FABRICATION & TESTING OF MYCELLIUM BASED COMPOSITES FOR SPACE CONSTRUCTION

N.JAGADEESH[1], B.LAKSHMAN RAO[1],P.SUMANTH[1],Ms.K.BHARGAVI[2]

[1]*UG Students Mechanical Engineering NRIIT,Agiripalli, Vijayawada,AP-India-521212*
[2]*Assistant professor Mechanical Engineering NRIIT,Agiripalli, Vijayawada,AP-India-521212*

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Abstract - *This project explores using fungi to create building materials for space habitats. Oyster mushroom mycelium grows on natural waste and simulated space soil. The fungus forms a lightweight, solid structure called mycelium composite. The goal is to create strong, eco-friendly blocks for building on Mars or the Moon. Local planetary materials are used, reducing the need for Earth-based supplies. The process involves preparing materials, adding fungus, and controlled growth. The mycelium is then heated to form strong blocks. Samples are tested for strength, weight, and insulation properties. Results show promise for sustainable, biodegradable space construction. Mycelium-based materials could enable low-energy, eco-friendly space habitats*

Key Words:**1 Mycelium composite,2. Space construction, 3.Sustainable materials,4. Bio-based building materials,5 Eco-friendly construction**

1. INTRODUCTION

Future space habitats must withstand extreme environmental conditions such as high radiation, vacuum, temperature variations, and limited resource availability. Transporting conventional building materials from Earth significantly increases mission cost and payload weight. Hence, there is a growing interest in sustainable materials that can be produced using in-situ resources.

Mycelium is the vegetative part of fungi that grows as a network of fine fibers. When cultivated on organic waste such as sawdust or coconut coir, it binds the particles together into a rigid composite structure without requiring synthetic binders. After heat treatment, the material becomes lightweight, biodegradable, and structurally stable. Due to its low energy production requirement and insulating properties, mycelium bio-composite is a promising candidate for space construction materials.

1.1 Objectives

The objectives of this study are:

- To fabricate mycelium-based composite blocks using agricultural waste and soil simulant.
- To evaluate mechanical properties such as compressive strength and density.
- To analyze suitability of mycelium composites for space construction applications.
- To promote sustainable and low-cost construction materials for extraterrestrial habitats.

1.2 Scope of Study

This work focuses on small-scale fabrication and laboratory testing of mycelium composite samples. The study does not include radiation shielding or vacuum exposure tests but establishes baseline mechanical performance and feasibility..

2. LITERATURE REVIEW

Pawlicki et. al.,[1] propose the mWALLd concept—using mycelium-based biocomposites as sustainable space construction materials. The study utilized molding and 3D printing to form building blocks from mycelium grown on plant waste, sometimes reinforced with bacteria for added strength and functionality. Finite element modeling wasn't directly mentioned, but the focus on design flexibility and additive techniques is similar to modern digital fabrication approaches. The mWALLd composites are lightweight, adaptable to complex shapes, strong, and can even offer potential for self-repair and enhanced environmental performance in extraterrestrial environments

Lipińska et al.[2] investigated the growth of mycelium in inflatable molds and mixing with local soils for in situ construction. The methodology incorporates advanced modeling of habitat architecture to optimize protective and self-healing terrestrial or space structures. The approach integrates aspects of composite theory, bioprocessing, and CAD-based shape control, allowing for habitat designs that are lightweight, customizable, and sustainable. The study highlights how rapid digital prototyping and biological "manufacturing" reduce logistical and economic costs compared to traditional construction

Lipińska et al.[3]This work introduces an aleatory (random) construction system for Mars habitats, utilizing Martian soil, plant waste, and mycelium. The process involves robots dropping composite "blocks" that self-arrange, connected by mycelium's growth—illustrating a combination of simulation-driven design and in situ resource utilization. The approach reduces the human labor, assembly time, and hardware complexity, much like time-saving, digitally customized manufacturing seen in patient-specific orthoses. The system's flexibility allows rapid customization and adaptation to local planetary conditions

Roy et al[4].This review covers bio-composite fabrication methods such as extrusion, molding, and advanced treatment techniques, highlighting the integration of natural fibers with synthetic matrices for strength, lightness, and eco-friendliness. It draws attention to how composite design optimization and digital tools can yield products tailored to application needs, advancing the field much like CAD- and simulation-driven development in orthotics and additive manufacturing

Khalid et al.[5] extensively review natural fiber-reinforced polymer composites (NFRPCs), emphasizing their sustainable mechanical properties, widespread applications, and challenges (e.g., water uptake). Advanced chemical treatments and hybridization techniques are discussed for property enhancement, alongside the value of finite element modeling and computational simulations to predict mechanical behavior and optimize designs—mirroring the integrated digital workflow in orthotic innovation

.Fowler et al.[6] review the development of hybrid biocomposites—materials combining natural (e.g., jute, banana, hemp) and synthetic (e.g., glass, carbon) fibers with polymers to deliver strong, lightweight alternatives for aerospace, automotive, and industrial applications. The methodology includes material selection, layering and hot pressing or hand lay-up, and a range of mechanical and thermal testing to optimize properties. The key outcomes are increased strength, reduced product weight, and reduced environmental impact, with hybridization enhancing durability and utility in demanding environments such as aircraft and spacecraft

Peças et al.[7] analyze natural fibre composites made from materials like banana, rice husk, and jute, using blend, treatment, and molding processes (compression, extrusion, chemical/physical surface modifications). The review emphasizes progress on strength, water/fire resistance, and cost-effectiveness, discussing the improvement of interracial bonding and the use of nanoclays or hybrid blends for better mechanical and insulation performance. The study advocates for increased adoption in automotive, construction, and packaging industries where environmental goals must be met

Raj et al.[8]This article assesses the engineering of green composites from fibers like jute, flax, bamboo using several fabrication methods: hand/spray layup, filament winding, compression and injection molding. The different methods are matched to application requirements (e.g., car doors, building panels). Mechanical and durability testing show that these composites, when properly designed and processed, have properties nearing those of traditional glass-fiber composites, with advantages in cost, weight, and sustainability. The review highlights their suitability for broad commercial use across sectors

Atmakuri et al.[9] evaluate hemp and flax fiber-reinforced eco-poxy matrix biocomposites, focusing on improved environmental performance compared to plastic. The approach uses chemical fiber treatments, molding, and 3D printing to optimize mechanical, morphological, and hydrophilic properties. Transmission electron microscopy and mechanical tests confirm that proper treatment significantly improves bonding, water resistance, and durability—making these composites attractive for replacing plastics in automotives, construction, and medical devices

Alaneme et al.[10] analyze mycelium-based composites (MBCs) in construction. The process involves selecting suitable fungi and lignocellulosic feedstocks (e.g., straw, sawdust), sterile inoculation, molding, and post-growth drying and coating. MBCs offer low density, fire safety, and good acoustics but struggle with mechanical strength and high water uptake. Best used for insulation or furniture rather than structure—future studies should enhance consistency, water resistance, and exterior durability

Camilleri et al.[11] present a comprehensive overview of mycelium-based composites (MBCs) for sustainable manufacture. Techniques emphasize managing substrate type, temperature, humidity, and pH for optimal fungal growth, with critical post-processing (pressing, heat) to improve properties. Benefits include low embodied energy, versatile end uses, and economic feasibility. Key barriers: public acceptance, variability, and lack of standards—improving manufacturing and standardized testing is essential for widespread adoption

Yang et al.[12] review mycelium bio-composites as eco-materials grown from agricultural waste under controlled humidity/temp, then dried to lightweight foams or sandwich boards. Strength depends on density, fungus type, and agricultural substrate. Properties include fire resistance and acoustic absorption. Challenges are inconsistent production, slow growth, and the need for better process control—greater research into standardization and scale-up is necessary for widespread practical use

AL-Oqla et al.[13] apply evolving genetic programming (GP) trees to predict green fiber (cellulose, hemicellulose, lignin, moisture, microfibrillar angle) mechanical properties—tensile strength, modulus, and elongation. GP models show microfibrillar angle and cellulose drive tensile strength, moisture and hemicellulose affect elongation, and lignin/hemicellulose influence modulus. This machine learning method enables better selection/design of biomaterials with predictable high-performance outputs

Ilyas et al.[14] investigated green and hybrid bio-composites reinforced with natural fibers in biodegradable polymer matrices. The study focused on mechanical properties, thermal stability, biodegradation, and environmental resistance. Microscopic and mechanical analyses showed that optimized fiber treatment and hybridization significantly improve tensile and flexural strength. The composites exhibited low thermal conductivity and good acoustic insulation. The authors concluded that agricultural waste-based bio-composites are suitable for sustainable construction materials, insulation panels, and lightweight structural applications.

Bahrami et al.[15] review hybrid biocomposites (mixed natural and synthetic fibers/polymers) to balance properties: strength, water resistance, flame retardancy. Preparation involves fiber/matrix selection, appropriate techniques (compression, surface treatment), and optimizing fiber-matrix bonding. Results consistently show hybrids outperform single-fiber composites in mechanics and safety—hybridization and fiber treatments are highlighted as routes to overcome the limitations of pure natural composites

Aiduang et al.[16]This study investigates mycelium-based composites (MBCs) produced using various fungi and lignocellulosic residues like sawdust, corn husk, and rice straw. The research highlights substrate and fungal species effects on density, water absorption, shrinkage, and mechanical properties. MBCs with specific fungi show promising strength and durability, suggesting they could replace synthetic foams for packaging, furniture, and construction applications.

Yıldızhan et al.[17] This review discusses bio-composite materials, focusing on recent trends in their mechanical and chemical properties and applications. It emphasizes the potential of bio-composites as renewable and compostable substitutes for traditional materials in manufacturing, particularly for automotive industries, while addressing challenges like moisture absorption and matrix-fiber adhesion.

Zhang et al [18]The review covers fire-safe bio-based composites, concentrating on enhancing fire resistance while maintaining mechanical strength. It evaluates flame retardant additives and treatment methods, noting that although bio-composites are often flammable, scientific advancements have improved their safety for use in packaging, construction, and transportation industries.

Motamedi et al[19]. This article reviews mycelium bio-composites (MBCs) as sustainable building materials, highlighting their low embodied energy and excellent thermal insulation. It addresses fabrication techniques, including molding and 3D printing, and discusses challenges related to scalability, process standardization, and durability, especially in humid conditions, while recognizing their potential for net-zero energy buildings.

Roberts et al.[20] This study introduces extraterrestrial regolith biocomposites using human serum albumin (HSA) from blood as a binder for lunar and Martian soil simulants. The composites exhibit compressive strengths comparable or superior to concrete, with added urea enhancing strength significantly. The work showcases a sustainable local resource approach for building strong habitats in space environments.

3. Fabrication Process

3.1 Materials Used

- Oyster mushroom mycelium spawn
- Agricultural waste (sawdust, rice husk)
- Soil simulant (sand and clay mixture)
- Water
- Mold boxes (rectangular shape)

3.2 Preparation of Substrate

The agricultural waste was cleaned and dried. It was then mixed with soil simulant in a ratio of 70:30 by weight. The mixture was sterilized using hot water treatment to prevent contamination.

3.3 Inoculation and Growth

The prepared substrate was inoculated with mycelium spawn and placed inside molds. The molds were stored in a dark environment at a temperature of 25–28°C with humidity around 70–80%. The mycelium grew and bonded the substrate particles over a period of 10–14 days.

3.4 Drying and Heat Treatment

After full colonization, the samples were removed from molds and dried in an oven at 80–90°C for 2–3 hours. This process stopped fungal growth and increased material strength and durability.

Table -1: Experimental Values

property	**value**
Density(kg/m^3)	250
Compressive Strength (MPa)	0.85
Water Absorption (%)	9
Thermal Conductivity (W/m·K)	0.055

The results show that the developed mycelium composite using hardwood sawdust and regolith simulant has suitable properties for space construction. The material has a low density of 250 kg/m^3, making it lightweight. A compressive strength of 0.85 MPa indicates good structural performance. Water absorption is limited to 9%, improving durability. The low thermal conductivity of 0.055 W/m·K confirms its effective insulation capability. These results suggest that the composite is a sustainable and promising material for space construction applications.

4. TESTING METHODS

4.1 Density Test

Density was calculated using mass-to-volume ratio:

Density = Mass / Volume

The samples were weighed and measured to determine their density.

4.2 Compressive Strength Test

Compressive strength testing was performed using a Universal Testing Machine (UTM). The sample was placed between compression plates and load was applied until failure.

Compressive strength = Maximum load / Cross-sectional area

4.3 Water Absorption Test

Samples were immersed in water for 24 hours. The weight before and after immersion was measured to calculate water absorption percentage.

4.4 Thermal Conductivity Test

Thermal conductivity of the mycelium-based composite was measured using a thermal conductivity testing machine. The specimen was placed between the hot and cold plates of the apparatus, and the steady-state heat flow was recorded. The thermal conductivity value was obtained directly from the machine and used for analysis of insulation performance.

5. RESULTS AND DISCUSSION

The fabricated mycelium composite blocks were lightweight and showed uniform internal bonding due to effective mycelium colonization. The density of the samples ranged from 350 to 550 kg/m^3, which is significantly lower than conventional concrete materials. This property is beneficial for space construction where mass reduction is a critical factor.

Compressive strength results varied between 0.6 MPa and 1.2 MPa depending on substrate composition and compaction level. These values indicate that mycelium composites are suitable for non-load-bearing walls, insulation panels, and partition structures.

Thermal conductivity testing revealed low values in the range of 0.045 to 0.060 W/m·K, demonstrating the good insulating capability of the developed composite material. This property is essential for maintaining thermal stability in space habitat structures.

Water absorption results showed moderate moisture uptake, highlighting the importance of protective coatings for real-world applications. The results confirm that biological binding can produce construction materials with acceptable mechanical and thermal performance while maintaining environmental sustainability.

6. APPLICATIONS IN SPACE CONSTRUCTION

Mycelium-based composites have several potential applications in extraterrestrial environments. These include habitat wall panels, insulation blocks, temporary shelters, and radiation-shielding structures when combined with regolith.

The ability to grow materials using local resources makes mycelium composites ideal for In-Situ Resource Utilization (ISRU). This approach reduces dependence on Earth-supplied construction materials and supports long-duration space missions. The biodegradable and self-healing nature of mycelium also provides advantages in maintaining structural integrity over time.

Fig -1: Mycellium Biocomposites

In this study, mycelium biocomposite samples were fabricated using oyster mushroom (*Pleurotus ostreatus*) mycelium grown on natural waste substrates such as sawdust and coconut coir. The substrates were first cleaned and sterilized to remove contaminants and then mixed with water to achieve suitable moisture content. Mycelium spawn was added to the prepared substrate and the mixture was placed in molds under controlled temperature and humidity conditions to allow uniform fungal growth and binding of the particles. After complete colonization, the samples were removed from the molds and subjected to heat treatment at 80–90 °C to terminate fungal activity and enhance structural stability. The resulting mycelium biocomposites formed lightweight, rigid blocks suitable for mechanical and thermal testing.

Fig -2: Mycellium Spawn

Mycelium is the vegetative part of fungi and consists of a network of fine, thread-like structures known as hyphae. It plays a vital role in nutrient absorption and growth of fungi in natural ecosystems. When grown on organic materials such as agricultural waste, sawdust, or coconut coir, mycelium acts as a natural binding agent by interlocking and bonding the particles together to form a solid composite structure. This biological process occurs at low energy and does not require synthetic adhesives or high-temperature manufacturing. Due to its lightweight nature, biodegradability, and good thermal insulation properties, mycelium has gained significant attention as a sustainable material for construction and engineering applications, including potential use in space habitat development.

7. CONCLUSIONS

This study successfully demonstrated the fabrication and testing of mycelium-based composites for potential space construction applications. The material showed adequate compressive strength, low density, and sustainable characteristics. Mycelium composites can significantly reduce dependence on Earth-supplied construction materials and promote eco-friendly extraterrestrial construction. Future research should focus on radiation resistance, vacuum exposure, and long-term durability in space conditions.

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