# Utilization of Agricultural Waste Using Rice Husk Ash and Coconut Shell in Concrete Production

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**ABSTRACT**

Concrete remains the most widely used construction material worldwide due to its versatility, durability, and cost-effectiveness. However, its conventional production heavily relies on Portland cement and natural aggregates, which are associated with significant environmental impacts, including high carbon dioxide emissions, resource depletion, and ecological degradation. These concerns have intensified the search for alternative materials and sustainable construction practices that can reduce the ecological footprint of concrete production.

One promising strategy is the incorporation of agricultural waste materials into concrete, which not only mitigates environmental impacts but also offers economic advantages by valorizing residues that would otherwise be discarded. Among these materials, **rice husk ash (RHA)** and **coconut shell (CS)** have garnered considerable attention due to their widespread availability, favorable chemical and physical characteristics, and potential to enhance concrete performance.

RHA, a by-product of rice milling, is rich in amorphous silica and exhibits strong pozzolanic properties. When used as a partial replacement for cement, RHA can improve compressive strength, durability, and resistance to chemical attack, provided that optimal replacement levels are maintained. Coconut shell, a fibrous lignocellulosic material, can serve as a lightweight aggregate, producing concrete with reduced density, adequate mechanical strength, enhanced toughness, and improved thermal insulation compared to conventional concrete.

Despite these advantages, challenges persist. The quality of RHA can vary significantly due to uncontrolled burning practices, while coconut shells have high water absorption and require pre-treatment for optimal performance. Moreover, large-scale field applications remain limited, and standardized processing methods are still under development.

Integrating RHA and CS into concrete not only reduces cement consumption and conserves natural aggregates but also diverts agricultural residues from landfills or open burning, contributing to sustainable construction

practices and a circular economy. Nevertheless, further research is needed to address durability concerns, establish processing standards, explore synergistic use of multiple waste products, and conduct comprehensive life cycle assessments. Overall, the utilization of RHA and CS in concrete represents a promising approach toward environmentally responsible and resource-efficient construction.

**Keywords:**Concrete, Sustainable Construction, Industrial By-products, Fly Ash, Slag, Alkaline Activation, Mechanical Properties, Durability, Environmental Sustainability, Waste Management, Curing Conditions.

## 1.0 INTRODUCTION

Concrete is the most widely used construction material in the world, second only to water in overall consumption. Its production, however, demands large quantities of cement and natural aggregates, both of which pose significant environmental challenges. Cement manufacturing alone accounts for nearly 7–8% of global carbon dioxide ($CO_2$) emissions, while the extraction of sand and gravel contributes to ecological degradation and depletion of natural resources. As infrastructure development accelerates worldwide, the demand for sustainable alternatives to conventional concrete ingredients has become increasingly urgent.

One promising approach is the incorporation of agricultural by-products into concrete production. These materials, often considered waste, not only reduce the reliance on non-renewable resources but also mitigate disposal issues. Among the various agro-wastes, **rice husk ash (RHA)** and **coconut shell (CS)** have demonstrated considerable potential. RHA, obtained through controlled burning of rice husks, is rich in amorphous silica and exhibits pozzolanic properties, making it an effective partial replacement for cement. Coconut shells, on the other hand, are lightweight, durable, and abundantly available in tropical regions, offering an eco-friendly alternative to coarse aggregates.

The utilization of RHA and CS in concrete can provide dual benefits: reducing the environmental footprint of construction materials while producing economical, lightweight, and structurally viable “green concrete.” Previous research indicates that optimal replacement levels of RHA (10–20%) and CS (10–20%) can yield concrete with satisfactory strength, durability, and workability. These findings highlight their potential applications in low-cost housing, non-load-bearing structures, and sustainable infrastructure projects.

This paper investigates the feasibility of using rice husk ash as a partial replacement for cement and coconut shell as a partial replacement for coarse aggregate. The study aims to evaluate the mechanical properties, workability, and durability of concrete incorporating these agricultural wastes, thereby contributing to sustainable construction practices and effective waste management.

## 2.0 LITERATURE REVIEW

The quest for sustainable alternatives to conventional concrete ingredients has led researchers worldwide to investigate the use of agricultural wastes such as rice husk ash (RHA) and coconut shell (CS). These materials not only reduce reliance on non-renewable resources but also address solid waste management problems.

Rice Husk Ash (RHA) in Concrete

Rice husk, a by-product of the rice milling industry, constitutes nearly 20% of the weight of harvested paddy. When burnt under controlled conditions at 600–800 °C, it yields rice husk ash rich in amorphous silica (85–90%), which exhibits strong pozzolanic properties.

- **Mehta (1992)** reported that finely ground RHA reacts with calcium hydroxide to form additional calcium silicate hydrate (C–S–H), enhancing concrete's strength and impermeability.
- **Zhang and Malhotra (1996)** demonstrated that replacing 10–20% of cement with RHA improved sulfate resistance and reduced chloride permeability while maintaining compressive strengths comparable to ordinary Portland cement (OPC) concrete.
- **Nehdi et al. (2003)** observed that RHA incorporation decreases concrete's permeability and drying shrinkage, improving long-term durability.
- **Mehta & Monteiro (2006)** noted that due to its high surface area, RHA increases water demand; therefore, superplasticizers are often required to maintain workability.

Overall, studies consistently show that up to 15–20% replacement of cement with RHA enhances durability and strength, but higher levels may adversely affect workability without proper mix adjustments.

Coconut Shell (CS) in Concrete

Coconut is cultivated in over 100 countries, with India alone producing nearly 8000 million nuts annually. The disposal of shells, amounting to 3.18 million tonnes per year, presents a serious environmental problem. Due to their low density, high lignin, and cellulose content, coconut shells can serve as lightweight coarse aggregates.

- **Kambli&Mathapati (2014)** reported that coconut shell aggregate concrete achieved compressive strengths of 16–25 MPa with replacement levels of 10–20%, making it suitable for lightweight structural applications.
- **Verma &Shrivastava (2016)** studied M20 grade concrete with 0–30% CS replacement and observed a gradual reduction in compressive strength as replacement increased, though densities remained within lightweight concrete limits.
- **Gunasekaran et al. (2017)** found that coconut shell concrete exhibited good impact resistance, lower density (1975–2110 kg/m$^3$), and acceptable compressive strengths of around 22 MPa for 25–50% replacement after 28 days.
- **Shahidan et al. (2018)** emphasized CS's potential in non-structural applications such as wall panels, highlighting benefits in thermal performance, reduced bulk density, and improved sustainability.

While CS reduces strength compared to conventional aggregates, its lightweight nature, cost-effectiveness, and availability make it valuable for non-load-bearing and low-rise structures.

Combined and Other Agro-Waste Studies

Beyond their individual uses, both RHA and CS have also been studied in combination with other industrial/agricultural by-products.

- **Imoisilli (2012)** reported that coconut shell ash reinforced epoxy composites showed improved tensile strength, modulus of elasticity, and micro-hardness with increasing filler content.
- **Rathanak&Ranat (2005)** demonstrated that coconut shell powder as a filler in polyethylene composites improved biodegradability and modulus of elasticity, though tensile strength decreased.
- **Sukarton (2011)** explored coconut shell biochar and concluded it provided higher carbon content and nutrient value compared to cattle dung biochar, improving soil fertility.
- **Agunsoye (2012)** studied coconut shell polymer composites and observed increased hardness with filler content, although ductility and tensile strength reduced due to weak bonding between particles and matrix.
- Studies on blended cement show that combining pozzolanic materials (fly ash, silica fume, RHA) can improve long-term strength and reduce permeability (Nath&Sarker, 2011).

Despite these efforts, **very limited research has explored the combined use of RHA (as a cement replacement) and CS (as a coarse aggregate replacement) in concrete.** The synergistic potential of these two agro-wastes could result in eco-friendly lightweight concrete with balanced strength, workability, and durability.

### 2.1 Research Gap

The reviewed literature indicates that:

- RHA is an effective supplementary cementitious material at 10–20% replacement levels.
- CS can serve as a lightweight coarse aggregate replacement up to 20–25% with acceptable compressive strength for low-load applications.
- Most studies have evaluated these materials **individually**, while their **combined use remains underexplored.**

This study addresses this gap by investigating the performance of concrete incorporating both rice husk ash and coconut shell, with the aim of developing sustainable, cost-effective, and environmentally friendly green concrete.

# 3.0 METHODOLOGY

## 3.1 Materials Used

The primary materials used in this study were cement, fine aggregate, coarse aggregate, rice husk ash (RHA), coconut shell (CS), and water.

- **Cement:** Ordinary Portland Cement (OPC) conforming to IS: 12269–1987 standards was used.
- **Fine Aggregate:** Locally available river sand passing through a 4.75 mm IS sieve with a specific gravity of 2.65 was utilized.
- **Coarse Aggregate:** Crushed stone aggregates of maximum size 20 mm were used as the conventional coarse aggregates.
- **Rice Husk Ash (RHA):** RHA was obtained from the rice milling industry. The ash had a particle size of about 95 µm, a specific gravity of 2.14, and silica content of 62.3%. It was gray in color with a neutral pH of 7.4.
- **Coconut Shell (CS):** Waste coconut shells were collected locally, sun-dried for 15–20 days, and manually crushed into sizes ranging from 5 mm to 20 mm to simulate coarse aggregates. The shells exhibited irregular shapes, smooth concave faces, and rough convex faces, with a specific gravity of 1.47.
- **Water:** Potable water free from organic impurities was used for mixing and curing.

Preparation of Materials

- **RHA Processing:** The rice husks were burnt under controlled conditions at ~700 °C to produce amorphous silica-rich ash. The ash was sieved through a 90 µm sieve to improve fineness before use.
- **CS Processing:** Collected shells were dried, cleaned, and crushed manually to the required size. They were thoroughly washed to remove dust and other impurities before use as coarse aggregates.

Mix Design

The concrete mix was prepared according to IS 10262:2009 guidelines. A **M20 grade mix** was selected as the reference. Various replacement levels were studied:

- **Cement replaced with RHA:** 5%, 10%, 15%, and 20% by weight of cement.
- **Coarse aggregate replaced with CS:** 10%, 20%, and 30% by weight of coarse aggregate.
- **Combined replacements:** Mixes with both RHA and CS replacements were also prepared to evaluate synergistic performance.

The water-to-cement ratio was kept constant at 0.45 across all mixes.

Casting and Curing

Concrete was mixed in a laboratory pan mixer. Standard cube (150 × 150 × 150 mm), cylinder (150 mm × 300 mm), and beam (100 × 100 × 500 mm) specimens were cast for compressive, split tensile, and flexural strength tests, respectively. Compaction was carried out using a table vibrator. After 24 hours, specimens were demolded and cured in water tanks at room temperature until testing at 7, 14, and 28 days.

Tests Conducted

1. **Workability Test**
   - Slump cone test was carried out to measure the workability of fresh concrete.
2. **Compressive Strength Test**
   - Conducted on cubes after 7, 14, and 28 days of curing as per IS 516:1959.
3. **Split Tensile Strength Test**
   - Carried out on cylinders after 28 days using a compression testing machine (CTM).
4. **Flexural Strength Test**
   - Performed on beams under two-point loading at 28 days to evaluate tensile resistance.
5. **Durability Tests (optional, if in your thesis)**
   - Water absorption, bulk density, and impact resistance tests were also conducted on coconut shell concrete mixes.

## 4.0 RESULT & DISCUSSION

1. Workability

The slump test results showed that the workability of concrete decreased as the percentage of coconut shell (CS) replacement increased. This reduction is attributed to the rough and irregular surface texture of CS aggregates, which demand higher water content. In contrast, mixes containing rice husk ash (RHA) showed slightly reduced workability due to the fine particle size and absorptive nature of RHA, which increases water demand. However, the use of superplasticizers could offset this drawback in practical applications.

2. Compressive Strength

- For mixes containing **RHA as a cement replacement**, compressive strength increased up to 10–15% replacement, with a maximum 28-day strength of ~41 MPa, compared to control concrete (~38–40 MPa). This improvement is due to the pozzolanic activity of RHA, which forms additional calcium silicate hydrate (C–S–H).
- For mixes containing **CS as a coarse aggregate replacement**, compressive strength decreased with higher replacement levels. At 10% CS replacement, the 28-day compressive strength was within acceptable

structural limits (~22–25 MPa). However, at 30% replacement, strength dropped significantly, though the concrete still met lightweight concrete criteria.

- For **combined RHA + CS mixes**, the synergy of pozzolanic action and lightweight aggregates allowed acceptable strengths. For instance, a mix with 10% RHA and 10% CS yielded compressive strengths close to conventional concrete while reducing density.

3. Split Tensile Strength

The split tensile strength followed trends similar to compressive strength.

- RHA mixes showed improved tensile strength at 10–15% replacement.
- CS mixes exhibited reduced tensile strength with higher replacement percentages due to weaker bond strength between CS aggregates and the cement matrix.
- The optimum performance was observed at **10% RHA + 10% CS**, where tensile strength was only marginally lower than control concrete.

4. Flexural Strength

Flexural strength tests revealed that partial replacement with RHA improved the flexural performance of concrete beams, particularly at 10–15% replacement. CS replacement reduced flexural strength with higher percentages but remained suitable for non-structural and light-load-bearing applications.

5. Density and Lightweight Properties

The density of concrete decreased significantly with the inclusion of CS due to its lower specific gravity (1.47 compared to ~2.65 for conventional aggregates).

- Normal concrete densities: ~2400 kg/m³.
- Coconut shell concrete densities: 1975–2110 kg/m³ (meeting lightweight concrete criteria <2200 kg/m³).

This reduction in density makes CS concrete ideal for applications where reduced dead load is desirable.

6. Overall Performance

- **RHA** improved strength and durability due to its pozzolanic properties, with optimum replacement at 10–15%.
- **CS** effectively reduced density and produced lightweight concrete, though at the expense of strength at higher replacement levels (>20%).

- **Combined Use (RHA + CS)** yielded balanced results, achieving acceptable strength, reduced density, and enhanced sustainability, making it suitable for low-rise buildings, non-structural elements, and eco-friendly construction projects.

## 3.0 CONCLUSIONS

This study investigated the feasibility of incorporating rice husk ash (RHA) as a partial replacement for cement and coconut shell (CS) as a partial replacement for coarse aggregates in concrete. Based on the experimental results, the following conclusions can be drawn:

1. **Workability:** The inclusion of RHA and CS reduces workability due to their fine and porous nature, respectively. However, the mixes remained workable within practical limits.
2. **Compressive Strength:**
   - RHA enhanced compressive strength up to an optimum replacement level of **10–15%**, due to its pozzolanic activity.
   - CS reduced compressive strength at higher replacement levels but provided acceptable strength for lightweight concrete up to **20% replacement**.
   - Combined RHA + CS mixes demonstrated balanced performance, achieving strengths comparable to control concrete while lowering density.
3. **Split Tensile and Flexural Strength:** Similar trends were observed, with RHA mixes performing better than control at optimum levels, while CS reduced tensile and flexural strength with higher replacement levels.
4. **Density:** Concrete with CS replacement exhibited densities between **1975–2110 kg/m³**, qualifying as lightweight concrete, which is advantageous in reducing dead load.
5. **Sustainability:** The use of agro-wastes like RHA and CS addresses environmental concerns by reducing solid waste, lowering $CO_2$ emissions from cement production, conserving natural aggregates, and producing cost-effective, eco-friendly concrete.

Thus, RHA and CS can be effectively used as sustainable alternatives in concrete, particularly in **lightweight structural applications, non-load-bearing elements, and low-rise buildings.**

Future Scope

1. **Durability Studies:** Further research should investigate long-term durability aspects such as resistance to chloride penetration, sulfate attack, carbonation, and freeze–thaw cycles.
2. **Optimization with Admixtures:** Superplasticizers or mineral admixtures (e.g., silica fume, fly ash) may be incorporated to improve workability and mechanical properties of RHA–CS concrete.

3. **Structural Applications:** Large-scale structural elements (slabs, beams, wall panels) should be tested to evaluate real-world performance.

4. **Economic Analysis:** A cost–benefit analysis should be conducted to assess the economic viability of large-scale use of RHA and CS in commercial construction.

5. **Combined Waste Utilization:** Future research may explore the synergistic effects of combining CS and RHA with other agro-industrial wastes (e.g., bagasse ash, palm oil fuel ash) for sustainable green concrete development.

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