Mycelium: An Eco-Friendly Construction Material

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***Abstract*— We the users of the resources available on earth can see, that the higher demands & excessive use of these resources have led to gradual depletion or is leading to gradual depletion of the resources & global warming. These resources also include the construction materials. The basic materials used in construction include stone, cement, bricks, steel, etc. The processing of these material from making to putting them on site requires a lot of energy, this leads to increase in carbon footprint. Many companies, scientists, researchers are coming up with ways to reduce the effects by turning to eco-friendly & environmentally fewer impacting materials.**

One of the very recently found materials is mycelium (roots of the fungi / mushroom). It can be used in many forms such as furniture, insulation panels – myco boards (replacement to MDF), kayaking boats, bricks, packaging material & also the fashion industry. The following are its characteristics: good fire resistance, good water-resistant capacity, light weight, low-cost, good insulation.

Study for the following topic will be conducted using research papers & case studies. It will cover the material making process, but also the mechanical aspect.

Keywords: Mycelium, eco-friendly, low-cost, light weight, biodegradable, sustainable material

I. INTRODUCTION

With growing population there is a significant amount of pressure being put on the construction industry as well as other industries, this has led to increase in construction waste (debris) as well as other wastes. This very waste is hard to dispose as the processes to discard it leads to contribution of greenhouse gases, carbon footprint & damaging the eco-system. Luxury & comfort comes at the cost of polluting our land, air & water, which belong to the list of basic needs of a living species.

The amount of energy required to harvest or extract primary material; right from their manufacturing, to transport & build a structure is up to 36% of the lifetime energy demand of a typical dwelling. Structure that consumes less energy (low energy buildings or green buildings) are environmentally damaging as they require raw materials such as higher insulation, high density materials, thicker wall, advanced technologies; this leads to 46% of the lifetime energy demand of a typical dwelling.

It is also used in packaging as an alternative to polystyrene, companies like IKEA & DELL have replaced their packaging with mycelium-based packaging. Mycelium based packaging is made / created by using organic waste as a substrate for the growth of mycelium; it is further broken down & put into moulds for the solid form to grow.

II. COMPONENTS / MATERIALS USED TO GROW MYCELIUM

A. Mushroom Spores or Spawns.

They are the reproductive part or the seeds & are present in the gills of the mushroom

B. Potato dextrose Agar (PDA).

Most fungi & bacteria species are grown with the help of potato dextrose (agar & broth) as they are common microbiological growth media.

C. Subtrate.

It is a mixture made of natural materials which help with the growth of mycelium. The mixtures are as follows: paddy straw, fine paddy powder, saw dust, wheat grain.

But the best suited mixture for the growth of mycelium is 70% Rice Husk (RH) + 30% Wheat Grain (WG) work well in comparison to other mixtures. The mixture follows a sterilization process before use.

Note – Mycelium cultivation process is completely eco-friendly, zero-carbon, less time consuming, has a scope for mass production & also no residue of any sorts is left behind pre & post production. Mycelium products can be reused or can be mixed with soil post usage.

III. SWOT ANALYSIS

- **Strengths –** Mycelium is it's a versatile material. When partnered with other materials like wood or even sandwiched, its performance is improved, it is also known as mycelium composites. It has great absorption, insulation, water resistance & fire resistance.
- **Weakness** – mycelium lacks Compressive strength & it's the only drawback so far
- **Opportunities** – if worked on the only weakness mycelium can be used in many industries. It's already grabbed market in to packaging (IKEA & DELL), food industry by replacing meat, furniture, outdoor products like boats.
- **Threats** – So far mycelium has not been a threat of any sort.

IV. WHAT IS COMPOSITE MYCELIUM?

When mycelium is paired with a substrate for growing as well as increasing its performance, they are known as mycelium composites. The substrate type can be changed according to the need of & use of the mycelium composites.

A. Tables

The following tables will give the mechanical properties & they have been derived from the literature studies.

Growth Substrate	Density (kg/m^3)	Elastic Modulus in compression (MPa)	Yield Compressive Strength (MPa)	Average Ultimate Compressive Stress (MPa) at (X% deformation) when material fails
Cotton Carpel	66.5-224	N.A.	N.A.	0.07 (N.A.)
Red-oak sawdust	318	N.A.	0.05	0.5 (>16%)
Woodchip & sawdust of Chinese albizia	420	4.00	0.17	1.2 (31%)
Sugarcane & Dried Waste of Cassava Root	470	21.10	1.1	6.4 (50.6%)
Wheat Straw	277	N.A.	0.02	0.07 (N.A.)
White Oak Sawdust	552	N.A.	0.15	1.02 (N.A.)
Cotton seed hull	181	N.A.	0.18	N.A.
Cotton seed hull & 5% latex	225	N.A.	0.34	N.A.

Table 1: Light-Weight Mycelium-Bound Materials in Brick Form.

Material	Density (kg/m^3)	Tensile Strength (MPa)	Elastic Modulus in Tensile (MPa)	Flexural Strength (MPa)	Elastic Modulus in Flexural (MPa)
MycoBoard reported by Jones et. al. as evocative design product.	801	N.A.	N.A.	15	2640
Hot-Pressed Mycelium-bound wood particles.	600	N.A.	N.A.	105	220
Hot-Pressed Hybrid Mycelium-bound wood particles with 2.5% wt cellulose Nanofibrils.	600	N.A.	N.A.	305	575
Cold-Pressed Mycelium-bound Cotton.	240	0.03	6	0.24	12
Hot-Pressed Mycelium-bound cotton	350	0.13	35	0.64	34
Cold-pressed Mycelium-bound rapeseed.	240	0.03	9	0.21	15
Hot-Pressed Mycelium-bound rapeseed	390	0.24	97	0.87	72

Table 2: Dense Mycelium-Bound Boards.

ISSN: 2278-0181
NCA - 2022 Conference Proceedings

V. CASE STUDIES.

A. The Hy-Fy

The following structure was built in 2014 by 'The Living Embodied Computation Lab', it was commissioned by Princeton University in Queens, New York. A specially formulated mycelium was used into the making of the structure, where brick shaped molds were used to shape the mycelium into brick shapes.

The mixture assembled into a lightweight solid object over the few days. 10,000 bricks were made & the structure stood 13 meters tall.

Later when the structure was demolished, the mycelium bricks were composted resulting into soil & were distributed to the local garden.

Figure 1: Top View

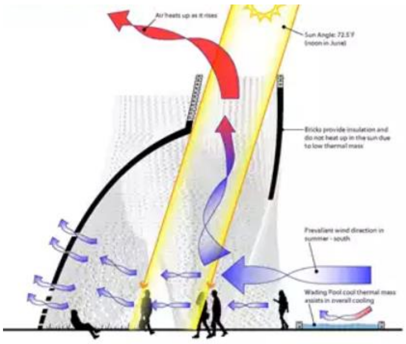

Figure 2 : Light Penetration & Ventilation

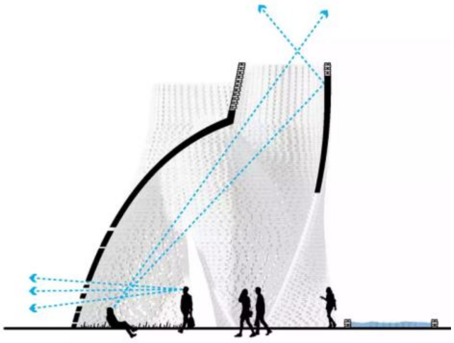

Figure 3 : Line Of Vision.

B. Mycotree

Architect Drik Hebbel & Philippe Block created a tree-shaped self-supporting structure out of mycelium components formed from the root networks of mushrooms. The brick shaped mycelium blocks have bamboo panels attached to both its ends for support & the structure stands on the attachment of metal dowels. The mycelium blocks used in mycotree structure were designed in a 3D program & the fabrication was done with the mixture of mycelium spawn / spore with saw dust & sugarcane. After the mycelium growth was complete, it was dehydrated to form a solid block & to halt the growth. The creators of this structure want to show that when a weak component is coupled with a strong component it can still create wonders.

The architect went ahead to create Mycotree 2.0. The base material was kept the same but the species was changed & also the composition of the substrate, this made the mycelium bricks denser in nature.

Figure 4: View Of The Myco-Tree.

Figure 5: Making of the Myco-Bricks

Figure 6: Assembling Of The Myco-Bricks

Figure 7: Close-up View Of The Myco-Tree.

C. The Growing Pavilion

As the name rightly suggests 'The Growing Pavilion' was built with naturally forming fungi (self-assembling). It was a temporary structure erected to host multiple events at Dutch Design Week.

The components used to build to this structure are: mycelium, timber & bio-based coating originally developed by the Inca people around 12th century. The frame was built first using timber, then the mycelium panels were fitted into the timber frame. Panel fitting was done in such a way that it could be removed & re-used for other purposes.

Figure 8: View of The Growing Pavolion.

Figure 9: Inside View of the Pavilion.

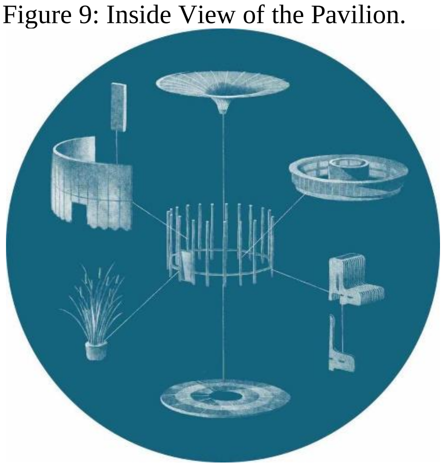

Figure 10: Component Use in Exploded View

D. The Shell Mycelium Installation.

It was a temporary study structure erected under the abstract: a critique of the use of heavy materials in temporary structure for events such as the Olympic or expos around the world. the specifications of the project are as follows: -

Location: Kochi, Kerala.

Lead Architects: Giombattista Areddia, Asif Rahman, Mohmad Yassin.

Collaborator: Nikhil Ommen Mani, Beetles 3.3 Architecture

Materials Used: Mycelium, Plywood, Steel, Coir Pith (Coconut Husk), Local Lumber.

Figure 11: Top View of The Structure.

The structure was intended to grow & then degrade by itself, the idea behind it was to show that the structure can be erected for a certain purpose but later demolishing & disposing is very difficult & environmentally challenging. Therefore, this could be the answer for the problem faced

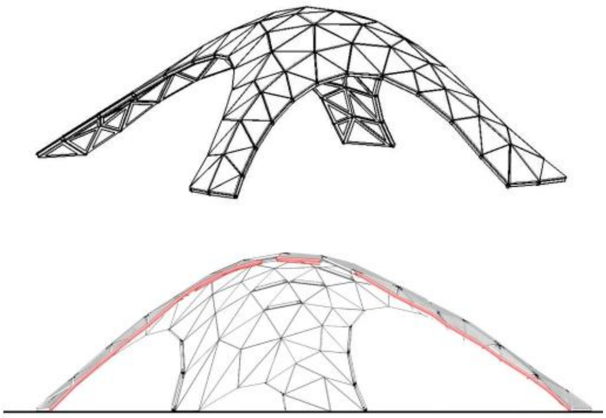

Figure 12: Exploded View Showing the Assembly Details

Figure 13: Inside View of the Shell.

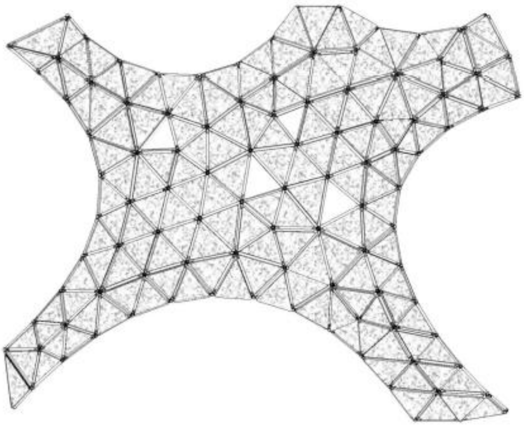

Figure 14: Plan View (Top)

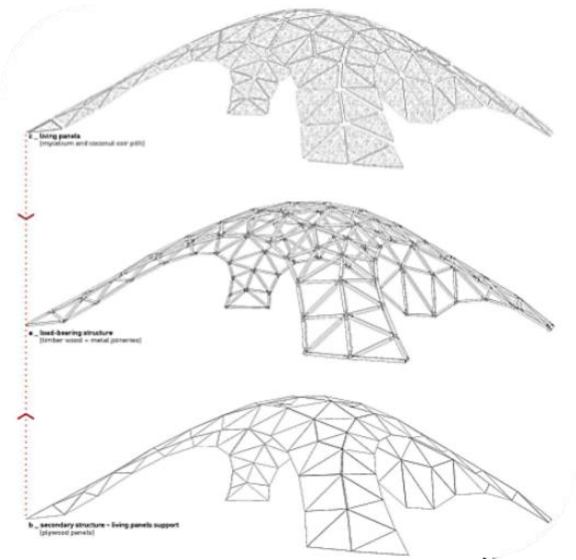

Figure 15: Assembly Details in Exploded View.

Ease of Design: the design of the panels & the connecting member sizes was kept repetitive for the ease of designing.

Ease of Assembly: The structure only used screws for the assembly, they are easy to disassemble as an when required. This also allows for temporary presentation for the required event.

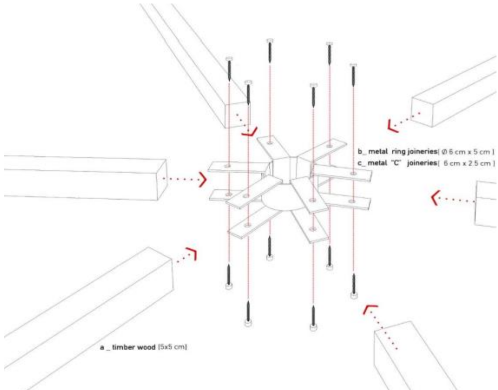

Figure 16: Panel Frame Assembly in Exploded View.

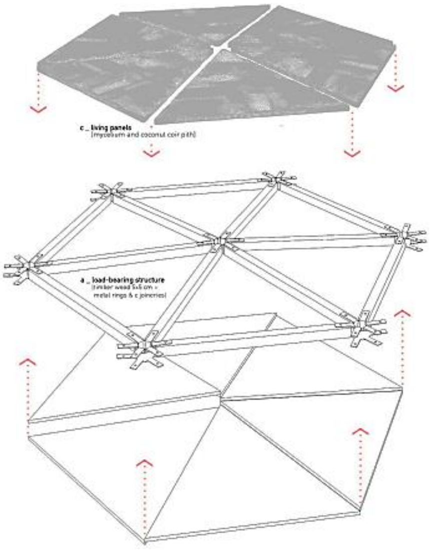

Figure 17: Panel Assembly in Exploded View

VI. ANALYSIS OF THE CASE STUDIES

The analysis of the case studies has been put down in a tabular format for better & easy at a glance understanding of them.

Name of The Structure	Material Used		Type Of Construction	Positive Points	Negative Points
	Virgin Mycelium	Composite Mycelium			
a. The Hy-Fy by Princeton University	Virgin Mycelium		Temporary Construction Using Mycelium Bricks	The bricks are light weight & zero-carbon. After the disposal of the structure the bricks were decomposed to soil & distributed to neighboring gardens, zero residue.	The compressive strength of mycelium as a standalone structure is less.
b. Mycotree by Ar. Drik Hebbel & Philippe Block	Composite Mycelium. 3D printed bricks + bamboo panels		Temporary construction made using metal dowels.	great compressive strength when paired with other materials, reusable.	None as it's an indoor structure.
c. The Growing Pavallion		Composite Mycelium in panel form	Temporary structure made using mycelium spawns, timber.	The mycelium species used for the panels has great interconnecting property making the panels dense. Panels are re-usable.	Lacks water resistance leaving it vulnerable to contact to water.
d. The Shell Mycelium Installation in Kochi, Kerala.		Composite Mycelium made Mycelium + plywood	Temporary structure made to replace temporary stadiums, exhibition centers, etc.	Low-cost, light weight, reusable, doesn't leave any debris when disposed, eco-friendly disposal.	Lacks water resistance.

VII. CONCLUSIONS.

The following paper does not just give us hope but a new path that can be followed for the saving of the resources, earth & human species as a whole. All of this is backed up by the case studies given which have been done in various parts of the world, this also means that mycelium can sustain in all types of climates if it is processed in the right way.

Mycelium is just a hay in the stack of new innovative ideas. But it can create wonder if we collectively educate the future users of the world to make it, process it & use it to its fullest. So far none have complained of any toxic effect of mycelium in any of the uses specified above.

More study needs to be done to make mycelium strong enough to stand & make itself recognizable against the conventional as well as the modern environment damaging materials.

Advantages	Disadvantages
• It is 100% biodegradable leading to construction of temporary structure which are easily installed & demolished depending on the use. • Mycelium traps more heat as compared to fiberglass, it's also fire-resistant & non-toxic. • Dried mycelium is stronger than concrete & also light in weight. • Production of mycelium is low-cost, less time-consuming, fast growing. • If maintained in stable & favorable conditions, the lifespan of mycelium brick is 20 years. • They also absorb carbon dioxide.	• Water resisting capacity decreases over time leading the brick to exposure of mould & humidity & cannot be used for long-term standing structures. • Lacks compressive strength as a stand also material. • Mycelium bricks expand, contract & relax according to the environment & climate. • When mycelium touches the ground, it absorbs moisture.

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