

Sustainable Practice on Cement Brick with Coconut-Shell-Ash

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ABSTRACT

The increasing demand for sustainable construction materials has led to the utilization of coconut waste as a partial replacement for conventional building materials. This study aims to investigate the use of coconut shell ash as a partial replacement for the production of cement bricks. Coconut shell ash is one of the most available agro-coconut-waste, offers an eco-friendly solution to cement material in the construction industry, whose production contributes significantly to global carbon-dioxide emissions. Bricks of cement material were manufactured with 5% and 10% replacement of cement by and evaluated through various tests, such as compressive strength, water absorption rate, hardness, soundness effect, impact resistance, and efflorescence. These experimental results demonstrated that incorporated bricks exhibited satisfactory performance and satisfied standard requirements. The study concludes that coconut shell ash can be effectively used as a partial cement replacement in cement brick manufacturing & contributing to sustainable development and reduced environmental impact.

Keywords:- Agro-Coconut-Waste, Coconut Shell Ash, Cement Bricks, Sustainable Practice

1. INTRODUCTION

The construction industry is a major contributor to economic development and urban growth; however, it is also responsible for significant environmental impacts due to the extensive use of natural resources and energy-intensive materials. Among various construction materials, bricks are one of the most widely used components in building construction because of their durability, availability, and structural performance. The increasing demand for bricks has led to the excessive consumption of cement, aggregates, and other raw materials, resulting in resource depletion, high energy consumption, and environmental degradation.

Ordinary Portland cement (OPC) is a primary binding material in cement brick production, but its manufacturing process releases a large amount of carbon dioxide (CO₂) into the atmosphere. Cement material production, which contributes nearly 5% of global greenhouse gas emissions due to the calcination of limestone and the combustion of fossil fuels. With the rapid growth of construction activities, the demand for cement continues to rise, further intensifying environmental concerns such as global warming and climate change. Therefore, reducing cement consumption has become a crucial objective in sustainable construction practices. In recent years, the use of industrial and agricultural waste materials as partial replacements for cement has gained significant attention. Agricultural wastes, in particular, pose serious disposal problems and contribute to environmental pollution if not managed properly. Coconut shells are abundantly available agricultural by-products in many regions and are often discarded as waste. When burned under controlled conditions, coconut shells produce coconut shell ash (CSA), which exhibits pozzolanic properties and can be utilized as a supplementary cementitious material.

The incorporation of coconut shell ash as a partial replacement for cement in brick production offers multiple benefits, including reduced cement usage, lower CO₂ emissions, effective waste management, and cost savings. Additionally, CSA has the potential to enhance certain strength and durability properties of cement bricks. This study focuses on evaluating the mechanical and durability performance of cement bricks containing coconut shell ash and comparing them with conventional cement bricks to assess their suitability for sustainable construction applications.

1.1 Problem Statement

The increasing use of cement in brick production has led to high carbon dioxide emissions, resource depletion, and rising construction costs. At the same time, large quantities of coconut shell waste are generated and improperly disposed of, causing environmental pollution. There is a need to explore sustainable alternatives by partially replacing cement with coconut shell ash in brick production to reduce environmental impact while maintaining the strength and durability of conventional cement bricks.

1.2 Objectives

- To find the quality of CSA bricks by testing them through field tests.
- To find the water absorption rate of the CSA bricks
- To find the compressive strength of the CSA bricks.

2. LITERATURE REVIEWED

Cement production has significant environmental impacts, prompting research into sustainable alternatives. Coconut shell ash, an agricultural waste, can partially replace cement in bricks, improving strength, durability, and sustainability. This review summarizes previous studies on its use and identifies areas for further research.

- **Taku J. K., Utsev J.T. (2008):** Studied the suitability of coconut shell ash (CSA) as a partial replacement of cement in concrete. The study determined the optimum replacement level of OPC with CSA for the required compressive strength and compared the setting times of OPC and OPC-CSA pastes.
- **Abdulfatah Abubakar & Muhammed Saleh Abubakar (2011):** Conducted laboratory experiments to assess coconut shell as coarse aggregate in concrete, following BS 4550 and BS 812 standards.
- **Amarnath Yerramala & Ramachandrudu C. (2012):** Investigated the strengths and transport properties of concrete with coconut shell (CS) as coarse aggregate. Also studied the effect of fly ash as cement and aggregate replacement on concrete properties.
- **Ahlawat D., Kalurkar L.G. (2012):** Assessed the feasibility of using coconut shells as coarse aggregate in concrete, highlighting their potential as an alternative to natural aggregates.
- **Gopal Charan Behera & Ranjan Kumar Behera (2013):** Developed mix designs for lightweight aggregate concrete using coconut shells as coarse aggregate, studying the effect of replacement percentages on mechanical properties, and verifying results with international codes.
- **Kumar L., Pandey K.K., Khan S. (2017):** Found that coconut shells are suitable as low-strength lightweight aggregates, reducing construction costs due to their abundance and low price.
- **Desai B.M., Umrvavia N., Gujarat K.B. (2017):** Investigated CSA substitution for OPC, showing acceptable performance in compressive strength, sorptivity, and sulfate resistance.

2.1 Conclusion Based on Reviewed Literature

The reviewed literature indicates that coconut shell ash (CSA) and coconut shells are effective and sustainable alternatives in construction. CSA can partially replace cement in concrete and bricks, providing adequate compressive strength and durability while reducing CO₂ emissions. Coconut shells can also be used as lightweight coarse aggregates, lowering material costs and utilizing agricultural waste. Most studies suggest optimum replacement levels between 5% and 20% for cement, depending on strength requirements. Overall, CSA and coconut shells offer an eco-friendly solution for sustainable construction, though further research is needed to standardize mix designs and evaluate long-term performance.

Identified Research Gaps

Although coconut shell ash (CSA) shows promise as a partial cement replacement, research gaps remain. There is no standardized optimum replacement level, and long-term durability aspects of CSA bricks are underexplored. Limited studies assess all key properties together, and variations in local CSA quality are not fully considered. Additionally, practical structural applications and detailed economic or environmental benefits of CSA bricks require further investigation.

3. METHODOLOGY

3.1 Materials

3.1.1 Cement

In this experimental study, ordinary Portland cement (OPC) is used, as it is the most common type of cement worldwide. The rising cost of cement has encouraged researchers to explore pozzolanic materials as partial replacements to reduce costs and make construction more affordable. Historically, non-hydraulic cements were used as early as 6500 BC, and later the Greeks and Romans developed hydraulic cement (Li, 2011). Cement remains a widely used construction material today due to its malleability, adaptability, strength, and workability. The global demand for cement continues to grow, with current consumption estimated at around 12 million tons per year and rising steadily (Khitab, 2020). However, cement production has severe environmental impacts. It generates large amounts of heat and emits significant quantities of carbon dioxide (CO₂), a major contributor to greenhouse gas emissions (Bheel et al., 2020; Mangi et al., 2019). On average, producing one ton of cement releases approximately one ton of CO₂ into the atmosphere. Cement production alone accounts for 5–7% of CO₂

emissions from industrial sources (Bheel et al., 2020). Additionally, the extraction and processing of raw materials for cement contribute to environmental pollution and depletion of natural resources (Mangi et al., 2019).

3.1.2 Crushing Aggregate

6 mm crushing aggregate consists of small stones about 6 millimeters in size, obtained by crushing larger rocks. In cement brick making, it is mixed with cement, sand, and water to provide strength, stability, and durability while reducing shrinkage and cracking during curing. The aggregates enhance compressive strength, improve resistance to weathering, and stabilize the brick mixture. After mixing, the material is poured into molds and allowed to cure, with cement binding the aggregates into solid bricks. Bricks made with 6mm crushing aggregate are widely used in residential, commercial, and infrastructure projects. Proper aggregate quality, mixing ratios, and curing conditions are essential to ensure optimal brick performance.

3.1.3 Coarse Aggregate

Crushed granite stone with a nominal size of 12.5 mm served as the coarse aggregate. The material had a bulk density of 1650 kg/m³ and a specific gravity of 2.7. Water absorption rate was measured at 1.14%, while no free moisture was observed during the time of testing. Sieve analysis of a 2 kg sample confirmed the particle distribution was in line with IS 383:1970 standards. Nearly all particles passed the 12.5 mm sieve, while a significant portion was retained on the 10 mm and 4.75 mm sieves, ensuring a good mix of large and medium particles. The calculated fineness modulus was 6.35, indicating a standard grading ideal for structural concrete applications.

3.1.4 Fly Ash

Fly ash is the inorganic mineral residue obtained after burning coal or lignite in boilers. It is primarily collected from the hoppers of electrostatic precipitators (ESP), while pond ash is collected from ash ponds, and bottom ash from the bottom of boilers. The properties of fly ash depend on the type of coal or lignite used and the efficiency of the boilers.

India relies heavily on coal for power generation, and as power production increases, the generation of fly ash is also expected to rise from about 100 million tons to an estimated 170 million tons by 2010. Improper disposal of fly ash can pose serious environmental challenges. The proposed study considers the use of both fly ash and pond ash in construction, depending on their availability, to promote sustainable material utilization.

3.1.5 Coconut Shell Ash

Coconut shell powder (CSP) is widely used in products such as decorative materials and ropes due to its low cellulose content, which allows it to absorb less water (Gummadi, 2012). Coconut shells, a waste product from the agricultural industry, have little economic value, and improper disposal can cause environmental problems. They are also suitable for producing carbon black because of their natural structure and low ash content. In this study, coconut shells were burned under controlled conditions at 500–550 °C for two hours to produce coconut shell ash (CSA). The ash was then sieved through a #200 sieve and can be used as a partial cement replacement in concrete or bricks, promoting sustainable construction practice

3.1.6 Water

Ordinary tap water was used in the production of bricks. Water is one of the most important elements in construction, but people still ignore the quality aspect of this element. The water is required for the preparation of mortar, mixing of cement concrete, and for curing work, etc., during construction work. The quality and quantity of water has much effect on the strength of mortar and cement in construction work. Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials, or other substances that may be deleterious to bricks. Portable water is generally considered satisfactory for mixing. The PH value of water should not be less than 6.

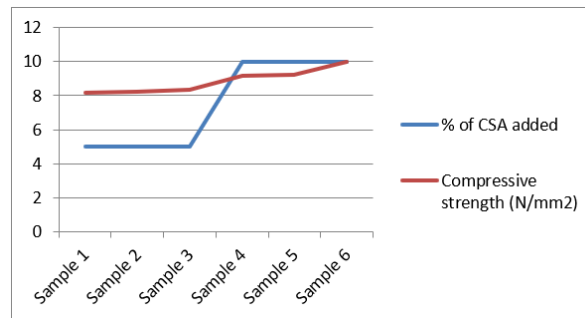
3.2 Design, Mixing, and Moulding of Materials

In this study, first-class cement bricks were produced with a target compressive strength of 7–10 N/mm². The standard mixture for one brick consisted of 60 % fly ash, 30 % sand or stone dust, and 10 % cement. Cement was partially replaced with coconut shell ash (CSA) at 5 % and 10 % levels. For 5 % replacement, the mixture included 1380 g fly ash, 690 g sand dust, 218.5 g cement, and 11.5 g CSA, with a water ratio of 0.43, resulting in a compressive strength of 8.90 N/mm² after curing. For 10 % replacement, the mixture included 1440 g fly ash, 720 g sand dust, 216 g cement, and 24 g CSA, with a water ratio of 0.41, achieving 9.5 N/mm². Both mixtures produced first-class bricks, confirming the suitability of CSA as a partial cement replacement.

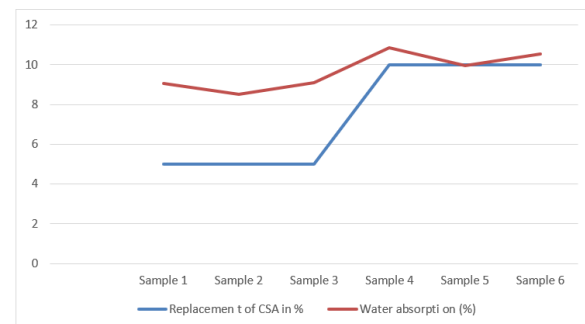
4. RESULTS AND DISCUSSION

4.1 Compressive Strength Test

The compressive strength of cement bricks increased with the percentage of coconut shell ash (CSA) used. For bricks with 5 % CSA, the load at failure ranged from 180,230 N to 188,700 N, corresponding to compressive strengths between 8.19 N/mm² and 8.35 N/mm². When CSA was increased to 10 %, the load at failure ranged from 204,520 N to 225,000 N, resulting in compressive strengths of 9.15 N/mm² to 10.00 N/mm². All tested samples had a loaded area of 22,000 mm². These results demonstrate that partial replacement of cement with CSA enhances the compressive strength of bricks, with higher CSA content producing stronger bricks suitable for first-class classification.



4.2 Water Absorption Test



The water absorption of cement bricks increased slightly with higher coconut shell ash (CSA) content. For bricks with 5 % CSA, the dry weights ranged from 2,090 g to 2,120 g, wet weights from 2,280 g to 2,300 g, resulting in water absorption values between 8.49 % and 9.09 %. For 10 % CSA bricks, dry weights ranged from 2,370 g to 2,410 g, wet weights from 2,620 g to 2,660 g, with water absorption between 9.95 % and 10.83 %. These results indicate that while CSA slightly increases water absorption, the values remain within acceptable limits for first-class brick standards.

4.3 Quality Tests of CSA Cement Bricks

The CSA cement bricks demonstrated excellent quality in all tested aspects. They have a uniform rectangular shape and consistent size, indicating good workmanship. The bricks also exhibited a consistent and satisfactory color. Structural integrity tests confirmed their sound construction. In the impact test, bricks dropped from a height of 1 meter did not break, while hardness testing showed no scratches or impressions when marked with a nail. Additionally, the efflorescence test revealed no visible salt deposits on the brick surfaces. Overall, these results confirm that CSA cement bricks are of high quality and suitable for construction purposes.

5. CONCLUSION

The use of coconut shell ash (CSA) in cement brick production offers an eco-friendly solution by reducing agricultural waste and conserving natural resources. CSA's low density also helps produce lighter bricks. Quality tests—including size, color, structure, sound, impact, hardness, and efflorescence—show that CSA cement bricks are of good quality. Water absorption values for 5 % and 10 % CSA bricks are 8.87 % and 10.44 %, well below the 20 % limit, while average compressive strengths are 8.23 N/mm² and 9.46 N/mm², respectively. These results indicate that CSA bricks can effectively replace traditional bricks, and further research with other agricultural ashes could enhance their properties even more.

6. RECOMMENDATIONS

Based on the experimental study, it is recommended to use coconut shell ash (CSA) as a partial replacement for cement in brick production to promote sustainable construction and reduce environmental impact. CSA can be used up to 10 % replacement without compromising strength or durability. Further research is suggested to

explore different mix proportions, curing methods, and the use of other agricultural wastes such as groundnut shell ash or eggshell ash to enhance the mechanical and durability properties of bricks. Adoption of CSA bricks in construction can also reduce material costs and support waste management initiatives.

7. REFERENCES

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