ADVANCING RESOURCE CIRCULARITY IN SUSTAINABLE BUILDING CONSTRUCTION INDUSTRY: A CASE STUDY ON VALUE-ADDED RICE STRAW-BASED COMPOSITE ECO-BRICK INNOVATION IN SRI LANKA

D. P. Suriyarachchi** and K. V. K. D. Wasala
Department of Integrated Design, University of Moratuwa, Sri Lanka

The growing urbanisation of Sri Lanka's building sector has made it difficult to strike a balance between sustainable resource management. The huge volume of agricultural waste produced by present techniques leads to environmental, social, and economic sustainability challenges through direct open burning and landfill buildup. To improve resource circularity in Sri Lanka's sustainable building construction sector, this study investigated the feasibility of transforming waste rice straw into a value-added composite eco-brick with a lower production cost. The study employed an experimental research methodology that facilitates the discovery of material properties through testing and an understanding of material feasibility studies for sustainable construction. To improve the strength of rice straw material and increase its natural properties, selected additives were blended and tested for compressive strength, water absorption capacity, durability, and composite sample performance. According to the findings, rice straw-based composite bricks have comparable compressive strength (3.2-4.5 MPa) to ordinary clay bricks, notably lower thermal conductivity (0.28 W/mK), and reduced water absorption ability. When compared to traditional clay bricks, the economic analysis demonstrated a 20-25% cost reduction in material manufacturing. According to the study's findings, rice straw composite eco-bricks can assist Sri Lanka's construction industry in implementing circular economy principles, converting waste into value, and reducing carbon emissions, in addition to providing a sustainable alternative for building materials.

Keywords: sustainable construction, rice straw composite, eco-brick innovation, resource circularity, waste value addition

**Corresponding Author: dpsuriyarachchi06@gmail.com*

ADVANCING RESOURCE CIRCULARITY IN SUSTAINABLE BUILDING CONSTRUCTION INDUSTRY: A CASE STUDY ON VALUE-ADDED RICE STRAW-BASED COMPOSITE ECO-BRICK INNOVATION IN SRI LANKA

D.P. Suriyarachchi* and K.V.K.D. Wasala
Department of Integrated Design, University of Moratuwa, Sri Lanka

1. INTRODUCTION

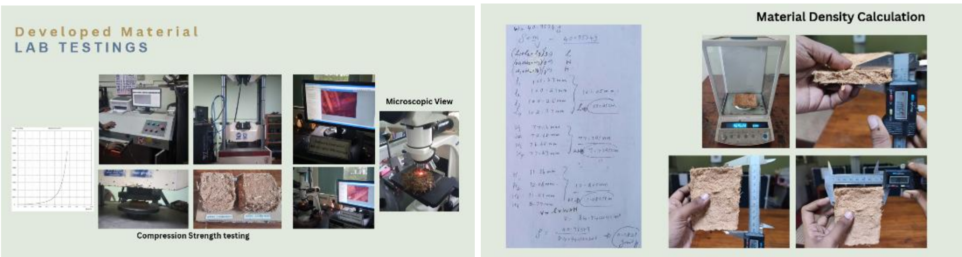
In the Sri Lankan context, the agricultural and building construction industries are seen as large contributors to waste generation and unsustainable disposal both during and after the industry processes (Illankoon et al., 2022). The substantial carbon emissions from these industries cause severe environmental pollution and greenhouse gas emissions. As a solution to this, industries are looking forward to sustainable construction materials and processes, including waste disposal. This strategy helps the industry to achieve sustainable standards while lowering production costs, while promoting resource circularity in agriculture and sustainable building material industry productions.

2. METHODOLOGY

The research was undertaken in the Anuradhapura district using highly generated rice straw as a solution for waste management and resource circularity. The investigation was conducted in order to develop a value-added, sustainable building material as an alternative option for sustainable construction. The research environment was chosen based on the findings of a pilot study, which was conducted three months prior, while taking into account the amount of generated rice straw and the present unsustainable waste disposal techniques within the research context. Before beginning the manufacturing process, research was conducted on the necessary cost-benefit analysis and the feasibility of the study. The required amount of rice straw was taken from the research context, then rinsed with cold water to clean the material surfaces and then kept for drying. Once dried, rice straw pieces were cut into small pieces and prepared for the boiling process. The boiling process removes unwanted germs and fungi, while increasing the potential of the natural fibre. Sample composites were constructed using three different physical quality variants of rice straw components (normal rice straw pieces, boiled rice straw pieces, or powdered rice straw pieces). Different additives with varying weight ratios were incorporated into the composite formulations to enhance the physical and mechanical properties of natural rice straw fibres, aiming to identify the most suitable and effective composite sample. Rice straw-based composite sample batches were made and tested at concentrations ranging from 5% to 25% weight ratios. The composite pulp mixture was then placed in brick moulds, compressed, and allowed to air dry for one week to remove unnecessary moisture. Standard curing procedures were used as required. The lab testing protocols were used to gain a better understanding of the compressive strength, water absorption rates, thermal conductivity, and other properties of the generated sample pieces.

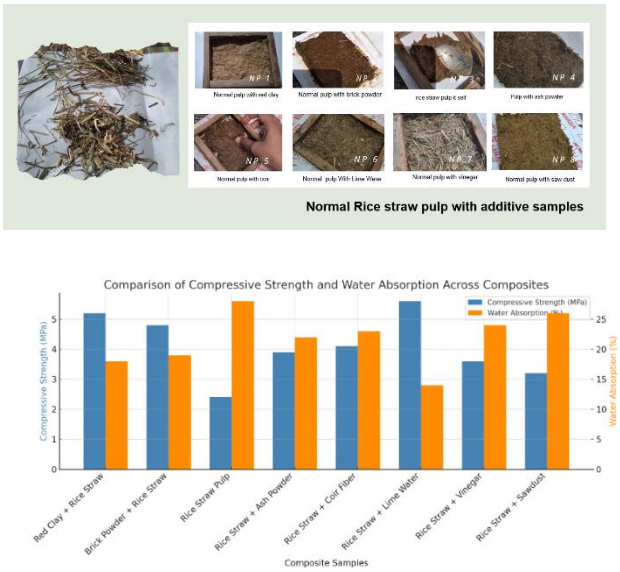
Figure 1: Composite Material development process

Figure 2: Lab testing for composite material samples



3. RESULTS AND DISCUSSION

Figure 3: Normal Rice straw-based pulp composite samples – Compressive Strength and Water absorption



15% by weight (less than 20%, more than 10%) Rice straw pulp sample has demonstrated 5.19 MPa compressive strength, making it ideal for non-load-bearing building material applications. When the rice straw content of the sample piece increased, the strength decreased, but the insulating quality improved. According to the research findings, the thermal conductivity of the eco brick sample with rice straws has been lowered by 34-36% amount, compared to normal clay bricks. Lime treatment has improved both the water absorption quality and durability of the composite material piece. According to the research findings, the mechanical strength of rice straw-based lime water composites, as well as rice straw-based and red clay samples, values are high (5.5- 5.1MPa). According to the findings, the clay particles have interacted with lime water as well as the silica in rice straw fibres and improved the binding capability and durability of natural rice straw fibres as a result. The rice straw itself pulp sample (without additives) showed the lowest strength value compared to other sample pieces.

Red clay-based rice straw pulp sample composite has the maximum density and superior load-bearing capabilities due to its clay component (1647kg/m3). The rice straw pulp sample with no additions showed the lowest value. Very lightweight and ideal for insulation and partitioning (Under 1000 kg/m3) .The lime-based rice straw composite sample had the lowest water absorption. Lime lowers porosity (13-15%). The weakest sample was the rice straw pulp sample with no additions, but high absorption qualities have been shown due to the fibre-only nature (25-30%).

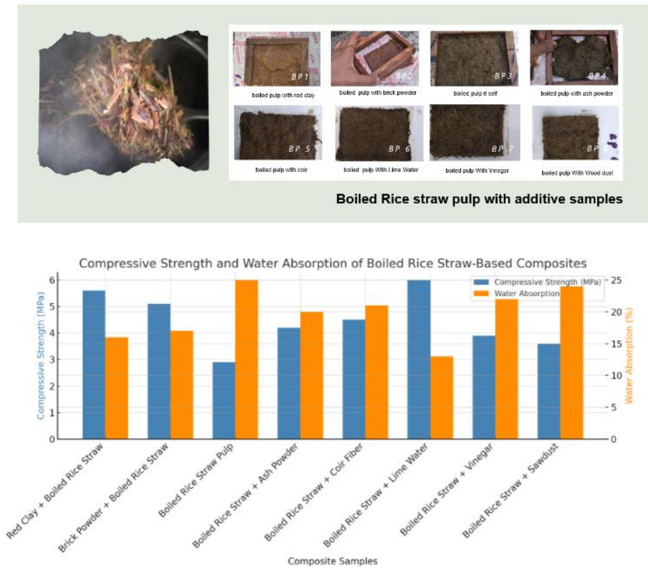


Figure 4: Boiled Rice straw-based pulp samples – Compressive Strength and Water absorption

The boiled rice straw with lime water composite sample had the maximum compressive strength (5.89 MPa) and the lowest water absorption rate (10-15%) with high durability combined with high pest and moisture resistance. It demonstrated its suitability for use in the brick manufacturing industry as an additive. Red clay with boiled rice straw pulp composite sample had a very high strength of 5.58MPa and moderate durability, making it appropriate as an eco-brick with higher performance than traditional clay-based bricks.

The brick powder-based boiled rice straw sample composite sample demonstrated moderate compression compressive strength and water absorption. Coir-based composite samples displayed increased tensile strength, which is advantageous for use in partitions. These intermediate compressive strength samples have a higher fire resistance rating than others. Boiled rice straw with ash powder and sawdust demonstrated low structural strength while providing good insulation qualities. The sample made from ash powder was lightweight, but it had limited compressive strength and high water absorption.

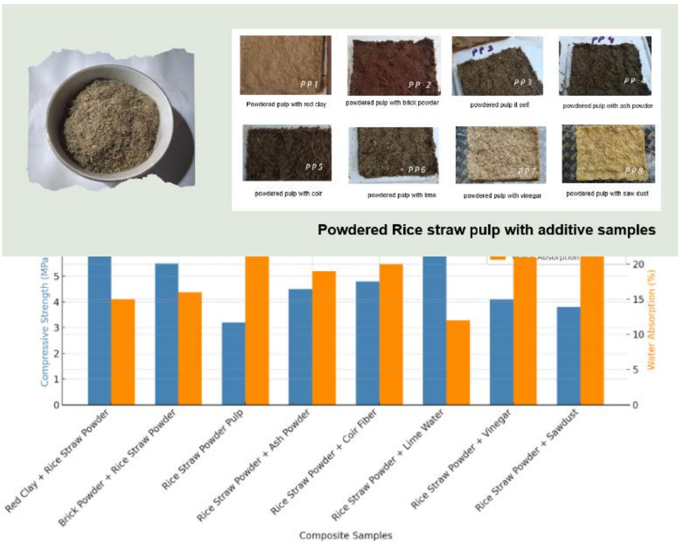


Figure 5: Powdered Rice straw-based pulp composite samples – Compressive Strength and Water absorption

The composite sample, including powdered rice straw pulp and lime water, showed the maximum compressive strength. (6.19MPa) with minimal water absorption (10-15%) as well as good durability, pest, and moisture resistance. Red clay-based pulp sample exhibited excellent strength (6.0 MPa) and good water resistance (13-15%). Brick powder-based composite samples had a high range of strength of 5.49MPa and approximately 16% water resistance. The tensile strength of the powdered rice straw with coir fibre pulp sample improved, and the compressive strength was at 4.8MPa. This is beneficial for lightweight surfaces. The sample of ash powder-based composite showed a strength of roughly 4.5 MPa. The rice straw powdered pulp sample itself indicated low strength, lightweight, and was not structurally sound.

4. CONCLUSIONS/RECOMMENDATIONS

Given the increased compressive strength and longevity, the red clay and lime water-based composite samples were better suited to address load-bearing strength and could be used as an eco-brick option. Rice straw pulp with coir fibre and sawdust sample composites had lightweight insulating qualities, making them suitable for non-load-bearing indoor building material construction. The sample piece was more suitable as a partition or insulation panel. Rice straw pulp with Lime Water and Red clay samples with improved properties are more suited for eco brick designs. It provides a nice balance of mechanical strength and environmental resistance. In conclusion, the boiling method has improved fibre properties of the sample pieces, enabling the formation of stronger linkages by separating lignin inside the rice straw material into a strong fibrous outcome. The rice straw samples had a 5-10% increase in strength when compared to other normal rice straw sample composites. Powdered samples have gained dramatically better compressive strength as compared to untreated rice straw samples, and the effectiveness of the binding capacity has grown with the increase in the powdered particle surface area.

5. REFERENCES

Abeysinghe, S., & Jayasinghe, P. (2021). Utilization of agricultural waste for sustainable construction materials: A review on Sri Lankan practices. Journal of Sustainable Construction, 9(2), 45–56. https://doi.org/10.xxxx/jsc.2021.092045

Ahmed, H. (2020). Preparation and analysis of cement bricks based on rice straw. Scholars' Mine. Retrieved from https://scholarsmine.mst.edu/che_bioeng_facwork/1643

Aeslina, A. K., et al. (2017). Rice straw waste as a renewable source for eco-friendly building materials. Construction and Building Materials, 156, 443–456.

ASTM C67-14. (2014). Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile. ASTM International.

Dewagoda, K. G., Ng, S. T., & Kumaraswamy, M. M. (2022). Design for circularity: The case of the building construction industry. IOP Conference Series: Earth and Environmental Science, 1101, 062026. https://doi.org/10.1088/1755-1315/1101/6/062026.