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Mechanical Performance of Mycelium Reinforced with Buri Palm Fiber as a Lightweight Partition Wall Material

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Abstract
This study investigates the mechanical performance of Ganoderma lucidum mycelium reinforced with buri palm fiber. Mycelium offer a promising avenue for sustainable construction materials due to their biodegradable nature and low environmental impact. Mycelium were reinforced with varying proportions of buri palm fiber at 2%, 4%, 6%, and 8% by total weight to assess their impact on density, compressive strength, and water absorption. Experimental results reveal that the incorporation of buri palm fiber leads to notable improvements in mechanical properties. Different proportions of fiber reinforcement are identified, demonstrating significant enhancements in compressive strength at 6% replace of buri palm fiber, the density shows a lower value compared to lightweight non-load bearing concrete hollow-blocks and louver blocks. This study sheds light on the potential of utilizing natural fibers to enhance the mechanical performance of mycelium-based construction materials, thereby contributing to the development of sustainable and resilient building solutions.

Keywords: *Buri Palm Fiber, Ganoderma Lucidum, Mycelium, Compressive Strenth, Sustainable Construction Materials*

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I. INTRODUCTION

Mushroom farming has been in Philippines since the 19th century, although it was a profitable business only few Filipinos venture in mushroom farming because of lack of awareness and the low market mushroom demand ranging 10% as of 2020 [13]. The low market demand could be address through different strategies and of them is by innovating this as a raw material for a sustainable construction industry.

As early as 4-6 week mushrooms in bags can grows and varies according to its type [13,14] while harvesting can last up to 3 months [16]. In tropical countries like the Philippines, Mushrooms can grow in all parts of the country; they only need a cool, dark place to live and the right humidity.

Developing eco-friendly construction materials is a common goal of engineers for a healthier construction environment. Lesser carbon footprints in construction materials make construction waste easier to dispose [9]. The construction industry faces a many critical challenges and one of them is to develop a sustainable and eco-friendly building materials to mitigate the environmental impact of traditional practices it was also highlighted on the Sutainable development Goals of the United Nations to Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

Conventional materials like concrete and steel contribute significantly to greenhouse gas emissions and resource depletion, prompting the exploration of innovative alternatives. In this context, mycelium have emerged as a promising biomaterial with several unique properties: rapid growth, low embodied energy, and biodegradability [10, 11].

Buri tree (Corypha elata), or locally known as buli tree, is a tropical plant and one of the largest varieties in the palm family. Buri palms naturally thrive in many parts of the country, particularly in lowland areas and along coasts, contributing to the readily available supply of the resource [12]. The abundance of Buri trees all over the country is a sign that Buri is a good source of raw materials. The long lifespan of Buri trees and large leaf trunks make them ideal for fiber extraction.

The long leaf trunk has natural, strong fiber that has been used in rope and other products. Buri palm fibers stand out for their remarkable tensile strength, ranging from 150MPa to 400 MPa, and compressive strength of 10–40 MPa, exceeding other natural fibers like coir [4, 11] and their low density makes them lightweight additions to the composite [4]. The idea of light weight and strong materials can lead to new options for construction that are faster, easier, and less prone to accidents due to their lighter weight.

Ganoderma lucidum, commonly known as reishi mushroom, possesses unique properties relevant to this study. The fungal network exhibits strong binding abilities due to its interwoven hyphal structure [7]. Myceliumderived materials possess qualities such as lightness, porosity, thermal insulation, fire resistance, and water resistance, making them suitable for applications in food packaging, cushioning, and insulation products [2]. This, coupled with its potential for self-healing, makes it an attractive candidate for using this a construction material. Self-healing properties can be useful in the construction industry, especially in walls where cracks are common. The imperfections of walls can be lessened by the use of self-healing materials.

The potential of mycelium as new sustainable material with reinforcement of buri fiber brings the idea of thoroughly conducting experimental study on its mechanical performance as a reinforcement in lightweigh partition wall. The study compared the properties of reinforced and unreinforced sample, focusing on parameters like compressive strength, density and water absorption. The findings will contribute to the development of sustainable and high-performing construction materials, offering valuable insights for the future of eco-friendly building practices.

The study delves into the mechanical properties of composite materials incorporating Buri palm fibers and mycelium-based sample, with a specific focus on understanding the potential synergies between the fibrous structure of Buri palm and mycelium. The investigation aims to evaluate how their combined presence influences mechanical characteristics, including compressive strength, water absorption, and density. The analysis seeks to uncover the unique contributions of each component and explore how the interplay enhances or modifies the overall mechanical performance of the composite material.

Five distinct sample groups were prepared. The first group served as a control, containing no buri palm fiber. The research followed the increments of fiber reinforcement in cement (1%, 2%, 3%, and 4%) [6]. However, due to the anticipated lower density of the substrate compared to cement, it was deemed necessary to adjust the increments accordingly to ensure optimal mechanical performance. Through the course of this research, during experimentation, it became necessary to increase the increments of fiber reinforcement, leading to the idea of doubling them. This resulted in the following percentages of fiber reinforcement: 2%, 4%, 6%, and 8%. The adjustment accounts for differences in material density and aims to maintain consistency in the evaluation of mechanical properties.

In the experimental setup, different test were conducted; density, water absorption, and compressive strength. To identify density, a total of 15 test sample were utilized, with three test sample allocated for each sample. Following the density identification, the same test sample were then utilized for the compressive strength test. For the water absorption test, five test sample were prepared, with one brick designated for each sample. This approach ensured comprehensive data collection, with a total of 20 test sample employed across the various tests.

1.1 Test Sample Preparation procedure

1.1.1 **Preparation of Substrate**

One sack containing 45 kg of sawdust was combined with 5 kg of rice bran, 1 kg of lime or apog (calcium carbonate), and 5 kg of molasses. Before mixing, the molasses was dissolved in 300 ml of water, and this molasses-water mixture was then incorporated into the sawdust blend. The sawdust mixture underwent a fermentation process lasting 20 days. This fermentation period is essential to reduce the acidity of the sawdust, thereby creating conditions conducive to mushroom growth. The method was adapted from Agrifungus website, a reputable online resource for mushroom cultivation techniques.

1.1.2 **Preparation of Buri Palm Fibers**

Buri palm stalks were harvested using a clean knife. Subsequently, the stalks were split open to expose the inner fibers, which will then be manually separated by hand. The collected fibers underwent a washing process with water followed by boiling for one hour. After boiling, the fibers were dried to the appropriate moisture level, ensuring they are still slightly moist but without any water dripping when squeezed.

1.1.3 **Preparation of Test sample**

550 grams of the prepared substrate was distributed into each of the 20 plastic bags. Following this process, weights of 11, 22, 33, and 44 grams of fibers were measured, respectively representing the 2%, 4%, 6%, and 8% fiber reinforcement levels. This entailed 4 samples for each percentage. To maintain the proper ratio of fibers to sawdust, the sawdust and fibers were combined in separate bags for each sample.

The plastic bags containing the substrate were compacted into a rectangular mold measuring 10 by 20 by 4 cm. A rectangular wooden board was used to ensure the top surface of the brick is flat. The compacted bags were then sealed with rubber bands and subjected to an 8-hour steam sterilization process. Following sterilization, the test sample were allowed to cool for an additional 10 hours before the mushroom spawn is planted.

1.1.4 **Mycelium Cultivation**

After removing the rubber bands to open the bags, a tablespoon of reishi mushroom grain spawn (equivalent to approximately 100 seeds) was carefully added to each bag. This task was conducted in a controlled environment with minimal airflow to prevent contaminants from entering the bags. Subsequently, the bags were sealed once again using rubber bands.

The inoculated bags were placed in a room devoid of direct sunlight. The room was regularly moistened by sprinkling water to maintain humidity levels, ideally every 3 hours to ensure the environment remains adequately damp. The temperature within the room was monitored using a thermometer. The mycelium was allowed to grow for a period of 28 days.

The test sample were carefully removed from the bag and subjected to air drying for a period of one day. This step is essential to stop the growth of mushrooms within the test sample.

1.2 Compressive strength of different foaming agents [5]

Physical Foaming/Chemical Foaming	Compressive Strength (MPa)
H_2O_2	≥0.24
Air foam	1.7
Tea safonin	1.34
anion surface-active substance	1.2
$A1_2(SO_4)_3$	2.65
animal protein foaming agent	0.42

II. RESULT AND DISCUSSION

2.1. Identifying the Optimal Ratio of Buri Palm Fiber Blend

The researchers created five samples to determine the optimal fiber proportion for producing mycelium test sample. The fibers were blended with the substrate and then casted into a mold sized 20 cm by 10 cm by 4 cm. After allowing the five samples to grow for 28 days, they were subjected to compressive strength testing using a Compression Testing Machine at the NEMATEC Construction Testing Center. The result of the test are shown in Table 1 and illustrated in Figure 5.

2.1.1 Compressive Strength Test Result

Mixture	Sample No.	Compressive Strength (Mpa)	Average (Mpa)
A (0% Fiber)	1	1.45	1.42
	2	1.48	
	3	1.34	
B (2% Fiber)	1	1.62	1.63
	2	1.77	
	3	1.50	
C (4% Fiber)	1	1.83	1.71
	2	1.68	
	3	1.62	
D (6% Fiber)	1	1.72	1.75
	2	1.89	
	3	1.65	
E (8% Fiber)	1	1.76	1.67
	2	1.62	
	3	1.64	

Figure 2.1 Variation of Average Compressive Strength across Samples

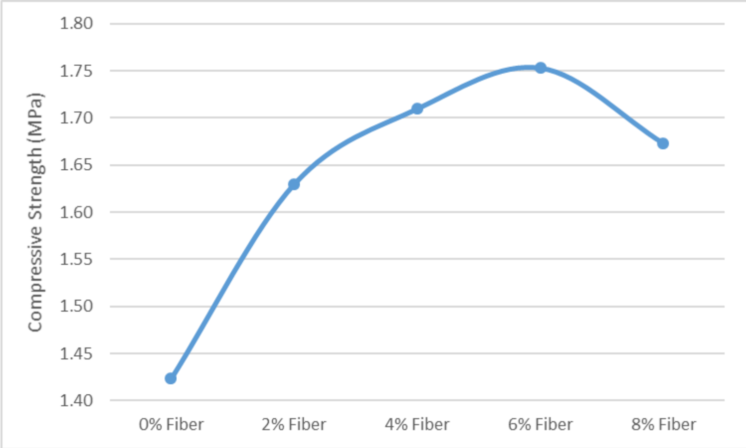


Figure 2.1 reveals a distinct trend in compressive strength relative to fiber content. Initially, there is an upward trajectory in strength, reaching its pinnacle of 1.75 MPa at a 6% fiber content. Subsequently, there is a decline in strength beyond this threshold. Notably, the 6% fiber content exhibits a noteworthy enhancement of 23% in compressive strength compared to the fiber-free sample.

The achieved peak strength of 1.75 MPa is comparable to Air foam's compressive strength of 1.70MPa, indicates its viability as a lightweight partition wall material.

2.1.2 Density of Specimen

Sample	Weight of Specimen (g)	Volume of Specimen (cm^3)	Density (kg/m^3)	Average (kg/m^3)
A (0% Fiber)	252	800	315	315
	251	800	314	
	253	800	316	
B (2% Fiber)	257	800	321	322
	258	800	323	
	257	800	321	
C (4% Fiber)	262	800	328	328
	261	800	326	
	263	800	329	
D (6% Fiber)	269	800	336	335
	267	800	334	
	268	800	335	
E (8% Fiber)	273	800	341	342
	275	800	344	
	274	800	342	

Figure 2.2 Variation of Average Density across Samples

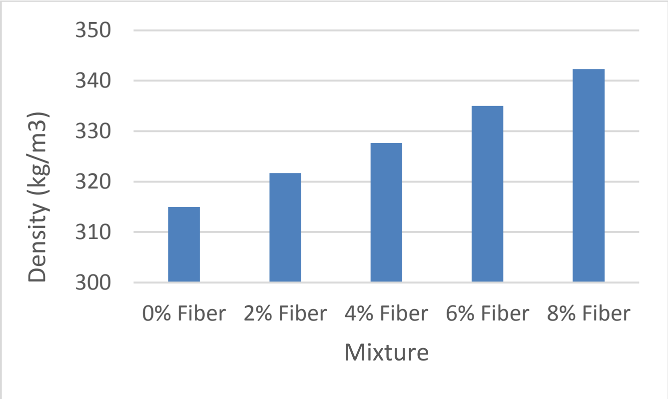
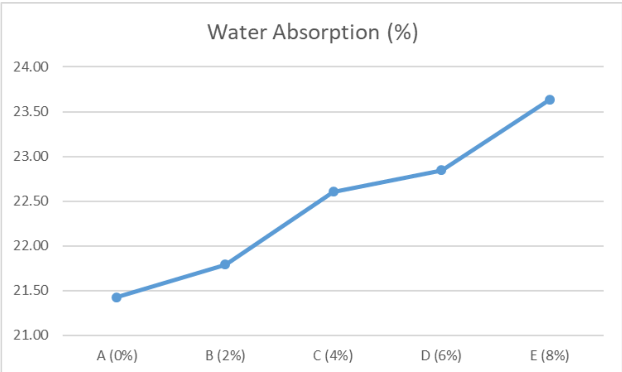


Figure 2.2 demonstrates the relationship between density and buri palm fiber content in the mycelium test sample. As the volume of buri palm fibers increases, the density of the test sample also increases. The sample without buri palm fiber exhibits the lowest density, while The sample with optimal compressive strength, containing 6% fiber content, achieves a notably low density of 335 kg/m^3. The result of this density is almost 5times lower than the density of lightweight non-load bearing Concrete Hollow Blocks and Louver Blocks. [5]

2.1.3. Water Absorption Test Result

Sample	Oven Dry Weight (g)	Wet Weight (g)	Water absorption (%)
A (0%)	252	306	21.43
B (2%)	257	313	21.79
C (4%)	261	320	22.61
D (6%)	267	328	22.85
E (8%)	275	340	23.64

Figure 2.3 Variation of Average Water Absorption across Samples



The figure illustrates that as the fiber content increases, the water absorption of the test sample also rises. There are minimal variations in their water absorption levels. The sample with optimal compressive strength, containing 6% fiber content, exhibits a water absorption rate of 22.85%,

III. CONCLUSION

The test on Mycelium Reinforced with different proportions of Buri Palm at 2%,4%,6%,8% shows a positive correlation between the percentage of buri palm fiber reinforcement and the compressive strength of the mycelium sample, reaching its maximum compressive strength of 1.75MPa at 6% replacement of buri palm, representing a 23% improvement compared to samples without fiber content. The compressive strength of the test samples are comparable t different foaming agents used in partition walls which indicates its viability as a lightweight partition wall material. Remarkably, it exhibited a low density of 335kg/m^3, the result of this density is almost 5times lower than the density of lightweight non-load bearing Concrete hollow blocks and louver blocks.

Recommendations

The following recommendations have been put forward based on the study's findings:

1. Considering the non-fulfillment of all samples to meet compressive strength standards but exhibit low density, it is suggested to utilize them as substitutes for drywalls or partition walls.
2. Given that mycelium sample can replicate the shape of their mold and are lightweight, they could be efficiently employed for wall cladding or architectural applications.
3. To broaden the research scope, it is proposed to explore the use of other mushroom species in similar applications.
4. Instead of employing a fixed length for mycelium growth, varying lengths should be considered to investigate the potential impact of growth duration on strength.
5. Explore additional applications for mycelium sample reinforced with Buri palm fiber, such as in structural elements, insulation materials, or sustainable building components, to expand their utility in construction projects.
6. Investigate strategies to optimize production costs, such as refining production processes, sourcing materials more efficiently, or scaling up manufacturing, to enhance the competitiveness of mycelium sample compared to traditional building materials.
7. Conduct long-term durability assessments to evaluate the performance of mycelium sample reinforced with Buri palm fiber under diverse environmental conditions and exposure to factors like moisture, temperature variations, and biological degradation. This evaluation will ensure their suitability for enduring construction projects.

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