

Experimental Investigation on Partial Replacement of Cement in Concrete by Sugarcane Bagasse Ash

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Abstract—Concrete is the most widely used construction material in the world, and cement is a vital ingredient in its production. Cement production is responsible for large amount of carbon dioxide emissions, which contribute to global warming. This study aims in exploring alternative materials to replace cement in concrete. One such material is sugarcane bagasse ash, which is a byproduct of the sugar industry and is abundantly available in countries like India. Bagasse ash is a pozzolanic material that can react with cement to form additional cementitious compounds, thereby reducing the need for cement in concrete. Use of bagasse ash can increase the strength and reduce the permeability of concrete, making it more durable and resistant to corrosion. Further research and development in this area could lead to more sustainable and durable concrete solutions for the construction industry.

Index Terms—Aggregate, Cement, Compressive strength, Concrete, Sugarcane bagasse ash, Water

I. INTRODUCTION

Cement production is a major source of greenhouse gas emissions, accounting for approximately 8% of global CO₂ emissions. To address this environmental challenge, researchers are exploring alternative materials to partially replace cement in concrete, such as Sugarcane Bagasse Ash (SCBA), an agricultural by-product. Sugarcane is widely produced globally, with over 1.5 billion tons harvested each year. After juice extraction, about 30% of the sugarcane becomes bagasse, which is often burned for energy, leaving around 8% of its weight as ash. This SCBA, if not properly disposed of, becomes an environmental hazard.

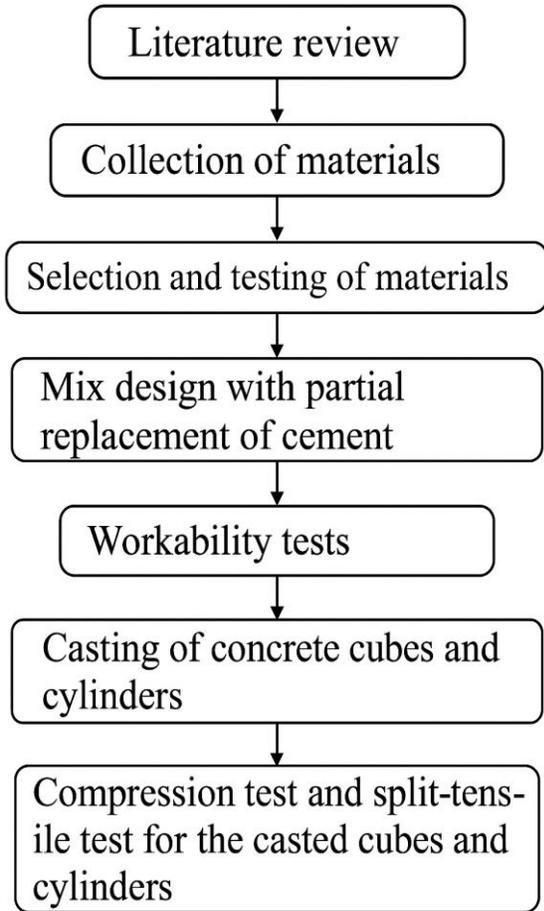
However, it possesses pozzolanic properties due to its high silica content, enabling it to react with calcium hydroxide in the presence of water to form compounds

that enhance the strength and durability of concrete. Studies have shown that replacing 10% of cement with SCBA can reduce CO₂ emissions by 4.4%, and a 20% replacement can achieve a 16.1% reduction. Additionally, SCBA can improve properties such as compressive strength and water tightness, depending on the replacement percentage and the fineness of the ash.

The chemical composition of SCBA can vary based on burning conditions and the soil where the sugarcane is grown, which affects its performance in concrete. Despite its benefits—such as cost savings, reduced environmental impact, and efficient waste utilization—further research is needed to determine optimal replacement levels and assess long-term durability and structural performance. SCBA holds significant promise as a sustainable and effective partial cement replacement in concrete production, especially in regions with abundant sugarcane processing.

II. METHODOLOGY

The study begins with a literature review on using Sugarcane Bagasse Ash (SCBA) in concrete. Materials such as cement, aggregates, water, and SCBA are collected and tested for physical and chemical properties. Concrete mixes are prepared by partially replacing cement with SCBA at varying percentages. Workability is assessed using the slump test. Concrete cubes and cylinders are cast, cured, and tested for compressive and split-tensile strength at 7, 14, and 28 days. Results are analyzed to evaluate the effect of SCBA on concrete strength and durability.



III. MATERIALS

Concrete is made by mixing cement, fine and coarse aggregates, and water. In this study, sugarcane bagasse ash (SCBA) is partially used in place of cement due to its pozzolanic properties. SCBA reacts with calcium hydroxide to form additional cementitious compounds, improving the strength, durability, and reducing the permeability of concrete.

Cement

Ordinary Portland Cement (OPC) of 53 grade was used in this project, sourced from a single batch for consistency. It was stored in airtight containers to prevent moisture-related deterioration. OPC mainly consists of calcium, silica, alumina, and iron, which are finely ground to form a powder used in concrete. The chemical composition of OPC significantly influences concrete properties like strength, setting time, and durability. Hence, using high-quality OPC from reliable manufacturers is essential to ensure optimal concrete performance.

Fine Aggregate

Due to the rising demand and shortage of river sand, manufactured sand (M-Sand) has become a preferred alternative in construction. Produced by crushing hard granite, M-Sand offers consistent quality, controlled grading, and is often more cost-effective. It is also dust-free, reducing pollution at construction sites. The M-Sand used in this project was selected for its durability, strength, and uniformity, making it suitable for quality concrete production.

Coarse Aggregate

Crushed coarse aggregates of 10mm to 12.5mm size were used, sourced from local crushing plants. They were washed to remove dust and impurities, then dried to a surface dry condition to prevent moisture-related issues in concrete. Broken stones were chosen for their strength and durability, ensuring the aggregates met required quality standards for use in construction.

Water

Water is vital in concrete for the hydration process that binds the mix. In this project, clean potable water free from impurities was used, with its quantity measured using a graduated jar as per mix design requirements. Maintaining the correct water-to-cement ratio is crucial for desired concrete properties. The water's pH was ensured to be above 7 to prevent steel corrosion and ensure concrete durability.

Sugarcane bagasse ash

Bagasse ash, a byproduct of burning sugarcane bagasse, has potential as a partial cement replacement due to its pozzolanic properties. With global sugarcane production exceeding 1500 million tons, a significant amount of this ash is generated. Using bagasse ash in concrete enhances strength and durability, reduces cement usage, lowers carbon emissions, and minimizes waste. Sugarcane yields about 30% bagasse and roughly 8% bagasse ash, though values may vary by processing methods. Incorporating this ash supports sustainable construction and helps mitigate climate change.

IV. TESTS CONDUCTED

TESTS ON CEMENT:

- **FINENESS TEST ON CEMENT:** Fineness test on cement is a procedure to determine the particle

size of cement. It involves the use of sieves to measure the amount of cement retained on each sieve and is an important factor in determining the quality and strength of concrete.

- **SPECIFIC GRAVITY OF CEMENT:** The specific gravity test on cement is a method used to determine the ratio of the weight of a given volume of cement to the weight of an equal volume of water. This test helps in determining the quality and strength of cement and is an important factor in designing concrete mixes.

TESTS ON AGGREGATES:

- **SEIVE ANALYSIS ON COARSE AGGREGATES:** Sieve analysis of coarse aggregate involves separating particles using sieves of various sizes to determine gradation and size distribution. This is essential for designing concrete mixes with optimal strength and workability.
- **SPECIFIC GRAVITY AND WATER ABSORPTION TEST ON COARSE AGGREGATES:** The specific gravity and water absorption test on coarse aggregate is a method used to determine the density and water holding capacity of the aggregate. This test helps in evaluating the quality of the aggregate, which is important in designing concrete mixes.
- **SEIVE ANALYSIS ON FINE AGGREGATES:** Sieve analysis on fine aggregate is a test used to determine the particle size distribution of the fine aggregate. This test is important for determining the grading of the fine aggregate, which affects the workability and strength of the concrete mix

TEST ON FRESH CONCRETE - WORKABILITY TEST

- **SLUMP TEST:** The slump test measures the workability of fresh concrete by observing how much it settles after the mold is removed. An inverted cone is filled with concrete, compacted, and lifted, and the slump height indicates if the mix meets the required consistency.

TEST ON HARDENED CONCRETE

- **COMPRESSION STRENGTH TEST:** Compressive strength is the ability of material or structure to carry the loads on its surface without any crack or deflection. A material under compression tends to reduce the size, while in tension, size elongates.

- **SPLIT TENSILE STRENGTH:** Concrete has low tensile strength due to its brittle nature, making it prone to cracking under tension. Determining its tensile strength is essential to assess the load at which cracks may form. The splitting tensile strength test, based on ASTM C496 and IS 5816:1999, is commonly used, where concrete cylinders (150 mm × 300 mm) are tested using a compression testing machine.
- **CASTING AND CURING:** At least three specimens should be tested at each selected age. If any specimen's strength deviates by more than 15% from the average, it should be discarded. The average strength of the remaining three specimens is taken as the concrete's compressive strength.

V. RESULTS AND DISCUSSION

- Fineness of cement is found to be 3.5%
- Specific gravity of cement in Le chatelier's Method is found to be 3.15
- Fineness modulus of coarse aggregates = 3.26
- The specific gravity of coarse aggregate = 2.84
- Water absorption of coarse aggregate = 0.41%
- Fineness modulus of Fine aggregates = 3.79
- Specific gravity of Fine aggregate = 2.71
- Water absorption of Fine aggregates = 1%
- Workability of Concrete- Slump test- 25 % of cement replaced with SCBA Slump is 84 mm
- Compressive strength of Concrete- 25% of cement replaced with SCBA for 14 days and 28 days is 35.7 N/mm² and 38.56 N/mm² respectively
- Split Tensile strength of Concrete- 25% of cement replaced with SCBA for 14 days and 28 days is 1.89 N/mm² and 2.52 N/mm² respectively

VI. CONCLUSION

The experimental study on M35 concrete with partial replacement of cement by Sugarcane Bagasse Ash (SCBA) revealed that 10% replacement yielded the highest compressive and tensile strength. Tests confirmed the quality of materials and showed that SCBA enhances strength, reduces CO₂ emissions, and supports sustainable construction by utilizing industrial waste. Economically, SCBA lowers cement usage and cost, while maintaining workability and

eliminating the need for super-plasticizers. Overall, SCBA proves to be an effective, eco-friendly, and economical alternative for cement in concrete.

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