Eco-Friendly Insulation Panel Using Mushroom Mycelium for Green Buildings

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Abstract: The current study examines the development and characterization of green insulation panels from oyster mushroom (Pleurotus ostreatus) mycelium grown on wheat straw substrate. Traditional insulation materials like polystyrene and polyurethane are energy intensive, non- biodegradable, and often flammable, making sustainable substitutes desirable. Mycelium, which is the vegetative part of fungi, grows spontaneously onto organic substrates to form porous, light-weight composites with intrinsic fire and heat resistance. Two 200 × 195 × 60 mm boards were made in this study without incorporating chemical additives or binders. The wheat straw substrate was pasteurized and inoculated with a mushroom spawn and then incubated in silicone molds at 24–28 °C for 10–14 days until the colonization process was completed. Consolidation was then done by oven-drying at 60°C. We tested the thermal conductivity, water absorption, compressive strength, and fire performance of the panels. The tests registered good insulation with a thermal conductivity of about 0.062 W/m·K. The natural fiber composites exhibited moderate water absorption with 38% water absorbed. The fire tests exhibited inherent fire safety with ignition retarding, limited flame spread, low char depth, and minimum mass loss. Its 0.065 MPa compressive strength further guaranteed that it was ideal for non- load-bearing applications. Overall, these findings confirm that mycelium-wheat straw panels, being light in weight, biodegradable, and sustainable materials, are an ideal replacement for conventional insulation material in green buildings. This research is a model of the possibility of upcycling wastage from agriculture while producing usable, sustainable building materials that contribute to green building methods.

Keywords: *Mycelium, Green Insulation, Compressive Strength, Thermal Conductivity, Fire Resistance.*

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I. INTRODUCTION

Due to their environmental footprint, the building materials traditionally used in construction are being increasingly replaced by sustainable and environmentally friendly alternatives. This is because conventionally used insulation products such as mineral wool, polystyrene, and polyurethane are energy-hungry, non-biodegradable, and often pose fire risks. The inherent capacity of mycelium to aggregate organic substrates into lightweight, porous, and thermally insulating panels has positioned mushroom mycelium-based composites as a viable option. Mycelium growth prospers here on wheat straw, an abundant agricultural waste product that provides a cheap and green substrate. In order to develop a totally biodegradable, chemical-free insulating material suitable for green buildings, this project aims to develop an eco-friendly insulation panel based on oyster mushroom (Pleurotus ostreatus) mycelium grown on wheat straw. The research not only investigates the production process but also compares the panels in terms of thermal conductivity, water uptake, compressive strength, and fire resistance to determine their performance against traditional insulation materials. The study aims to create panels from pure mycelium and wheat straw without additives, measure their thermal insulation properties, examine moisture retention behaviour, test mechanical strength in handling and non-load-bearing applications, and test fire resistance by ignition time, flame spread, char depth, and mass loss. In general, the research shows the effectiveness of mycelium–wheat straw panels as a light, biodegradable, and environmentally friendly material for sustainable building, helping with waste valorisation and resource-saving architecture.

II. PROPERTIES OF MATERIAL

➢ *Mycelium (Pleurotus Ostreatus)*

Mycelium is the vegetative, branching filamentous component of fungi that increases in size by sending thread-like hyphae into organic material. Mycelium is a biological

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adhesive, breaking down and binding straw, sawdust, or farm waste into a rigid, interlocking structure. Mycelium is light, porous, and biodegradable and has special properties including thermal insulation, resistance to fire, and restricted mechanical strength. Its ability to grow on low-cost, renewable substrates and form free- standing composites has made mycelium a new sustainable material for building, packaging, and insulation. It develops naturally with low energy inputs, and the resulting panels may be composted at the end of their life cycle, providing an excellent alternative to manmade insulation material.

Fig 1 Mushroom Spawn

➢ *Physical Properties of Mycelium*

Table 1 Physical Properties of Mycelium

Property	Density (Kg/m3)	Porosity	Moisturcontent	Colour	Odour
Values	180	65 %	8 %	White to off- white	Earthy, Mild

➢ *Chemical Properties of Mycelium*

Table 2 Chemical Property of Mycelium

Property	Lignin	Chitin	pH	Protein
Values	10 %	15 %	6.5	10%

➢ *Mechanical Properties of Mycelium*

Table 3 Mechanical Property of Mycelium

Property	Compressive Strength (MPa)	Flexural Strength (MPa)	Hardness
Values	0.065	0.18	Moderate

➢ *Wheat Straw*

Wheat straw is dry stalk that remains after wheat grain harvesting, which is usually regarded as an agricultural residue. It is primarily made up of cellulose, hemicellulose, and lignin, making it a tough, fibrous, and biodegradable substance. Because of its light weight and porous nature, wheat straw offers very good aeration and water retention properties, hence a suitable substrate for fungus growth, particularly for fungi such as Pleurotus ostreatus (oyster mushroom). Utilization of wheat straw in product manufacturing not only minimizes farm waste but also ensures sustainable resource usage by transforming a potentially wasted by-product into a beneficial, sustainable material for insulation and other sustainable building uses.

Fig 2 Wheat Straw

➢ *Physical Properties of Wheat Straw*

Table 4 Physical Properties of Wheat straw

Property	Density (Kg/m3)	Porosity	Moisture Content	Appearance
Values	110	70 %	10 %	Light yellow, Fibrous material

➢ *Chemical Properties of Wheat Straw*

Table 5 Chemical Property of Wheat Straw

Property	Lignin	ASH Content	pH
Values	17%	6 %	7

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➢ *Mechanical Properties of Wheat Straw*

Table 6 Mechanical Property of Wheat Straw

Property	Compressive Strength (MPa)	Tensile Strength (MPa)	Thermal Conductivity (W/m.K)
Values	0.08	45	0.061

III. METHODOLOGY

The methodology outlines the organized steps taken to examine the performance and properties of mushroom mycelium-based insulation panels. The research involves substrate preparation, mycelium inoculation, panel curing and growth, and examination of mechanical, thermal, and fire-resistant properties.

Two insulation panels were produced from oyster mushroom (Pleurotus ostreatus) mycelium that had been cultured on wheat straw substrate alone, without additives. Wheat straw was cut into 2–4 cm lengths and pasteurized in boiling water (70–80 °C) to kill off contamination, before cooling to room temperature. Spawn was incorporated at 10% by wet weight and mixed well to distribute the inoculum evenly. The inoculated substrate was filled into two 200 × 195 × 60 mm size silicone moulds, compressed gently to ensure porosity, and plastic-wrapped to preserve moisture with gas exchange. The moulds were incubated at temperatures ranging from 24–28 °C with over 80% humidity for 10– 14 days until colonization was complete. Following colonization, the panels were allowed to remain in the mould for 3–5 days for the mycelium to bind and consolidate before being oven-dried at 60 °C to constant weight to prevent further growth. Specimens were either used as whole panels or cut as necessary for testing. Thermal conductivity was determined by using a hot plate technique by imposing a constant temperature difference of 20 °C through the thickness of the panel. Water uptake was measured by weighing dry mass of panels and subjecting them to 24 hours water immersion. Compressive strength was assessed on the entire panel surface area (0.039 m²) with a universal testing machine by loading until failure. Fire resistance was tested by applying a small flame to panel surfaces in order to measure time to ignition, flame spread, after-flame time, and char depth and mass loss, with all tests safely completed using suitable PPE and ventilation. All measurements were taken in triplicate wherever possible for reliability, with means reported for analysis.

Table 7 Mix Proportion

Material	Wheat Straw	Mushroom Spawn	Water
Weight	800g	200g	600ml

IV. TEST RESULT

➢ *Thermal Conductivity Test:*

To measure the heat insulation ability of the mycelium–wheat straw panel. A smaller value of thermal conductivity implies the higher performance of insulation. The test of thermal conductivity was done by means of the hot plate method. The temperature gradient between the hot and cold sides was kept at 20°C, and the heat flow was observed. The mycelium–wheat straw panel had an average thermal conductivity of 0.061 W/m·K, which implies good performance of insulation. By the use of the formula:

Fig 3 Panel on Hot Plate

Table 8 Thermal Conductivity

Specimen	Thickness (mm)	Temp. Difference (°C)	Heat Flow (W)	Thermal Conductivity (W/m.K)
Panel 1	60	20	0.36	0.060
Panel 2	60	20	0.38	0.063

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➢ *Water Absorption Test*

To determine moisture gain, critical in terms of dimensional stability and durability. Testing for water absorption was carried out by soaking the mycelium–wheat straw panel in water for 24 hours. The mass gain after soaking was recorded, and water absorption was determined. The panel had an average water absorption of 38%, representing moderate water uptake, using the formula:

$$\text{Water Absorption } (\%) = \frac{W_{\text{wet}} - W_{\text{dry}}}{W_{\text{dry}}} \times 100$$

Fig 4 Panel Immersed in Water

Table 9 Water Absorption

Specimen	Dry Weight (g)	Wet Weight (g)	Water Absorption (%)
Panel 1	421	582	38.2
Panel 2	421	580	37.8

➢ *Compressive Strength Test*

To find the load-bearing capacity. Compressive strength testing was done with a universal testing machine. The mycelium–wheat straw panel was loaded to failure, and the load at failure was noted. The panel recorded an average compressive strength of 0.065 MPa, showing moderate structure stability, by the formula:

$$\text{Compressive Strength (MPa)} = \frac{\text{Maximum Load (N)}}{\text{Cross-sectional Area (mm}^2\text{)}}$$

Fig 5 Panel on CTM

Table 10 Compressive Strength

Specimen	Maximum Load (KN)	Area (m^2)	Compressive Strength (MPa)
Panel 1	2.5	0.039	0.064
Panel 2	2.6	0.039	0.067

➢ *Fire Resistance*

In order to evaluate the ignition, flame spread, and char growth. The fire resistance test was performed by exposing the mycelium–wheat straw panel to a flame for a certain period of time. The ignition time and the burning extent were measured. The panel showed an average fire resistance of 15 minutes, reflecting moderate fire-retardant characteristics, using the formula

$$\text{Mass Loss } (\%) = \frac{(w1 - w2)}{w1} \times 100$$

Fig 6 After Flame

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Table 11 Fire Resistance

Specimen	Time to Ignition (s)	Flame Spread (cm)	After- flame Duration (s)	Char Depth (mm)	Mass loss (%)
Panel 1	14	5	3	2.1	8.0
Panel 2	15	4	2	2.0	7.5

V. CONCLUSION

The research effectively showed the fabrication and performance of green insulation panels by using oyster mushroom (Pleurotus ostreatus) mycelium grown on wheat straw without chemical additives. Panels showed low thermal conductivity (~0.062 W/m·K), reflecting good heat insulation for green building applications. Water absorption test revealed a moderate moisture hold of 38%, indicating the requirement for proper installation in humid conditions but within acceptable levels for non-load- bearing insulation. Compressive strength values on the entire panel surface gave 0.065 MPa, which is good confirmation that the panels are appropriate for non-structure purposes. Fire resistance tests proved to exhibit late ignition, small flame spread, small char depth, and low mass loss, suggesting intrinsic fire safety benefits owing to mycelium charring behavior. In conclusion, the research certifies that mycelium–wheat straw panels are a sustainable, light, and biodegradable insulation material compared to traditional materials, presenting a promising option for green building while aiding in waste valorization and resource efficiency.

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