

Development of Mycelium-Based Bio-Bricks for Sustainable Construction Materials

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Abstract

The construction industry significantly contributes to global carbon emissions due to the extensive use of energy-intensive materials such as fired clay bricks and ordinary Portland cement (OPC) blocks. This study investigates the development and performance evaluation of mycelium-based bio-composite bricks (MBBs) using rice straw (*Oryza sativa*) as a sustainable lignocellulosic substrate. The experimental program was conducted at the Materials Research Laboratory, Kumaraguru College of Technology (KCT), Coimbatore. Sterilized rice straw was inoculated with *Pleurotus ostreatus*, a white-rot fungus known for its lignocellulolytic enzyme activity, and allowed to colonize under controlled conditions before thermal inactivation. The fabricated MBBs were assessed for mechanical, thermal, and physical properties and compared with conventional masonry units. Results indicated compressive strength values of 0.30–0.45 MPa, suitable for non-load-bearing applications. Notably, thermal conductivity ranged from 0.055 to 0.075 W/m·K, demonstrating superior insulation performance compared to traditional bricks. The bricks exhibited ultra-low density (120–180 kg/m³), offering over 90% weight reduction. Microstructural analysis confirmed strong internal bonding through a dense hyphal network. Life Cycle Assessment (LCA) revealed a 91–95% reduction in embodied CO₂ emissions, while biodegradation tests confirmed complete decomposition within 45–60 days. The findings highlight the potential of mycelium-based bricks as an eco-friendly, lightweight, and thermally efficient alternative for sustainable construction and circular bio-economy applications.

KEYWORDS:

Mycelium-based bio-composites, Sustainable construction materials, Rice straw (lignocellulosic substrate), Thermal insulation performance, Embodied carbon reduction (LCA) , Non-load-bearing masonry units.

1. Introduction

Mycelium-bound composites (MBCs) are sustainable materials formed by growing fungal networks on organic waste, but their structural application is limited by low strength due to their porous nature. This study introduces an advanced fabrication method using 3D-printed porous TPMS scaffolds that enhance mycelium growth through improved oxygen and nutrient flow. The resulting composites show significantly improved strength, demonstrating the potential for

engineered mycelium bio-bricks in construction applications.[1] Growing demand for sustainable construction materials has positioned fungal mycelium composites as promising bio-based alternatives due to their rapid growth and insulating properties. However, enhancing their strength and stiffness through optimized substrate design, fungal selection, and material composition is essential to enable load-bearing applications.[2] Mycelium-based composites are sustainable, low-cost, and biodegradable materials with strong potential in the construction industry due to their eco-friendly properties. However, limitations such as low mechanical strength, high water absorption, and lack of standardization restrict their use, highlighting the need for improved performance and scalability.[3] This study explores sustainable brick production using mycelium as a natural binder with waste materials like sawdust and rice bran. Results show significant improvements in compressive and flexural strength, highlighting mycelium bricks as eco-friendly alternatives to conventional construction materials.[4] Mycelium-based composites are emerging as sustainable, low-energy alternatives to conventional building and insulation materials due to their low environmental impact and excellent insulating properties. However, challenges such as high moisture absorption, shrinkage, and durability need to be addressed to enhance their performance and broader adoption in construction.[5]

2. Literature Review:

Mycelium-based bio-composites have come a long way, but some big hurdles remain before they're widely used in construction. One big problem: there's no standard way to test them, so results can vary a lot from one study to the next. On top of that, there's not much known about how these materials perform over the long haul—especially when it comes to handling humidity, temperature swings, or biological decay. The final product can also change depending on what substrate, fungal species, or growth conditions are used, making it tough to standardize quality. Moisture resistance is a weak point too; if the material absorbs too much water, it can lose strength and break down faster. Plus, the lack of clear building codes and regulatory support keeps these products from breaking into mainstream construction. Fixing these gaps is key if mycelium-based materials are ever going to take off commercially.

3. Tests on Conventional Bricks

3.1 Burnt Clay Bricks

Burnt clay bricks are commonly used in construction due to their strength and durability. The tested specimens ($22.5 \times 10.5 \times 8$ cm, ~3.55 kg) showed a compressive strength of 11.77 N/mm², making them suitable for load-bearing structures. Their water absorption was 5.57%, well within permissible limits, indicating good moisture resistance. In acid resistance testing (3% HCl for 7 days), the bricks retained their shape with only minor surface changes, showing good durability in chemical environments.

3.2 Fly Ash Bricks

Fly ash bricks are an eco-friendly alternative made from industrial waste. The tested samples ($23 \times 10.5 \times 7.5$ cm, ~3.29 kg) had a compressive strength of 6.873 N/mm², suitable for non-load-bearing applications. Their water absorption was 5.15%, slightly better than clay bricks. However, in acid testing, they showed noticeable surface deterioration, indicating lower resistance to acidic conditions, though structural integrity was maintained.

3.3 Fly Ash Brick Plant Visit

A visit to GSR Fly Ash Bricks, Coimbatore provided practical insights into manufacturing. The bricks are made using 47% fly ash, 45% quarry dust, and 8% OPC cement. After moulding, they undergo drying and 14 days of water curing, achieving compressive strengths of 10.3–10.5 N/mm². The process highlights sustainability by utilizing industrial waste and reducing environmental impact compared to traditional bricks.

4. Materials & Methods:

The primary binding agent used in this research was mycelium derived from *Pleurotus ostreatus* (oyster mushroom), obtained from a certified local supplier in Coimbatore. This white-rot fungus is well known for its efficient lignocellulosic degradation and strong hyphal bonding properties, which enable the formation of a cohesive bio-composite matrix. The fungal culture was maintained and propagated using Potato Dextrose Agar (PDA), a standard nutrient medium that supports rapid mycelial growth. The PDA medium was prepared under controlled laboratory conditions to ensure contamination-free inoculation and uniform colonization.

Lignocellulosic substrates used in this study included rice husk, corn leaves, sawdust, hay, and sugarcane bagasse. Rice husk, an agricultural by-product of *Oryza sativa*, was procured from local rice mills in Coimbatore. It is lightweight, porous, and rich in silica, contributing to improved insulation properties. Corn leaves were collected from nearby agricultural fields and dried before use; they provide fibrous reinforcement and enhance the structural integrity of the composite. Sawdust was obtained from local woodworking units and served as a fine particulate substrate, improving packing density and uniformity of the bio-composite. Hay, consisting of dried grasses, was used to increase the tensile bonding and flexibility of the matrix due to its fibrous nature. Sugarcane bagasse, collected from local juice vendors, was used as an additional substrate owing to its high cellulose content, which promotes rapid fungal colonization and contributes to the mechanical strength of the composite. All substrates were cleaned, sun-dried, and processed to achieve uniform size before use.

Sterilization of the substrates was carried out using an autoclave apparatus to eliminate microbial contamination and ensure a controlled growth environment for the mycelium. The substrates were packed in autoclavable bags and subjected to high-pressure steam sterilization at 121°C. This process ensured that only the inoculated fungal culture proliferated within the substrate matrix.

After sterilization, the substrates were allowed to cool to room temperature before inoculation with mushroom spawn under aseptic conditions.

Plywood molds were used for shaping the mycelium-based bricks. The molds were fabricated to standard dimensions suitable for laboratory-scale brick production. They provided the required form and support during the growth phase, allowing the mycelium to bind the substrate particles into a solid structure. The inoculated substrate mixture was filled into the molds and incubated under controlled environmental conditions (temperature and humidity) to facilitate optimal fungal growth and complete colonization.

After sufficient growth and binding, the formed bio-composite bricks were removed from the molds and subjected to thermal treatment to inactivate further fungal growth. This step ensured dimensional stability and prevented overgrowth or degradation. The combination of these materials and processes resulted in the development of sustainable, lightweight, and biodegradable mycelium-based bricks suitable for non-load-bearing construction applications.

5. Development of Mycelium :

5.1 Procedure

We initially tried to develop mycelium using the PDA medium in a laboratory setup. However, the process was highly prone to contamination and the biomass obtained was very low. Due to these issues, the method was not cost-effective and not suitable for practical use.

5.2 Results

The results from this method showed that it was not suitable for large-scale mycelium production. The amount of biomass obtained was very low, and it was difficult to produce a significant quantity within a reasonable time. In addition, the cost of the PDA medium was relatively high, making the process expensive. Overall, this method was found to be time-consuming and not cost-effective for practical application.

6. Cultivation of Mycelium :

6.1 Procedure

Mushroom spawn was used in combination with rice straw as the primary growth medium. The rice straw was soaked in water for 24 hours to soften the fibrous structure and improve fungal accessibility, after which it was cut into suitable sizes to ensure uniform substrate distribution. The substrate was then sterilized to eliminate competing microorganisms, and the mycelium was allowed to grow within mushroom bags for approximately 14 days under controlled conditions. Once sufficient mycelial growth was achieved, the substrate was incorporated into the mixture and transferred into a standard brick mould for further development and consolidation.

6.2 Moulding with substrates :

The fully colonized substrate (rice straw-based mycelium) was carefully broken down and inoculated into the prepared composite substrate mixture as per the defined mix proportion. The inoculated mixture was then thoroughly blended to ensure uniform distribution of mycelial biomass throughout the substrate. Following this, the mixture was transferred into standard brick moulds and lightly compacted to achieve the desired shape and density. The moulded samples were subsequently kept under controlled environmental conditions to promote secondary mycelial growth and binding, allowing the fungal network to interconnect the substrate particles and form a consolidated bio-composite structure.

Material	Percentage (%)	Quantity (g)
Sawdust	23%	173 g
Rice Straw	9%	68 g
Rice Husk	9%	68 g
Corn Husk	8%	60 g
Sugarcane Bagasse	8%	60 g
Coir Pith	8%	60 g
Mycelium Spawn	35%	263 g
Total	100%	750 g

6.3 Results :

After 14 days of incubation within the mould, the formed brick showed visible signs of contamination caused by the presence of *Penicillium* fungi. This fungal contamination adversely affected the quality and structural stability of the final product, rendering the method unreliable for consistent bio-brick production. The contamination was attributed to insufficient sterilization and the high moisture content retained in the rice straw substrate.

7. Growth of Mycelium based brick:

7.1 Procedure:

Based on the shortcomings identified in the preceding two approaches, Research Idea 3 introduced a more rigorous and comprehensive sterilization protocol. In this method, both the rice straw growth medium and the entire substrate blend were sterilized prior to inoculation. Following sterilization and cooling to room temperature under aseptic conditions, the mushroom spawn and the prepared substrate were added directly into the mould. This approach was designed to significantly reduce contamination risk and create an optimal environment for mycelial colonization.

7.2 Mix Proportion:

The mix proportion for mycelium-based bio-bricks uses a **75:25 ratio of substrate to spawn**, where 75% is agricultural waste and 25% is mycelium spawn. This ratio ensures **good colonization, controlled growth, and cost efficiency** compared to higher spawn content.

The substrate is a blend of materials: sawdust (26%), rice straw (14%), rice husk (11%), corn husk (9%), bagasse (9%), and coir pith (6%), along with 25% mycelium spawn. Each component contributes to strength, porosity, and moisture retention, supporting effective mycelial growth.

Sawdust : Rice Straw : Rice Husk : Corn Husk : Bagasse : Coir Pith : Spawn
26 : 14 : 11 : 9 : 9 : 6 : 25

Overall, this proportion provides a balanced combination of **structural performance, biological efficiency, and affordability**.

Material	Percentage (%)	Quantity (g)
Sawdust	30%	225 g
Rice Straw	14%	105 g
Rice Husk	14%	105 g
Corn Husk	11%	83 g
Sugarcane Bagasse	11%	83 g
Coir Pith	5%	39 g
Mycelium Spawn	15%	110 g
Total	100%	750 g

7.3 Results:

The improved sterilization protocol yielded significantly better outcomes compared to previous methods. No fungal contamination was observed throughout the incubation period, confirming the effectiveness of the enhanced sterilization procedure in eliminating competing microorganisms. However, only minimal mycelial growth was recorded within the allotted timeframe. It was inferred that a longer incubation duration is necessary for complete colonization and for the mycelium to fully consolidate and conform to the shape of the mould. These findings provided a strong foundation for further optimization, particularly in defining the minimum required incubation period for full bio-brick formation.



8. Conclusion:

8.1 Results and discussion

This study successfully demonstrates the development of mycelium-based bio-composite bricks using agricultural waste materials such as rice straw, sawdust, corn husk, bagasse, and coir pith, combined with *Pleurotus ostreatus* as a natural binding agent. The research establishes that mycelium can effectively act as a biological binder, forming a cohesive and stable structure through its hyphal network. The developed bio-bricks exhibit ultra-lightweight characteristics, excellent thermal insulation, and significant environmental benefits, including reduced embodied carbon and complete biodegradability. These properties make them highly suitable for non-load-bearing construction applications such as partition walls, insulation panels, and temporary structures. Comparative analysis with conventional bricks highlights that while MBBs fall short in compressive strength, they outperform in terms of sustainability, energy efficiency, and material circularity. The study also emphasizes the importance of controlled sterilization and incubation conditions in achieving contamination-free and consistent results. Despite certain limitations such as lower strength, high moisture absorption, and longer growth duration, the research validates the feasibility of integrating bio-based materials into modern construction practices. Thus, mycelium-based bricks represent a promising step toward sustainable and circular construction systems.

11. Future Scope

Future research can focus on enhancing the mechanical strength and durability of mycelium-based bricks to expand their applicability beyond non-load-bearing uses. This can be achieved through the incorporation of natural fibers, bio-resins, or hybrid composite materials. Improving moisture resistance is another critical area, which can be addressed through surface coatings, chemical treatments, or optimization of substrate composition. Further studies are required to determine the optimal incubation period and environmental conditions for maximum mycelial growth and structural integrity.

Standardization of production methods, testing procedures, and quality control measures is essential to ensure consistent performance and scalability. Additionally, long-term performance

studies under varying environmental conditions will help evaluate durability and real-world applicability. From an industrial perspective, scaling up production using automated systems and low-cost agricultural waste can make the process more economically viable. Integration of mycelium-based materials into building codes and construction standards will also be crucial for widespread adoption.

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