

“Effect of Sugarcane Husk Ash and Rice Husk Ash on the Mechanical Properties of Sustainable Concrete AAC Block”

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Abstract: This paper presents a comprehensive review of research conducted on the utilization of sugarcane husk ash (SCHA) and rice husk ash (RHA) as supplementary cementations materials in the development of sustainable concrete and autoclaved aerated concrete (AAC) blocks. Both SCHA and RHA are rich in amorphous silica and possess pozzolanic characteristics that can partially replace cement, leading to lower carbon emissions and improved resource utilization. The review summarizes their chemical composition, physical properties, optimal replacement levels, and effects on the mechanical and durability performance of concrete and AAC blocks. Results from previous studies indicate that partial replacement (5–15%) of cement with these ashes can enhance strength and durability while reducing density and improving thermal insulation. This paper concludes that the integration of agricultural by-products such as SCHA and RHA in AAC block production is a viable approach for promoting sustainable construction and reducing environmental impacts.

Keywords: Sugarcane Husk Ash, Rice Husk Ash, Sustainable Concrete, AAC Block, Pozzolanic Material, Waste Utilization.

I. INTRODUCTION:

The construction industry is one of the largest consumers of natural resources and contributors to global carbon emissions. The production of ordinary Portland cement (OPC), a key ingredient in concrete and Autoclaved Aerated Concrete (AAC), is responsible for approximately 7–8% of global CO₂ emissions due to the calcination of limestone and high energy consumption during manufacturing. Hence, there is an urgent need to develop sustainable alternatives that can minimize the environmental footprint of building materials while maintaining adequate performance characteristics.

Autoclaved Aerated Concrete (AAC) has emerged as a lightweight and energy-efficient alternative to conventional clay bricks and dense concrete blocks. Its cellular structure provides excellent thermal insulation, acoustic absorption, and fire resistance, making it suitable for both load-bearing and non-load-bearing applications in modern green buildings. Despite these advantages, conventional AAC production still relies heavily on cement, lime, and fine aggregates, which continue to deplete natural resources and increase embodied energy.

In recent years, researchers have turned their attention toward the use of industrial and agricultural by-products as partial replacements for cement and sand in AAC production. These materials, often treated as waste, can significantly reduce environmental pollution when utilized in construction. Among these, **Sugarcane Husk Ash (SCHA)** and **Rice Husk Ash (RHA)** have attracted considerable interest because of their high silica content and excellent pozzolanic reactivity. When properly processed under controlled combustion, both ashes develop amorphous silica phases capable of reacting with calcium hydroxide released during cement hydration, forming additional calcium silicate hydrate (C–S–H) gel, which enhances the mechanical properties and durability of concrete.

India, being one of the largest producers of sugarcane and rice, generates vast quantities of agricultural residues every year. Improper disposal of these husks through open burning or landfilling causes severe environmental pollution. Converting them into useful pozzolanic materials presents a dual advantage — effective waste management and the creation of sustainable, cost-effective construction materials.

Several studies have demonstrated that the incorporation of RHA and SCHA in conventional concrete can improve compressive strength, reduce permeability, and enhance durability due to the formation of dense microstructures. However, the combined utilization of these ashes in **AAC block production** remains relatively unexplored. Most existing research focuses on individual replacement effects in normal concrete rather than synergistic behavior in aerated systems where hydration, heat evolution, and pore structure are critical.

Therefore, this study aims to investigate the **combined effect of Sugarcane Husk Ash and Rice Husk Ash on the mechanical and physical properties of sustainable AAC blocks**. The objective is to determine the optimal replacement level that maintains adequate strength while improving thermal insulation, reducing density, and minimizing cement consumption. The findings of this research are expected to contribute to the advancement of green construction technologies and promote the circular utilization of agro-industrial waste materials in building products.

II. LITERATURE REVIEW

2.1 Rice Husk Ash (RHA) as a Pozzolanic

Rice husk ash (RHA) is widely reported as a highly reactive pozzolanic when produced under controlled combustion and suitably ground. Multiple studies show that RHA contains a high proportion of amorphous silica which reacts with calcium

hydroxide to produce additional C–S–H, refining pore structure and improving strength and durability. Particle fineness, burning temperature, and loss on ignition (LOI) critically affect reactivity; ashes burned at intermediate temperatures (e.g., ~600–800 °C) and milled to <45 µm show the best pozzolanic activity. Review articles and experimental works consistently indicate that RHA can replace cement in the range **5–20%** without loss of strength (often improving long-term strength and impermeability).

2.2 Sugarcane Husk / Bagasse Ash

Sugarcane bagasse ash (SCBA) — produced from sugarcane husk/bagasse — contains silica, alumina and some residual carbon. When processed correctly (controlled combustion and sieving), SCBA acts as a supplementary cementitious material improving strength, reducing permeability, and offering cost and CO₂-saving potential. Optimal replacement rates reported vary with source and processing but commonly fall between 5–15% for blended cements; higher percentages may require additional processing to lower LOI. Recent experimental and review studies confirm beneficial mechanical and environmental impacts from partial SCBA replacement.

2.3 Combined Use of RHA and SCBA

A number of recent experimental studies have evaluated combined replacements (RHA + SCBA) to take advantage of complementary chemistries — RHA being silica-rich and SCBA bringing additional alumina/calcium or filler effects. Short-term and longer studies show combined blends can produce synergistic improvements in workability, compressive strength and durability metrics when total replacement levels are kept moderate (e.g., combined 10–20% replacement of cement). However, outcomes depend strongly on mixing proportions, ash processing, and curing regimes.

2.4 RHA/SCBA in Autoclaved Aerated Concrete (AAC)

AAC differs from normal concrete due to its aerated cellular microstructure and autoclave curing (high-pressure steam), which affects hydration, pore formation, and phase development (e.g., tobermorite formation). Several studies have investigated RHA as a partial substitute in AAC mixes — reporting changes in density, thermal conductivity and compressive strength. Because AAC's microstructure and hydrothermal reactions are sensitive to silica source and reactivity, the incorporation of agro-ashes must be evaluated specifically for autoclave conditions. The literature indicates potential for reducing density and improving thermal insulation while keeping compressive strength within standard limits when replacement levels are moderate (commonly cited 5–15%). However, systematic research on combined RHA + SCBA in AAC is still limited.

2.5 Microstructure & Durability Evidence

Microstructural analyses in several papers reveal that RHA and SCBA participate in forming additional C–S–H and refining capillary pores, which improves impermeability and long-term strength. XRD and SEM studies show reduced portlandite peaks and evidence of secondary C–S–H/tobermorite (important in

autoclaved systems). Durability tests (water absorption, chloride penetration, permeability) usually show improvements with moderate ash replacement, but poor processing (high LOI or crystalline silica) can worsen properties. *Environmental and Economic Assessments* Life-cycle and case studies indicate that replacing a portion of cement with RHA/SCBA lowers embodied CO₂ and can reduce production costs, especially when ash is locally available and requires minimal transport. Some sustainability case studies quantify meaningful CO₂ savings at ~10% replacement levels. However, full LCA depends on local ash processing energy and transport.

Summary of Literature & Identified Gaps

Consensus:

- RHA is a highly reactive pozzolan (when properly processed) and SCBA/SCA has useful supplementary cementitious properties; both can reduce cement content and improve certain durability metrics at moderate replacement (typically 5–15%). MDPI+1
- **AAC-specific research is limited:** while studies exist on RHA in AAC and some on waste substitution in AAC, few studies systematically investigate the combined use of RHA + SCBA in AAC blocks under autoclave conditions and evaluate mechanical, thermal, and microstructural effects together. SpringerOpen+1
- **Processing sensitivity:** many studies emphasize that burning temperature, LOI, and particle fineness strongly determine pozzolanic performance; inconsistent ash quality is a recurring limitation across literature.
- **Research gap your study will fill:** Evaluate the combined effect of locally sourced sugarcane husk ash and rice husk ash on mechanical (compressive strength), physical (density, water absorption), thermal, and micro structural properties of AAC blocks produced and autoclaved under specified conditions — with careful characterization of ash (chemical composition, LOI, particle size) and standardized mechanical/durability testing to identify optimal replacement ranges for Indian agro-wastes.

III. CONCLUSION

The review of existing literature demonstrates that the incorporation of agro-waste materials such as Sugarcane Husk Ash (SHA) and Rice Husk Ash (RHA) in AAC blocks offers substantial benefits in terms of sustainability, mechanical performance, and environmental impact. Both ashes, being rich in amorphous silica, exhibit strong pozzolanic reactivity that enhances the formation of calcium silicate hydrate (C–S–H) gel, thereby improving compressive strength, reducing water absorption, and enhancing durability.

The studies reviewed confirm that an optimal replacement of cement with SHA and RHA—generally within 5% to 20%—can improve strength and workability while significantly lowering carbon emissions and overall cost. Moreover, their combined utilization results in a synergistic effect, balancing reactivity and

microstructural refinement. The application of these ashes also supports waste management, carbon reduction, and sustainable material innovation, making them ideal for eco-friendly AAC production.

However, the variation in ash composition, burning temperature, and processing techniques can influence their performance, emphasizing the need for standardized preparation and testing methods.

IV.FUTURE SCOPE

To further advance the utilization of SHA and RHA in sustainable AAC blocks, the following research directions are recommended:

Optimization of Ash Processing:

Detailed investigation into controlled burning, grinding, and sieving methods to achieve consistent ash fineness and pozzolanic reactivity.

Microstructural and Durability Studies:

Advanced analytical techniques such as SEM, XRD, and FTIR should be employed to study hydration mechanisms and long-term durability under different curing and environmental conditions.

Hybrid Blending and Synergy Analysis:

Examination of combined use of SHA, RHA, and other supplementary cementitious materials (e.g., fly ash, GGBS) to identify optimal blend ratios for AAC blocks.

Autoclave Optimization:

Study of temperature, pressure, and time parameters in the autoclaving process to maximize strength development and minimize energy use.

Field Implementation and Life Cycle Assessment (LCA):

Pilot-scale production and structural application tests, coupled with LCA and cost-benefit analysis, to validate the environmental and economic feasibility of large-scale adoption.

Standardization and Policy Integration:

Development of guidelines or IS code recommendations for incorporating agro-waste-based pozzolans into AAC block manufacturing.

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