within permissible limits, ensuring durability and long-term performance. Additionally, cost analysis revealed that increasing SCBA content results in reduced concrete cost due to lower cement consumption.

Overall, the study concludes that SCBA can be safely used as a partial replacement of cement at lower percentages to achieve environmentally friendly, durable, and cost-effective concrete. The findings support the adoption of agricultural waste materials in concrete production, contributing to sustainable development in the construction industry.

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