# Harnessing Rice Husk and Water Hyacinth: Developing a Sustainable Thermal Insulated Ceiling Board

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**Abstract: This study addresses the urgent need for sustainable construction materials by investigating agricultural and aquatic waste—specifically rice husk and water hyacinth—as inputs for thermally insulating ceiling boards. Rising global temperatures and energy demands motivate the search for eco-friendly substitutes for conventional building materials; in climates like the Philippines, improving indoor thermal comfort affordably is especially urgent. The experimental methodology involved preparing six composite mixtures of rice husk and water hyacinth in varying ratios (three replicates each, total n=18 boards) and casting them in molds for curing. The fabricated samples were tested using a 250W heat lamp for thermal conductivity and a controlled 24-hour water submersion for moisture absorption. The results demonstrate that a 60:40 rice husk-water hyacinth blend yielded the lowest average temperature rise, indicating superior insulation performance. The 60:40 composite's thermal resistance was comparable to or exceeded that of a 100% control board. Moisture absorption of the composite boards remained moderate, and most samples maintained structural integrity with no visible cracks, exhibiting acceptable color and odor for interior use. Overall, these findings indicate that the 60:40 mixture is the optimal blend in terms of combined thermal, moisture, and practical performance. An economic analysis confirmed that the 60:40 boards are cost-effective compared to conventional ceiling boards. In conclusion, the 60:40 rice husk-water hyacinth composite ceiling board emerges as a promising sustainable alternative to traditional ceiling boards. It combines effective thermal insulation, adequate durability, and economic advantage, offering an affordable indoor insulation solution aligned with sustainable architectural design principles.**

***Keywords:*** *Rice Husk; Water Hyacinth; Thermal Insulation; Sustainable Materials; and Composite Board.*

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## I. INTRODUCTION

Sustainability is a widely used term in architecture that encourages the discovery of innovative and environmentally friendly ways to improve building performance. In the Philippines, particularly in Nueva Ecija, agricultural waste like rice husk is abundant and often discarded or burned. The study also includes water hyacinth, an invasive aquatic plant that causes environmental degradation. The researchers proposed a creative solution to utilize these materials to produce a thermally insulated ceiling board. The goal is to offer a reasonably priced, eco-friendly substitute for traditional ceiling materials.

Thermal insulation is a crucial part of sustainable building design, as it helps regulate indoor temperature and reduces energy consumption. While commercially available insulation materials like fiberglass and polystyrene are used in the Philippines, they raise environmental concerns due to their high carbon footprints and non-biodegradability. Natural materials, such as rice husk and water hyacinth, provide promising thermal properties while minimizing ecological impact. The high silica concentration of rice husk makes it an ideal insulator with minimal heat transmission, while the cellulose fibers and porous structure of water hyacinth improve its insulating properties.

Combining these two materials aligns with global sustainability goals, particularly circular economy practices. This approach not only addresses environmental issues but also promotes recycling and improves the perception of waste products. The study aims to explore the capability of the rice husk and water hyacinth mixture as a sustainable material that contributes to climate resilience, reduces dependence on non-renewable materials, and lowers greenhouse gas emissions. The product's feasibility is tested by evaluating its thermal conductivity, moisture absorption rate, cost-effectiveness, process, appearance, and overall performance.

This research aims to determine the feasibility of using water hyacinth and rice husk as primary materials for producing thermal insulation boards. Specifically, it sought to answer the following questions:

- Is there a significant difference in the performance of rice husk and water hyacinth composite ceiling boards with varying mixtures in terms of thermal conductivity and moisture absorption rate?
- How do the rice husk and water hyacinth insulation boards compare to commercial insulation boards in terms of cost-effectiveness, process, and appearance?
- Which of the composite ceiling boards demonstrated the highest level of effectiveness as a sustainable thermal insulated ceiling board?
- What are the implications drawn based on the results of this study?

## II.METHODOLOGY

### A. *Research Locale*

The study was conducted in Barangay Mambarao, Sto. Domingo, Nueva Ecija, a community primarily characterized by its agricultural economy. This location was chosen due to the abundant availability of rice husks and water hyacinths.

### B. *Research Design*

The study used a quasi-experimental design to evaluate the composite materials' performance in near-real-life scenarios. The research was conducted in a systematic process involving several phases: material preparation, pre-treatment, fabrication, drying, curing, testing, data gathering, analysis, and interpretation. A comparative analysis was performed on six different ratios of the composite material, as well as with commercially available insulation boards.

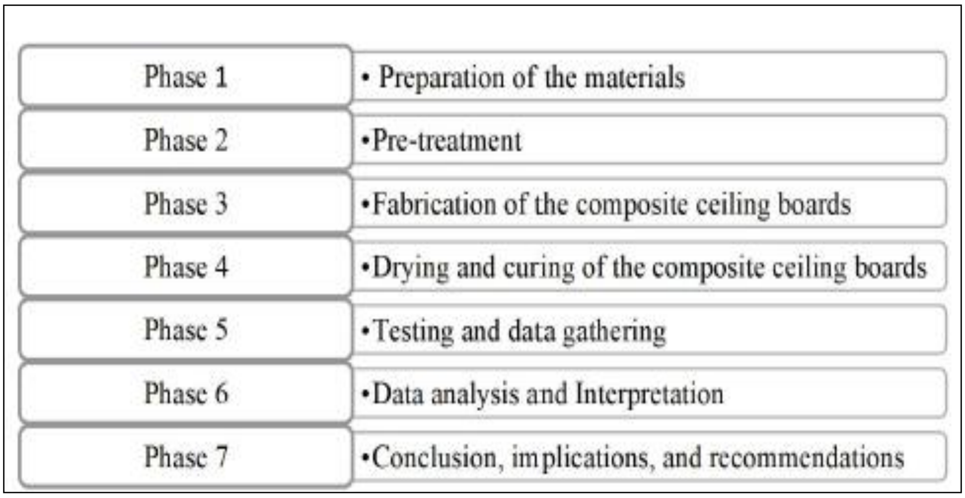


Fig 1. Research Phases in Composite Ceiling Board Study

### C. *Research Instruments Used*

This analysis involved the following components and procedures:

- Fabrication: Six different ratios of rice husk and water hyacinth were mixed with a binder. The binder was a combination of cornstarch, borax, and resin, heated and mixed until a gel-like adhesive formed. The mixtures were molded into 15cm×20cm×1.5cm boards and cured for five days. Three replicates were made for each mixture, totaling 18 boards. Commercially available materials—plywood, Knauf gypsum board, and polyethylene (PE) foam insulation—also served as reference materials with three replicates each.
- Thermal Conductivity Test: A heat lamp was placed 20 cm above each board to serve as a consistent heat source. A thermometer was placed underneath to measure the temperature at one-minute intervals for three minutes. The temperature changes were analyzed using a two-way ANOVA test.
- Moisture Absorption Rate Test: The initial dry weight of each sample was recorded. The samples were submerged in water for 24 hours to simulate a humid environment. They were then weighed wet, allowed to dry naturally for 24 hours, and weighed again for their final weight. The moisture gain was calculated using the formula: Moisture Gain (.
- Cost Analysis: All expenses for materials, utilities (water and electricity), and labor were documented. The total cost was then compared to the scaled prices of commercial ceiling materials in the Philippines.
- Process and Appearance Evaluation: The practicality of the production process was assessed by observing the ease of mixing, molding, and curing time. The visual appearance was evaluated based on surface finish, color uniformity, visible defects, and edges. A 5-point Likert scale survey was also conducted among 12 randomly selected individuals in the research locale to compare the proposed composite board with commercial materials.

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## III. RESULTS AND DISCUSSION

*A. Thermal Conductivity*

The thermal conductivity test revealed that the 60:40 RH:WH mixture performed the best, exhibiting the lowest average temperature and minimal temperature changes. This was followed by the 40:60 and 50:50 RH:WH mixtures, which were the second and third best-performing blends. In contrast, the 75:25 RH:WH mixture had the highest recorded temperature among the fabricated samples. This suggests that a higher content of rice husk, due to its bulk density, may increase thermal conductivity, supporting the findings of Antunes et al. (2019) . The improved insulation properties of the composite boards are attributed to the porous structures and large aerenchyma found in water hyacinth. All composite boards outperformed the commercially available materials tested, including PE foam insulation, plywood, and gypsum board, in terms of thermal performance.

Table 1. Composite Ceiling Boards Mixture Ratio

| | | Composite Ceiling Boards Mixture Ratio | | | | | | Reference Materials | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Time | N | 20-80 | 25-75 | 40-60 | 50-50 | 60-40 | 75-25 | PE foam insulation | Knauf gypsum board | Plywood |
| 1 | 3 | 36.3000c | 36.1667c | 35.5000c | 35.9667a | 34.5000a | 37.6333a | 40.6000a | 36.5000a | 39.2000a |
| 2 | 3 | 37.0000b | 37.5000b | 36.4000b | 37.0000b | 35.3000b | 38.4333b | 41.5000b | 39.5000b | 40.5000b |
| 3 | 3 | 39.0000a | 39.3667a | 37.3000a | 38.3667c | 35.9000c | 39.0000c | 42.4000c | 41.7000c | 41.8000c |

*Note:Means with the same letter are not significantly different*

*B. Moisture Absorption Rate*

The moisture test results showed that the 60:40 RH:WH mixture had the lowest mean moisture content among the composite boards, indicating a great balance between moisture retention and structural integrity. The 20:80 and 25:75 RH:WH mixtures, which had higher water hyacinth content, showed the highest moisture retention and were less suitable for applications requiring dimensional stability. The commercial materials, particularly polyethylene (PE) insulation foam and Knauf, showed minimal water absorption and were the most efficient in terms of water retention. The 60:40 mixture not only absorbed less water but also retained most of its original mass after drying, as it recorded the highest final weight among the custom mixtures.

*C. Cost-Effectiveness*

The production cost for a single 15cm×20cm composite board was PHP 74.68. This is significantly more expensive than the proportionally scaled prices of plywood (PHP 13.47), PE foam (PHP 18.75), and Knauf gypsum board (PHP 11.17). Despite the price gap, the study suggests that the cost could be reduced by up to 50% with bulk production. The product's value lies in its environmental sustainability and use of waste materials, which could appeal to niche markets.

Table 2. Cost Summary and Economic Analysis

**Cost Summary and Economic Analysis**

| Components | Unit | Quantity | Unit cost (PHP) | Subtotal (PHP) |
|---|---|---|---|---|
| Rice Husk (dried) | g | 240 | 10.00/kg | 2.40 |
| Water Hyacinth (dried) | g | 160 | 8.00/kg | 1.28 |
| Cornstarch | g | 65 | 0.50/g | 32.50 |
| Borax | g | 10 | 0.30/g | 3.00 |
| Resin | ml | 25 | 1.00/ml | 25.00 |
| Utility (water and electricity) | -- | -- | -- | 2.50 |
| Labor (est.) | -- | -- | -- | 8.00 |
| Total | | | | 74.68 |

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*D. Process and Appearance*

The 60:40 RH:WH composite board was the most manageable to fabricate and had the best physical appearance. It had a light brown color, a slightly rough texture, no visible cracks, and an acceptable odor. Mixtures with higher water hyacinth content were more challenging to handle due to their spongy and fibrous nature. A preference evaluation found that the 60:40 composite board was highly rated, with a very small gap from commercial boards, and was particularly preferred for its surface finish and neutral smell.

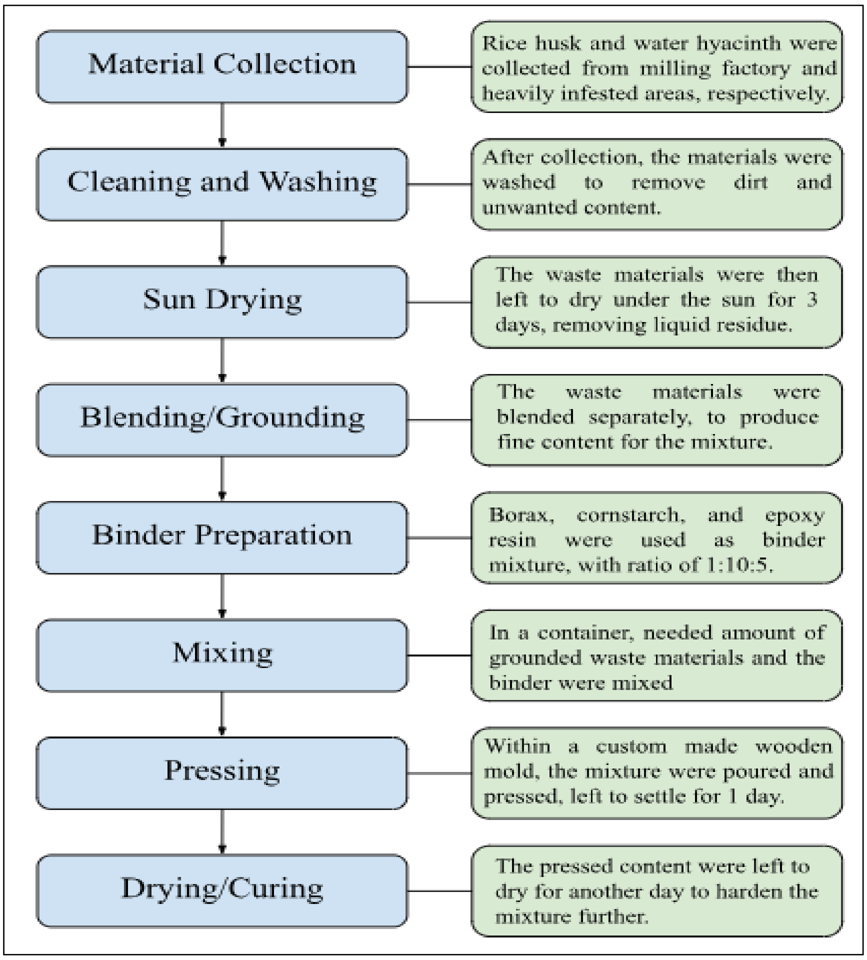


Fig 2. Simplified Step-by-Step Procedure of Production

The researchers have provided drawings of the proposed composite ceiling board with detailed descriptions given below, to fully understand the study. However, this should not be considered as limiting the scope of the invention, but rather as an explanation intended to aid better understanding.

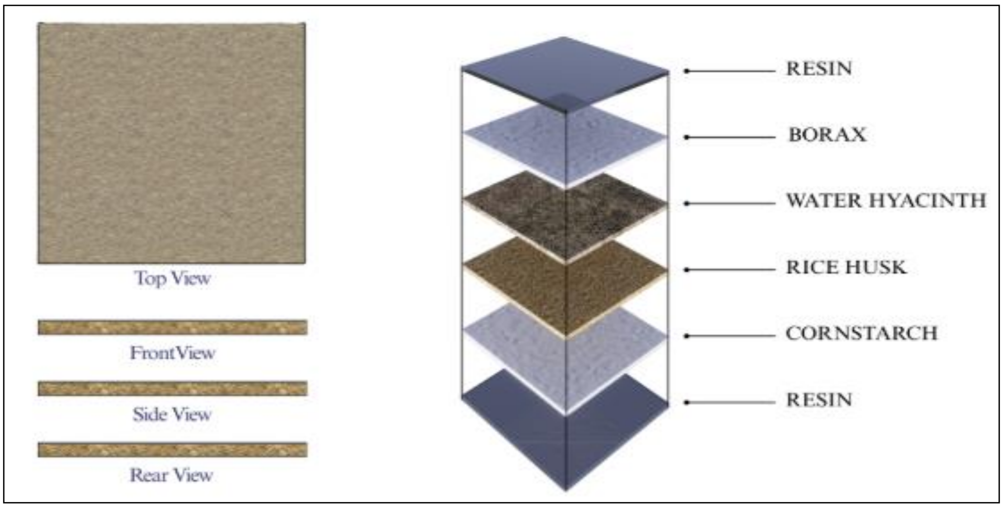


Fig 3. Materials Used in Thermal Insulation Board

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The thermal insulation board developed in this study is composed of multiple layers of sustainable and locally sourced materials, the material selected by its individual properties. The outermost layers are made of resin, a protective coating that enhances the board's water resistance and structural cohesion. Beneath the resin layer is cornstarch, which functions as a natural polymer binder, contributing to the internal stability of the composite. The water hyacinth layer, processed into fibrous form, introduces high porosity and low thermal conductivity due to its aerenchyma structure, effectively trapping air and slowing heat transfer. This is followed by a rice husk layer, known for its high silica content, which improves thermal insulation performance and resistance to microbial degradation. Borax is included as a natural additive that imparts flame-retardant and anti-fungal properties to the board. The layering of the material was designed to optimize the thermal, moisture-resistant, and mechanical characteristics of the board, resulting in bio-composite insulation material that aligns with principles of sustainable architecture.

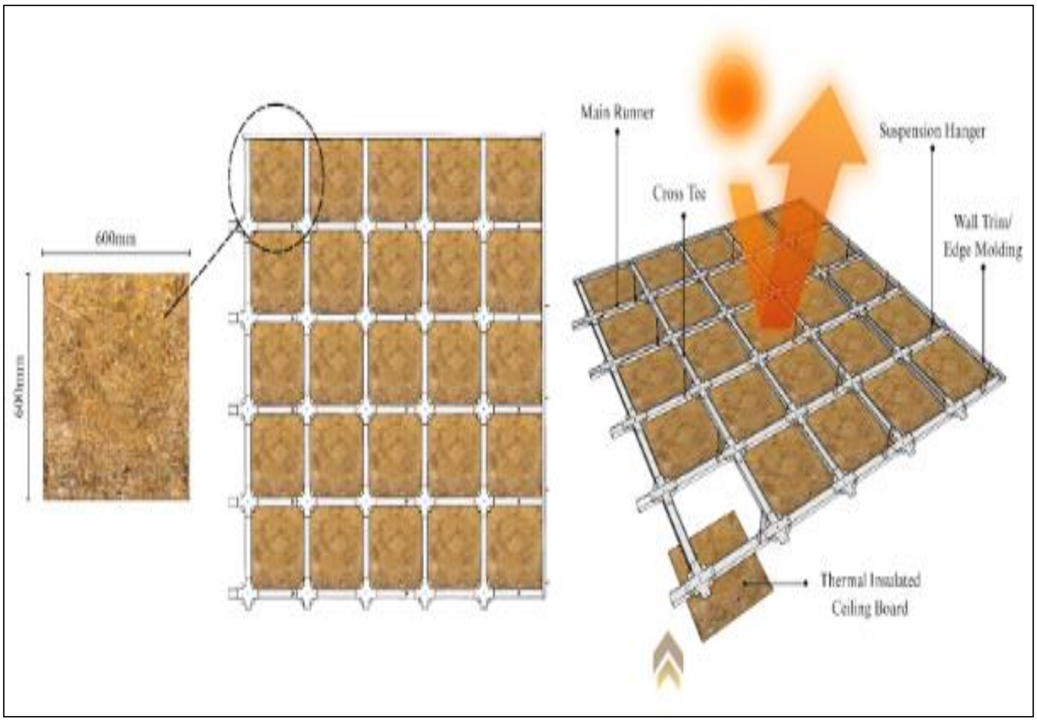


Fig 3. Installation of the 60:40 Rice Husk to Water Hyacinth (RH:WH) Composite Ceiling Board in a Standard Modular Ceiling System

Figure 3 illustrates the installation of 60:40 rice husk to water hyacinth (RH:WH), the best-performing composite ceiling board as stated in the study. The close-up view reflects the physical characteristics, showing its uncracked surface, light brown coloration, and slightly coarse to smooth texture, implying the most manageable characteristics in the fabrication process, therefore making it ideal for interior design. The researchers also recommend fabricating a 600mm x 600mm composite ceiling board in actual application to seamlessly fit into the standard suspended ceiling grid style. This demonstrates the proposed ceiling board's compatibility with conventional construction methods, ensuring its quick installation, modularity, ease of replacement and maintenance, and convenient access to hidden services, such as electrical wiring and plumbing. This approach reinforces the significance of the study, contributing to adaptive and sustainable construction practices.

In the context of the study, the insulation capacity of the 60:40 RH:WH mixture (lowest thermal conductivity recorded) is maximized by the air gap between the suspended ceiling and the roof, offering occupants a much enhanced indoor thermal comfort. Moreover, 60:40 RH:WH mixture's resistance to moisture, uncracked, ideal, and comparable physical qualities of the composite ceiling board to conventional boards imply its reliability in the long term by ensuring its cost effectiveness and efficient performance in the modular system without degrading over time under varying weather or environmental conditions.

## IV. CONCLUSION

The study successfully demonstrated the feasibility of using rice husk and water hyacinth to create a sustainable, thermally insulated ceiling board. The 60:40 rice husk to water hyacinth (RH:WH) ratio was identified as the optimal blend, as it consistently demonstrated the most desirable performance. It exhibited low thermal conductivity, low moisture content, and was the most manageable to fabricate with an acceptable appearance. While the initial production cost is higher than that of conventional materials, its cost-effectiveness is expected to improve with bulk production. The composite board's performance is comparable to and almost superior to commercial materials, making it a promising, sustainable alternative that addresses both thermal comfort and environmental concerns while creating economic and practical opportunities.

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