Strengthening Effect on Concrete by Using Bagasse Ash as Replacement of Fly Ash for Eco-Friendly Concreting

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Abstract:* Concrete remains the most widely used construction material in the world due to its versatility, strength, and durability. However, the production of its primary binder Portland cement is responsible for a significant share of global CO_2 emissions. In response to environmental concerns, researchers and engineers have increasingly sought sustainable alternatives through the use of supplementary cementitious materials (SCMs), such as fly ash, a by-product of coal combustion. This thesis explores the strengthening effect of Sugarcane Bagasse Ash (SCBA) as a partial replacement for fly ash in M25 grade concrete, with a focus on enhancing concrete performance while promoting eco-friendly construction practices. SCBA, an agro-industrial by-product rich in pozzolanic materials, offers a sustainable alternative to conventional cementitious additives such as fly ash. In this study, SCBA was used to replace fly ash at 0%, 5%, 10%, 15%, 20%, and 25%, and its impact on the compressive strength, split tensile strength, and workability of concrete was evaluated at curing ages of 7, 14, and 28 days

Keyword: Concrete, Bagasse Ash, Fly ash.

1. INTRODUCTION

Concrete remains the most widely used construction material in the world due to its versatility, strength, and durability. However, the production of its primary binder—Portland cement—is responsible for a significant share of global CO_2 emissions. In response to environmental concerns, researchers and engineers have increasingly sought sustainable alternatives through the use of supplementary cementitious materials (SCMs), such as fly ash, a by-product of coal combustion. While fly ash has proven to be effective in improving concrete properties and reducing cement usage, its availability is now being challenged by the global shift away from coal-based power generation. This has created a pressing need to explore alternative pozzolanic materials that are both effective and environmentally responsible.

Bagasse ash, derived from the combustion of sugarcane bagasse in sugar mills, emerges as a viable substitute. Abundantly available in sugar-producing regions, bagasse ash is rich in amorphous silica and possesses pozzolanic characteristics similar to fly ash. Its utilization in concrete not only provides a sustainable solution for waste management but also contributes to reducing the carbon footprint of construction activities. More importantly, recent studies have shown that bagasse ash has the potential to enhance the mechanical and durability performance of concrete, particularly when used as a replacement for fly ash.

This thesis focuses on investigating the strengthening effect of bagasse ash as a replacement for fly ash in concrete mixtures. The study examines key parameters such as compressive strength, workability, durability, and microstructure of concrete made with various proportions of bagasse ash in place of fly ash. Through experimental analysis, the research aims to identify the optimal replacement levels and understand the mechanisms behind the performance improvements. By promoting the use of agricultural waste in concrete production, this research contributes to the broader goals of sustainable construction, resource efficiency, and eco-friendly infrastructure development. The findings are expected to support the transition toward greener materials in the construction industry, especially in regions where bagasse ash is readily available and fly ash is becoming scarce.

A. Bagasse Ash

The sugar industry is one among the well-established industries in India which is a boon to farmers. As per the statistics of the Indian Sugar Mill Association, around 538 sugarcane factories are in operation in the country presently. In this century, most of the sugar industries in India have been developed as self-sustained ones by various means. It is one among the industries that generate electricity and export the excess to the government through the power grid.

Fig 1 Bagasse and Bagasse Ash

Table 1 Physical and mechanical properties

Properties	Bagasse Ash
Diameter (mm)	0.023 mm
Density(kg/m3)	940 kg/m^3
Bulk density (kg/m3)	555 kg/m^3
Fineness Modulus	0.6–1.4
Compressive strength (MPa) 10%	53.85 MPa.

2. STATE OF DEVELOPMENT

Blessen Skariah Thomas et al. (2021) The study discusses the impact of different processing methods on SCBA and its effect on concrete performance, including workability, compressive strength, and durability. The authors conclude that SCBA can be effectively used as a supplementary cementitious material, with optimal replacement levels ranging from 10% to 20%.

Duc-Hien Le & Yeong-Nain Sheen (2022) The testing results can be summarized as followed. Amorphous silica and high loss on ignition (14.3%) were specified for the treated ash. Addition of 5% bagasse ash improves the concrete workability; and further increasing cement alternative causes workability loss. Compressive and splitting tensile strengths of blended concrete decrease when increasing rate of cement replacement. On the other hand, enhancement of durability indices of concrete prepared with blended cement is noticeably observed. In three mix series, the lowest weight loss caused by sulfate attack and the highest electrical resistance were examined on specimens incorporating with 20% bagasse ash, although these concretes absorbed higher water when comparing to the respective controls This study investigates the effects of using controlled-burning SCBA as a partial replacement for cement in concrete. The results indicate that 5% SCBA enhances workability, while higher replacement levels (10% to 20%) lead to decrease compressive and tensile strengths. However, durability tests show improved resistance to sulfate attack and increased electrical resistance, suggesting that SCBA can enhance the durability of concrete

Blessen Skariah Thomas et al. (2021) This review discusses the performance of concrete containing sugarcane bagasse ash with its varying dosage and evaluates the properties of concrete in terms of fresh and hardened properties. Durability properties have been evaluated on the basis of permeability, chloride penetration, electrical resistivity, thermal conductivity, acid and sulfate attack. Centered on an explicit review, regulations for the succeeding investigations on the effective employment of bagasse ash are highlighted. The results from the study suggest improvement in the performance of concrete containing sugarcane bagasse; strength gain was noticed due to increased pozzolanic reactions, low heat of hydration, reduced permeability could be due to pore refinement bagasse ash blended concrete This chapter reviews various studies on the use of SCBA in concrete, focusing on its fresh, hardened, and durability properties. The authors highlight that SCBA can improve the mechanical properties of concrete, with optimal replacement levels varying between 10% and 20%. The study emphasizes the importance of processing SCBA to enhance its pozzolanic activity and recommends further research to standardize its use in concrete production

P. Jagadesh et. al. (2024) There is much agriculture and non-agricultural waste that contains pozzolanic material, which can be recommended to use as a partial replacement for Ordinary Portland Cement (OPC). One of the waste products from sugar industries, which possess pozzolanic properties, is Sugar Cane Bagasse Ash (SCBA). Because of the negative impact associated with cement production, OPC is being replaced by several supplementary cementitious materials / pozzolanic materials. In the current study, an effort has been made to use the

SCBA by partially replacing the OPC for mortar studies. SCBA has been processed to enhance the chemical and physical properties.

Noor Yaseen et. al. (2024) However, despite this decrease, mortars con taining up to 15 wt% SCBA achieved UPV values surpassing the literature-defined thresholds for good (3500 m/ s) and excellent (3800 m/s) quality cement mortar at 28 days, indicating yet a well-packed microstructure. The The study highlights the potential of using energy-efficient SCBA as a sustainable supple mentary cementitious material to improve mortar mix performance and contribute to the development of environmentally friendly cementitious materials.

Desmond. E. Ewa, et. al. (2022) The study investigated the suitability of Limestone Dust (LSD) and Sugarcane Bagasse Ash (SCBA) as stabilizer for the improvement of the geotechnical properties of Calabar subgrade soil. The un-stabilized soil had a maximum dry density of 1.74 kg/m3 at an optimum moisture content of 24.5%, with a 48-hours soaked California Bearing Ratio (CBR) value of 6.92%, and, an unconfined compressive strength of 103.66 KN/m3. Stabilizers were added at 0% − 50% by weight of soil. Results showed a reduction in the swelling potential of the soil, improvements incompaction characteristics by a range of 4.3−9.8%, an increase in CBR by 50% -78.5%, unconfined compressive strength by 23.8%-38.1%, as well as improvements in shear strength, and secant modulus. SCBA, showed better improvement compared to SCBA as a stand-alone

Michel Barro et. al. (2022) In this study, the sugar cane bagasse from Burkina Faso has been calcined at temperatures ranging from 550 to 750 °C with a heating stage of 2 or 3 h to produce pozzolanic ashes as supplementary cementitious materials for eco-cement production. The ashes obtained were subsequently characterized for their chemistry, mineralogy, and pozzolanic activity. The results of the characterization have shown that the ashes are rich in amorphous silica with a high Blaine specific area and a density around 2.5 g/cmn. The ashes are siliceous pozzolan type F. The main crystalline phases identified in these ashes are quartz (SiO2), calcite (CaCO,), muscovite.

Mohamed Amin (2022) There are many problems due to the cement industry around the world besides the air pollution by greenhouse gas emissions. The problem arises when a dense quantity of CO the conversion of calcium carbonate lime (CaCO 3 2 is emitted through) into calcium oxide lime (CaO), the main ingredient in cement. This transformation is made in an oven-dry by burning fossil fuels, in a process that releases more carbon dioxide. In this study, sugarcane bagasse ash (SCBA) and nano eggshell powder (NEP) are considered cementitious materials and were added to the cement at different percentages to reduce the cement contents in the concrete industry. Sixteen high- strength concrete (HSC) mixtures experimented with in this investigation contain SCBA and NEP other than the control mix. The SCBA and NEP were added to cement content by 5 %, 10 %, 15 %, and 20 % for SCBA, and 2.5 %, 5 %, and 7.5 % for NEP. This study evaluates the fresh and hardened properties of HSC.

3. SUMMARY OF LITERATURE

Pozzolanic Potential and Material Characteristics Multiple studies (Thomas et al., 2021; Barro et al., 2022; Abdalla et al., 2020) have affirmed the high pozzolanic activity of SCBA due to its silica-rich content, especially when processed correctly via calcination or controlled burning. Proper thermal treatment enhances the amorphous silica content, essential for effective cement replacement.

Processing and Optimization Controlled burning (Le & Sheen, 2022) and proper calcination (Barro et al., 2022) are crucial to optimize SCBA's performance. Over-burning or under-burning can reduce its reactivity. Pre-treatment, such as grinding or sieving, can also significantly influence physical properties and performance in concrete (Jagadesh et al., 2024).

Optimal Replacement Levels Most studies agree that 5–20% replacement of Ordinary Portland Cement (OPC) with SCBA is optimal:

- 5–15% improves compressive strength, durability, and workability (Noor Yaseen et al., 2024; Le & Sheen, 2022).
- Higher levels (above 20%) often lead to strength reductions but may still improve durability parameters (Amin & Attia, 2022; Abdalla et al., 2020).

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IS Code

- IS Code 383 2016 for course and fine aggregate
- IS 456 : Plain and Reinforced Concrete