

Optimization of Agro-Waste Ash Content for High-Performance Eco-Friendly Bricks: An Experimental Investigation

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Abstract - The global construction industry significantly contributes to resource depletion and carbon emissions, while the agricultural sector struggles with the disposal of vast waste quantities. This project investigates the feasibility of developing sustainable, eco-friendly bricks by using agricultural waste—specifically sugarcane bagasse ash (SBA) and rice husk ash (RHA)—as a partial substitute for conventional materials in percentages of 3%, 6%, 9%, and 12%. Utilizing these agro-wastes provides a solution to pollution and landfilling problems, reduces the high cost of building materials, and supports the goal of a circular economy. The experimental results indicate that a 6% replacement level is optimal, achieving a peak compressive strength of 5.90 N/mm², which represents a significant improvement over traditional bricks. Furthermore, these sustainable bricks offer practical advantages such as lighter weight, enhanced thermal and acoustic insulation, and increased porosity. By sourcing materials locally, this approach not only addresses environmental degradation but also creates new economic opportunities for rural communities.

Keywords - Agricultural waste, Sugarcane Bagasse, Rice husk, Sustainable brick.

I. INTRODUCTION

Bricks are considered to be one of the most significant ancient building material in the construction industry. Due to increase in population a rapid increase in the demand for construction building materials has occurred. In order to meet the needs of the increasing housing demand, there is an

exponential need for the production of masonry bricks. The traditional brick making procedure includes the mixing of raw materials (earth-based materials), moulding of bricks, drying and then firing them until they obtain the required

strength. Now-a-days cementations materials such as ordinary Portland cement, fly ash etc. are used for the production of concrete bricks.

The excessive usage of the earth materials that are utilized for production of fired bricks results in massive depletion of the natural resources and also high energy consumption. These bricks are also responsible for serious environmental

degradation due to the high greenhouse gas emissions. On the other hand, the concrete blocks are considered to be environmentally unfriendly, where they consume large amount of energy and also emit CO₂ and other greenhouse gases. By giving adequate attention to the use of appropriate building materials, effective solutions to the above problems can be developed. Incorporation of industrial and agricultural waste materials in brick production is an efficient method to diminish the environmental pollution, reduce the amount of generated wastes and protect the raw materials from depletion.

Making bricks from agricultural waste supports the idea of a circular economy, where waste is turned into useful products instead of being discarded. These sustainable bricks can also offer practical benefits, such as being lighter in weight, providing better thermal insulation, and potentially lowering costs. In addition, sourcing materials locally can create new opportunities for rural communities and support local economies.

In India, rice husk and sugarcane bagasse are primarily available as waste products from agro-processing industries. Key sources include over 130,000 rice mills (generating ~24 million tons of husk annually) and sugar factories (yielding ~120 million tons of bagasse), concentrated heavily in Maharashtra, Uttar Pradesh, Tamil Nadu, Karnataka, and Andhra Pradesh.

Traditional brick production heavily depends on natural resources like soil and cement, which leads to resource depletion, high energy consumption, and environmental pollution due to greenhouse gas emissions. At the same time, large amounts of agricultural waste such as sugarcane bagasse and rice husk are generated, which are often burnt or dumped, causing serious environmental and land pollution issues. Therefore, there is a need to develop a sustainable and eco-friendly alternative by utilizing agricultural waste in brick production to reduce environmental impact, manage waste effectively, and meet the growing demand for construction materials.

II. MATERIALS

A. Material used

Sugarcane bagasse: Sugarcane bagasse is the fibrous residue left after extracting juice from sugarcane, which, when incinerated, produces sugarcane bagasse ash (SCBA) that is

highly valuable for sustainable, low-cost, and "green" brick manufacturing. This industrial byproduct is rich in silica (SiO_2) and alumina (Al_2O_3), allowing it to be used as a pozzolanic material to partially replace cement or sand in brick production, which improves compressive strength and durability.

Chemical composition: The chemical composition of sugarcane bagasse primarily consists of cellulose (45-50%), hemicellulose (25-30%), and lignin (25%). However, the crucial component for brick making is the resulting ash (SCBA), which is mainly composed of silica (SiO_2) and smaller amounts of alumina (Al_2O_3), iron oxide (Fe_2O_3), calcium oxide (CaO), potassium oxide (K_2O), and sodium oxide (Na_2O). The amorphous silica in the ash reacts with lime in the presence of water, creating cementation properties that, when properly cured, result in high-performance building bricks.

Rice Husk: Rice husk, an abundant agricultural byproduct, is increasingly used as a sustainable additive in brick production. When mixed with clay or soil, rice husk enhances thermal insulation and reduces the density of bricks due to the formation of micro-pores during firing, as the organic material partially burns out. Rice husk and straw are lightweight, reducing the overall weight of bricks and making them easier to transport and install. Their fibrous structure increases porosity, which enhances thermal and acoustic insulation ideal for energy-efficient buildings.

Chemical Composition: The chemical composition of RHA produced by utilizing the fluidized bed type furnace is reported to be SiO_2 (80-95%), K_2O (1-2%) and un-burnt carbon (3-18%). The pozzolanic activity of rice husk ash is effective in improving the strength. Partial replacement of clay by RHA.

Clay: Clay is the primary raw material in brick manufacturing, providing plasticity, binding properties, and strength. It allows shaping, hardens upon drying and firing, and forms durable, load-bearing bricks. Its composition and quality directly affect the brick's mechanical and thermal properties.

Chemical Composition: The chemical composition of clay is primarily composed of alumina and silica.



Fig.2.1 Sugarcane bagasse

Fig.2.2 Rice husk

III. EXPERIMENTAL METHODOLOGY

A. Ash Making Process

1. Material preparation of different types of combination.
2. Sugarcane bagasse ash and rice husk ash
3. Burn the sugarcane bagasse in controlled environment to produce ash rich in silica. Maintain a specific temperature range between (500°C to 750°C) for duration (4-6 hrs.) to achieve the desired amorphous silica content.
4. After combustion the ash is cooled. Cooled ash is ground to a fine powder.
5. The ground ash is then sieved to specific particle size (75 mesh) to remove larger pieces.



Fig.3.1 Sugarcane bagasse ash

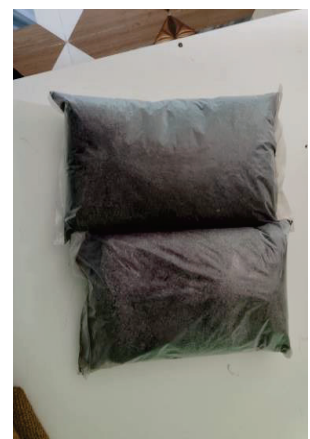


Fig.3.2 Sugarcane bagasse ash

B. Material mixing proportion:

We are going to prepare bricks using agricultural waste (sugarcane bagasse ash and rice husk ash) in proportions as follows:

Table.3.1 Materials required for SBA+RHA Bricks.

Percentage of material	Weight of clay required (kg)	Weight of SBA required (kg)	Weight of RHA required (kg)	Water required (adjustable) (lit)
0%	40	0	0	7
3%	38.8	0.6	0.6	7
6%	37.6	1.2	1.2	7
9%	36.4	1.8	1.8	7
12%	35.2	2.4	2.4	7

Table.3.2 Material mixing proportion

Sr no.	Agricultural waste	Material Proportions				
		0%	3%	6%	9%	12%
1	No. of bricks (Sugarcane bagasse ash + rice husk ash)	-	14	14	14	14
2	No. of Conventional bricks	14	-	-	-	-

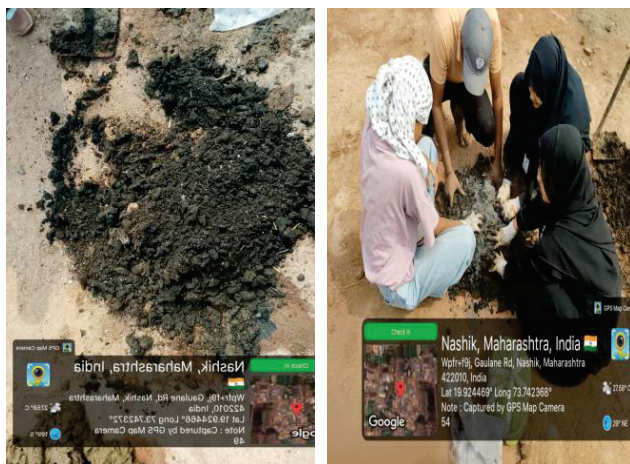


Fig. 3.1 Material mixing Process

C. Mix Design

1. References codes:

- IS 1077:1992
- IS 2117:1991
- S.K. Duggal – Building Materials
- IS 2185 (Part I): 2005

2. Brick Details:

Brick Size: 220 × 100 × 75 mm
 Volume of a Single Brick = 0.00165 m³
 Volume of 12 Bricks = 0.00165 × 12 = 0.0198 m³
 Dry Density of Brick = 1800 kg/m³ (Assume)
 Total Mass of Bricks = 1800 × 0.0198 = 35.64 kg

3. Waste of material:

Consider 10% Waste = (35.64 × 10) / 100 = 3.564 kg
 Total mass of brick with waste: 3.564 + 35.64 = 39.204 kg ≈ 40 kg

4. Water Content:

Consider 15% of water = 40 × (15 / 100) = 7 lit

5. Material Required:

Clay required for 3% of proportion = Total mass of brick percent of clay added/100

$$= \frac{40 \times 97}{100}$$

$$= 38.8 \text{ kg}$$

D. Brick Making Process

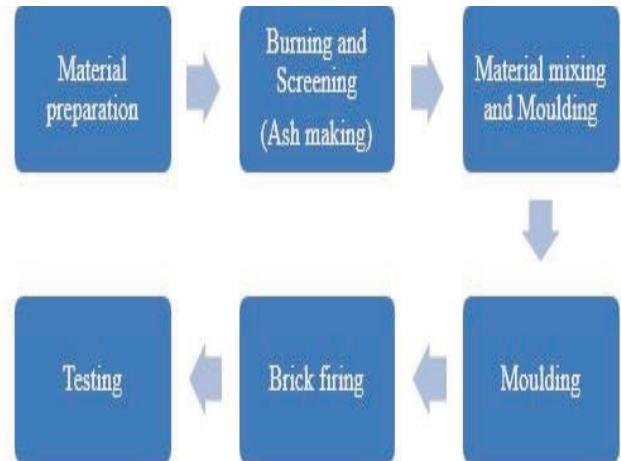


Fig.3.2 Brick making process



Fig.3.3 Bricks made with 3% (SBA+RHA)



Fig.3.4 Bricks made with 6% (SBA+RHA)



Fig.3.5 Bricks made with 9% (SBA+RHA)

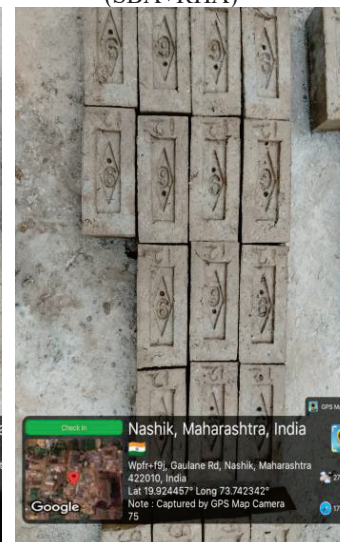


Fig.3.6 Bricks made with 12% (SBA+RHA)

IV. BRICK TESTING

We have performed several test on bricks as per indian standard to find the quality performance of these bricks.

A. Test Procedure

1. Compressive strength test (IS 3495 Part 1 :1992)

Pre Conditioning: Remove unevenness observed in the bed faces to provide two smooth and parallel faces by grinding. Immerse the specimen in water at room temperature for 24 hours. Remove the specimen from water and drain out any surplus water.

Fill the frog (where provided) and all voids in the bed face flush with cement mortar Store under the damp jute bags for 24 hours followed by immersion in clean water for 3 days. Remove, and wipe out any traces of moisture.

Place the specimen with flat faces horizontal, and mortar filled face facing upwards between two 3 ply plywood sheets each of 3 mm thickness and carefully centred machine. of between plates of the testing Apply load axially at a uniform rate 14 N/mm² per minute till failure occurs and note the maximum load at failure. The load at failure shall be the maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine.



Fig. 4.1 pre conditioning for compressive strength test

Compressive strength in N/mm²
 = Maximum load at failure in N /Average net area of the two faces under compression in mm²

2. Water Absorption Test (IS 3495 Part 2 :1992)

Preconditioning: Dry the specimen in a ventilated oven at a temperature of 105 to 115°C till it attains substantially constant mass.

Cool the specimen to room temperature and obtain its weight (M₁). Specimen warm to touch shall not be used for the purpose
 Procedure: Immerse completely dried specimen in clean water at of 27+- 2°C for 24 hours. Remove the specimen and wipe out any traces of water with a damp cloth and weigh the specimen. Complete the weighing 3 minutes after the speci- men has been removed from water (M₂)Water absorption, percent by mass, after 24-hour immersion in cold water is given by the following formula:

$$(M_2 - M_1 / M_1) * 100$$

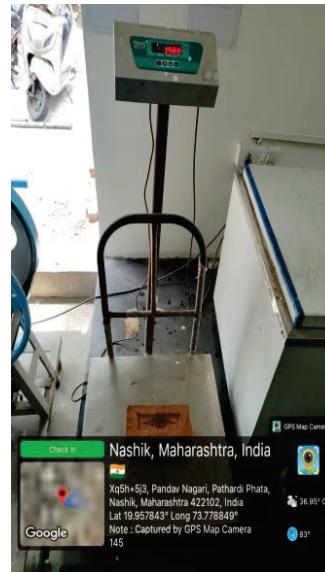


Fig.4.2 Initial and final weight taken for water absorption test



Fig. 4.3 Curing of bricks for water absorption test

- Efflorescence test (IS 3495 Part 3 : 1992) Observe after soaking and drying rated for salt deposits.
- Field tests such as Toughness test, Hardness test, Soundness test and Structure test as per (IS 1077:1992)

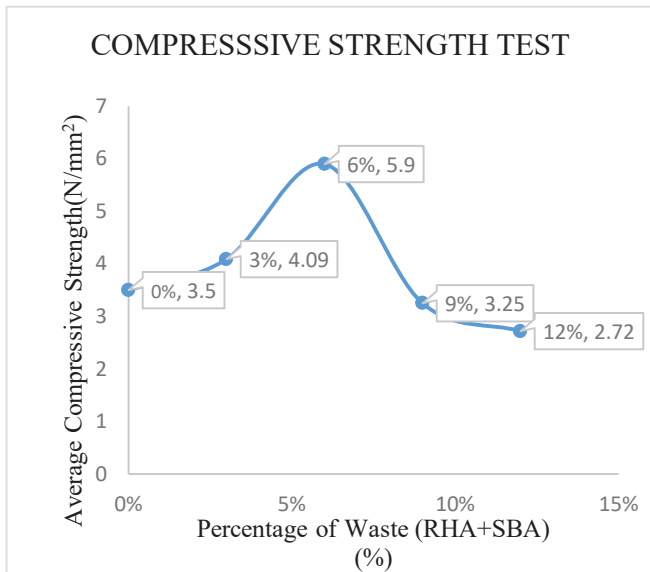
V. BRICKS RESULTS AND COCLUSION

1. Compressive Strength of bricks

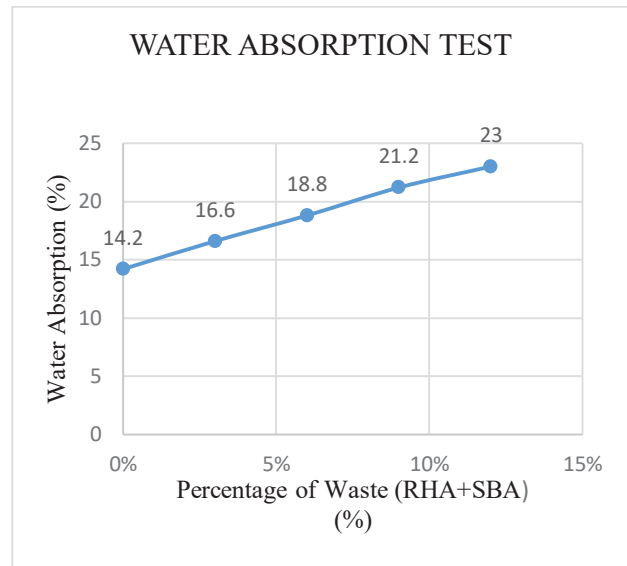
The compressive strength was tested for various percentages of agricultural waste (Sugarcane Bagasse Ash and Rice Husk Ash) replacing traditional soil content.

Table.5.1 Compressive strength of bricks.

Waste Percentage (RHA+SBA)	Average Compressive strength (N/mm ²)
0%	3.5
3%	4.09
6%	5.90
9%	3.25
12%	2.72



Graph.5.1 Compressive strength results



Graph.5.2 Water absorption test results

As per above results, The compressive strength of the bricks increases with the addition of agricultural ash up to a 6% replacement level, reaching a peak of 5.90N/mm². represents a significant improvement over the control (0%) brick. Beyond 6%, specifically at 9% and 12%, the strength begins to drop. This occurs because excessive ash increases the porosity and reduces the cohesive clay content, leading to a more brittle and less dense brick.



Fig.5.1 Performing Compressive strength test

2. Water Absorption of bricks

Water absorption is a critical factor for durability; per standard codes, it should generally not exceed 20% for first-class bricks.

Table.5.2 Water Absorption of bricks.

Waste Percentage (RHA+SBA)	Water Absorption (%)
0%	14.2
3%	16.6
6%	18.8
9%	21.2
12%	23.0

3. Efflorescence Test

Efflorescence test was conducted on the brick samples in accordance with relevant IS provisions. The bricks were immersed in water and dried under specified conditions.

Table.5.3 Efflorescence test

Waste Percentage (RHA+SBA)	Efflorescence	Remarks
0%	Nil	No visible salts deposit
3%	Slight	Thin white deposit on surface (<10%)
6%	Slight	Slight salt deposit, acceptable as per IS code
9%	Moderate	White deposit covering 10–50% surface
12%	Heavy	Heavy salt deposit covering >50% surface

From the above observations, bricks with 0%, 3%, and 6% replacement showed Nil to Slight efflorescence, indicating acceptable quality as per IS code.

4. Field Test

Hardness test:

A quality brick should be resistant to surface scratches. To assess this, a sharp object or fingernail is used to attempt scratching the brick's surface. No visible scratch marks are left. Hence, the brick is considered to be hard and durable.

5. Soundness Test:

The soundness test evaluates a brick's ability to withstand sudden impacts. In this test, two bricks are randomly selected and struck against each other. The impact produces a clear, ringing sound and the bricks remain unbroken, they are considered to be of good quality.

VI. COCLUSION

The research concludes that replacing traditional soil with a combination of sugarcane bagasse ash (SBA) and rice husk ash (RHA) is a viable sustainable solution, with an optimal replacement level of 6%. Bricks at this 6% threshold achieved a peak compressive strength of 5.90 N/mm², significantly outperforming traditional bricks while maintaining acceptable water absorption and efflorescence levels per IS standards. However, exceeding this 6% limit causes a decline in structural integrity due to increased porosity and reduced clay cohesion, making the 6% mix the most effective balance for eco-friendly construction.

Sustainable bricks at the 6% Waste outperformed (5.90 N/mm²) traditional (0%) bricks, which measured only 3.5 N/mm²

1. Adding ash beyond 6% (9% and 12%) caused strength to decline to 3.25 N/mm² and 2.72 N/mm²
2. Mixes with 3%, and 6% ash stayed within the 20% water absorption limit required for first-class bricks.
3. Efflorescence tests for the 3%, 6% mix showed Slight salt deposits, which is considered acceptable under IS code.
4. Environmental effects of wastes and disposal problems of waste can be reduced through this research.
5. Use of bagasse ash and wheat straw ash in brick can solve the disposal problem; reduce cost and produce a 'greener' Eco friendly bricks for construction.

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