IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.311 ⁙ Peer-reviewed & Refereed journal ⁙ Vol. 12, Issue 6, June 2025

DOI: 10.17148/IARJSET.2025.12638

SUSTAINABLE APPROACH OF USING BAGASSE ASH IN CEMENT-BASED COMPOSITES

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Abstract: The construction industry seeks high-performance mortar for strong and stable structures. However, industrial by-products like Sugarcane Bagasse Ash (SCBA) and Ground Granulated Blast Furnace Slag (GGBS) pose environmental and health concerns due to disposal issues. Interestingly, incorporating SCBA and GGBS into mortar can enhance its properties, such as water permeability and strength. This study aims to investigate the mechanical and durable properties of mortar using SCBA and GGBS as partial cement replacements, promoting sustainable construction practices. Five mortar mixes were prepared with varying SCBA content (5%, 10%, 15%, and 20%) and a constant GGBS content (30%). The samples were cast into 50x50x50 mm cube and 160x40x40 mm beam, cured for 7, 28, and 56 days, and then evaluated for their hardened properties and quality.

Keywords: Mortar, Mechanical and Durable properties, Industrial waste.

I. INTRODUCTION

The global construction industry, particularly the cement and concrete sector, plays a pivotal role in infrastructure development but simultaneously contributes significantly to environmental degradation. Cement production alone is responsible for nearly 8% of global carbon dioxide (CO_2) emissions, primarily due to the energy-intensive manufacturing process and decomposition of raw materials. As concerns over climate change, resource depletion, and environmental sustainability grow, there is a pressing need to adopt alternative, eco-friendly materials in construction.

One promising strategy is the partial replacement of Portland cement with industrial by-products known as supplementary cementitious materials (SCMs). Among these, Ground Granulated Blast Furnace Slag (GGBS) and Sugarcane Bagasse Ash (SCBA) have emerged as sustainable alternatives with favorable pozzolanic properties. SCBA, a waste product from sugar industries, is rich in reactive silica and alumina, making it suitable for forming calcium silicate hydrates during hydration. GGBS, a by-product of the iron and steel industry, offers enhanced durability and strength to cement composites.

Utilizing SCBA and GGBS not only reduces the carbon footprint of concrete but also helps in effective waste management. These materials improve key mechanical properties and durability indicators such as compressive strength, flexural strength, water absorption, and porosity. Thus, this study explores the performance of mortar made with partial replacement of cement using SCBA and GGBS, aiming to develop a sustainable and structurally efficient composite material.

Key Benefits:
- Reduced CO2 emissions
- Waste utilization
- Improved durability
- Sustainable construction

SCBA's Potential:
- High silica content (50-60%)
- Pozzolanic activity

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- Environmental benefits (reduced waste, lower CO2 emissions)
- Enhances mechanical properties and durability

By utilizing SCBA as an SCM, the construction industry can reduce its environmental footprint and promote sustainable development.

II. LITERATURE

Several researchers have examined the feasibility and performance of industrial waste materials as partial replacements for cement in concrete and mortar mixes. Li et al. (2022) reported that SCBA, when used at an optimal replacement level of 10–20%, can significantly enhance the mechanical strength and chemical resistance of concrete, including better performance under chloride and sulfate attacks. Similarly, Tanu and Sujatha (2023) investigated geopolymer concrete incorporating SCBA and GGBS and found that increasing the concentration of alkaline activators improved the strength and microstructure of the material.

Gupta et al. (2021) assessed SCBA at varying percentages (5–20%) and observed that 10% replacement provided a good balance between strength and durability. However, excessive SCBA increased water absorption and reduced flexural strength. Noor Yaseen (2024) confirmed that SCBA enhanced the 28-day compressive strength and ultrasonic pulse velocity up to a 15% replacement level, though higher percentages led to porous microstructures.

Studies by Siddique and Bennacer (2012) and Oner and Akyuz (2007) on GGBS have shown improved compressive strength and durability due to the formation of dense calcium-silicate-hydrate (C-S-H) gels. Notably, GGBS can replace cement up to 50% or more without compromising performance. Meanwhile, Spósito et al. (2023) proposed a life-cycle-based assessment of SCBA mortars, indicating significant environmental benefits despite minor trade-offs in mechanical properties at higher replacement levels.

Research also highlights the role of curing methods and mix designs in optimizing performance. For example, Kumar et al. (2023) and Khoshkbijari et al. (2024) demonstrated that curing conditions, binder composition, and filler interactions affect compressive strength, thermal stability, and resistance to aggressive environments.

In summary, both SCBA and GGBS have proven to be viable SCMs, capable of enhancing the sustainability and performance of cement-based composites. However, their optimal utilization depends on careful control of replacement levels, mix proportions, and curing conditions.

III. MECHANICAL PROPERTIES

1. **Compressive Strength**: The compressive strength of a material is determined by applying a gradually increasing load to a specimen until failure occurs, with the maximum load sustained before failure divided by the cross-sectional area to obtain the compressive strength, typically expressed in megapascals (MPa).

2. **Flexural Strength**: Flexural strength, also known as modulus of rupture, is evaluated using a three-point or four-point bending test on a rectangular bar-shaped specimen, where the maximum stress experienced before breaking is recorded as the flexural strength.

3. **Bulk Density**: Bulk density is calculated by measuring the dry weight and geometric dimensions of a specimen, providing insight into the material's compactness and its impact on thermal conductivity, strength, and other performance characteristics.

4. **Apparent Porosity**: Apparent porosity is measured using the water immersion method, where a dried sample is boiled in water to allow pore saturation, and the percentage of open pores is calculated relative to the total bulk volume.

IV. DURABILITY PROPERTIES

1. Water Absorption: Water absorption is determined by soaking a dried sample in water for a specified duration, with the increase in weight expressed as a percentage of the original dry weight, representing the water absorption capacity and influencing dimensional stability and strength over time.

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V. CONCLUSION

This study demonstrates that the incorporation of Sugarcane Bagasse Ash (SCBA) and Ground Granulated Blast Furnace Slag (GGBS) as partial cement replacements in mortar can significantly enhance its mechanical properties and durability. The findings of this research contribute to the growing body of evidence supporting the use of industrial by-products as supplementary cementitious materials (SCMs) in construction. By utilizing SCBA and GGBS, the construction industry can reduce its environmental footprint, promote sustainable development, and create more durable and efficient structures. The optimal replacement levels of SCBA and GGBS can vary depending on the specific application and desired properties, but the results of this study suggest that these materials have the potential to play a significant role in shaping a more sustainable future for the construction industry.

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