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Bio-Composite Brick from Agricultural Waste as Green Building Material

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ABSTRACT: In this paper, the environment is getting harmed by various industries and construction is one of the main contributors of pollution in the current scenario. This study, the use of agricultural waste with mycelium as the binder is studied and further research is being done around the world for the sustainable living that cuts the pollution of air and also acts as insulator against heat during extreme weather conditions. The aim is trying to reduce the carbon footprint by using mycelium-based bricks. For this purpose, mycelium bricks are grown, they are not made like traditional bricks. The scope is trying to achieve good compressibility of mycelium bricks depending on the constituent used in the bricks. The utilization of nature which agrees to the condition; favours bio-diversity with minimal effort and does not require heavy workforce or modern material. Using certain permutation and combination tools, we were able to find certain strengths of the mycelium brick like compressive strength of the brick. As compared to the traditional brick, the mycelium brick achieves good compressive strength. More research needs to be done on the **mycelium brick** so that it can be used as a green building material so that we can cut down the pollution of the environment. The way the mycelium brick can be termed as "Green Building Material" is that it is based on certain rating systems like **Indian Green Building Council Rating Systems (IGBCRating Systems)** where the material will be characterized under categories which will then have a scoring system based on certain tests and then the output is given by the rating systems, this is how we can get to know whether is a **green building material**.

I. INTRODUCTION:

Mycelium is the vegetative part of fungus or fungus like bacterial colon consisting of a mass of branching thread like hyphae. Mycelium is a fast-growing organism and one of its primary use is to decompose organic compounds. Petroleum products and some pesticides are organic molecules as they are built on a carbon structure, so they can be a potential carbon source for mycelium. As part of a study, will continue with the potential of this material to make a big difference to the material world. This 100 percentage of the material has been gradually developed across multiple disciplines, with the agricultural and construction industry recently taking interest in its possible implications. Much like wooden furniture indoors it will be strong and sturdy whilst inside, but will break down after being overly exposed outside. The process of producing with mycelium brings a huge reduction in using fossil fuels. Mycelium products can provide other benefits such as termite proofing, it can attract termites but when eaten cause a fungus spore to activate within the termite killing it and creating a fungus whose spores repel other termites. The mycelium bricks are bulletproof and absorb carbon dioxide, making them a sustainable material for the construction of our future buildings.

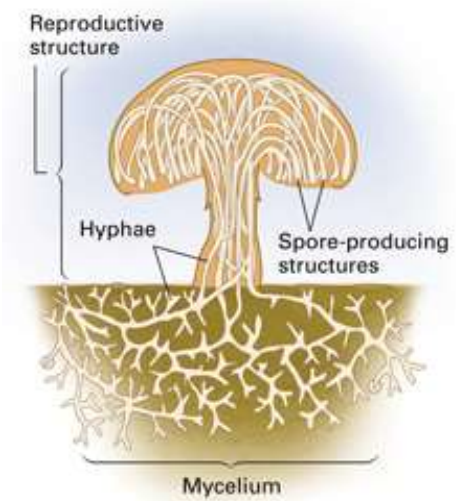

Figure 1

II. LITERATURE REVIEW:

1. **Sebastian Cox (2017)** studied that the vegetative part of a fungus can be used in different architectural design but he wanted to use the fungal material to create more everyday products. In his

study he has used discarded goat willow was sliced up to create thin strips, which were woven together to create individual moulds. Within these moulds, the designers added a type of fungus called fomes fomentarius, which was cultivated using more wooden strips as food. As further he researched on binding material for wood for this he goes to mycelium which has great qualities his **mycelium timber** was shown atSomerset House, Strand, WC2R 1LA for the London festival which was held on September 2017.

2. **Amy Frearson (2017)** in his studies on mushroom mycelium has gone one step forward with Architect Dirk Hebel and Engineer Philippe Block by using fungi to build self-supporting structure. Hebel who led the Sustainable Construction unit at Karlsruhe Institute oftechnology, AdBlock who founded the Block Research group at ETH Zurich, have created the tree shaped structure consisting almost entirely of mycelium. According to them, the material –which is formed from the root network of mushrooms – could provide the structure of a two-storey building, if it is designed with the right geometries. Hebel and Block are presenting the idea as part of the inaugural Seoul Biennale of Architecture and Urbanism, which held at September 2017 in the South Korean capital.

3. **Asif Rahman, andGiombattista Arredia and Mohamad Yassin (2016)**in their study have found that mycelium can grow in any shape. Mycelium which is the root part of the mushroomcan become an alternative to construction material that is particularly suitable for building temporary structure. Rahman,Arredia andYassin were introduced to the material bymycologistPhilip Ross, who has been looking at ways of combining mycelium with leather.The unique characteristic of the material is that canmerge with theframework to which it is added. In the case of theShell Mycelium pavilion, the material became combined with a triangulated timber framework. To make this happen, the architects created a series of tray-like cavities in the structure. These werefilled with fungus then covered over with coir pith, which consists ofcoconut husk fibers. In time, the toplayer dried up and died, creating a protective shell over themycelium. The shell pavilion is a pavilion made of spores and the wooden structure forms the growing ground," saidthe designers. "The mycelium eats it, merges with it, transforms it and grows through it. The projectformed part of the programmefor theKochi Muziris Biennale 2016, which took place from December 2016 until March 2017.

4. **Aleksi Vesaluoma (2017)** in his study has developed a technique for using mushroom mycelium as an environment friendly construction material. Vesaluoma, a student at London's Brunel University, developed a technique where the mycelium material is mixed with cardboard before being moulded into what he calls "mushroom sausages" using a tube-shaped cotton bandage. The long sausages are then placed over a mould and left to grow over a four-week period inside a ventilated greenhouse. According to Vesaluoma, the resulting structure is "bound together like glue", and could provide an environmentally friendly alternative to more commonly used construction methods and materials.

5. **Aniela Hoitink (2016)** has created a dress using disk shape piece of mushroom mycelium which she believes will change the way we use textiles. Herinitial intention for the experimentwas to create a textile out of living product, which could be then be used to make awearable garment. She began by combiningtextile elements with mycelium –the vegetative part of a mushroom fungus that many designers are turning into a biodegradable material for products and construction.

6. **Eric Klarenbeek (2014)** has created a3D-printed chair made of mushroom mycelium.Klarenbeek's Mycelium chair, which takes its name from the extensive threadlike root structure of fungi, combines organic matter with bioplastics to make a light and strong composite material that can be 3D-printed. He adapted the 3D-printer and invented a way to print straw injected with mycelium. By infusing this mushroom it acts as a kind of glue so that all these straw parts combine together and as soon as you dry it you get a kind of cork material, which is all bound together. The chair's exterior is also 3D-printed, but is made from a bioplastics, against which the mycelium root structure grows. Klarenbeek leaves the fungus to spread throughout the 3D-printed structure, reinforcing it in the process. It could be a table, or a whole interior, and that's where it becomes interesting for me. It's really strong, solid, light weight and insulating, so we could build a house.

7. Eben Bayer and Gavin McIntyre (2015) have developed Mushroom Materials to provide a natural alternative to traditional plastics and synthetic packaging. The product contains mycelium, the vegetative part of a mushroom

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fungus, which is natural glue. This material binds with crop waste like seed husks and corn stalks to form a bioplastics. Unlike normal plastics, which are made from petrochemicals, Mushroom Materials are plant-based and fully compostable. Their Companynamely **Ecovative** has also made the packing of the dell laptop which is also made from mycelium which is replacing standard thermocol packing.

8. **David Benjamin (2014)** has developed a 40feet tower of mycelium (the root part of mushroom) and cornstalks which he named as Hy-fi tower. The structure is built from entirely from biodegradable materials. Each of the bricks used to construct the tower were grown rather than manufactured, using a combination of agricultural byproducts and mushroom mycelium – a kind of natural digestive glue. Specially designed moulds were used to cultivate the bio-bricks. These were coated in a light-refracting film developed by materials firm 3M and some were then built into the structure around the top, helping to bounce light down inside.

9. **Danielle Trofe (2015)** has developed the Mush-Lume table Lamp, Mush Bloom flower pots, Mush-Lume Hemi pendant are all made of mushroom mycelium.

10. **Surf Organics (2015)** has developed the surf boards using the mushroom materials.

11. **Lou Corpuz-Bosshart (2014)** has developed the pavement block using mushroom mycelium. In his study he has mixed the mushroom mycelium in the sterilized sawdust for two weeks after it he sent it to green house at university of British Columbia from where the mix is chipped in wood chipper and packed in the mould and left for five days after which the block were taken out and dried.

12. **Philip Ross (2014)** has developed the leather like structure from the mushroom mycelium- the root part of mushroom. And also he has made a wooden like block from the same material now he is testing the mushroom as a construction material in his company named Myco works. He has made the small samples of mycelium brick with mycelium and agriculture waste which he is growing in his lab in different conditions.

13. **Celine Park (2015)** in his study has developed a new technique in which the filter made of fungus can be used in pipes in place of needles. These pipes are used to inhale the vaccine in place of injecting them in the body. She has observed that the fungi can be used as filter as it absorbs more viruses in it.

14. **Ecovative Designs (2014)** in their study has developed a technique in which the plastic can be replaced by mycelium. In their study with a team in the International Genetically Engineered Machine (IGEM) they have grown in the shape of a drone and skinned in sheets of bacterial cellulose. These were then coated with proteins cloned from the saliva of paper wasps to create the rigid chassis of the vehicle. The drone's circuitry is printed in a silver nano particle ink – a decision that was made to keep the vehicle as biodegradable as possible. The battery, rotors and controls were all made from more traditional materials and were sourced from a normal mechanical quad copter.

III. MATERIALS:

1.Mycelium that is grown from mushroom seeds:

Mycelium is the vegetative piece of parasite or growth like bacterial settlement, comprising of mass expanding, string like hyphae. The mass of hyphae is here and there called Shiro, particularly inside the pixie ring parasites (Figure 1). Parasitic settlements made out of mycelium are found in and soil and numerous substrates. A regular single spore sprouts into a homo karyotin mycelium, which can't duplicate sexually; when two good homokaryotic mycelia are joined and frame dikaryotic mycelium, that mycelium may shape fruiting bodies, for example, mushrooms. A mycelium might be minute, framing a province that is too little to see, or it might be broad.

Through the mycelium, a parasite assimilates supplements from its condition. It does this in a two-organize process. To begin with, the hyphae discharge proteins onto or into the sustenance source, which separate organic polymers into littler units, for example, monomers. These monomers are then retained into the mycelium by encouraged dispersion and dynamic transport.

Mycelium is imperative in earthbound and sea-going biological systems for their part in the disintegration of plant material. They add to the natural portion of soil, and their development discharges carbon dioxide once more into the air. Ectomycorrhizal extrametrical mycelium, and in addition the mycelium of Arbuscular mycorrhizal growths increments the effectiveness of water and supplement retention of most plants and present protection from some plant pathogens. Mycelium is a critical sustenance hotspot for some, dirt spineless creatures.

"Mycelium", like "parasite", can be viewed as a mass thing, a word that can be either particular or plural. The expression "mycelia", however, similar to "organisms", is regularly utilized as the favored plural frame. For mycelium see figure 1 and figure 2 for mushroom seeds.

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Figure 2

IV. SUBSTRATE:

A substrate is a material on which the mycelium can be grown. A substrate can be anything saw dust, wheat, agriculture waste etc.
Diverse kind of substrate as follows: -

l. Straw

Grain straw such as wheat, rye, and oat all make a good substrate. They are easy to get andcheap. As they contain microbes that can interfere in the growth of mycelium, so they must beprepared first.

Figure 2.1 Straws

2. Logs

As mentioned earlier mycelium can be grown on anything. Wooden logs are also a great substrate for mycelium. However, often any quickly decomposing hardwood that's not too dense will do. Elm, beech, alder, ash, and cottonwood are all good choices. Thicker hardwoods, such as oak,will take much longer to produce mushrooms. But wooden logs take too much time to colonize mycelium.

Figure 2.2 logs

3. Enriched Saw dust

Enriched sawdust is also a mushroom substrate more commonly seen with commercial rather than home cultivators. Although it works quite well with a variety of different mushrooms, there are a few factors to consider. Same as wooden logs Hardwood sawdust are best rather than softwood. Also, the sawdust to be sterilizing sawdust before colonizes mycelium.

Figure 2.3 Saw dust

4. Coco Peat

The effects of two different substrates, sawdust and coconut residue and mixture ratios on oyster mushroom cultivation were determined. The mycelium growth was unable to completely colonized the coconut residue substrates. Percentage of mycelium colonized on the substrate was reduced when percentage of coconut residue supplemented in cultivation substrate was increased. Even the mycelium growth was not totally colonized the coconut residue substrates, but the mass of whitish mycelium was thick, dense and comparatively compact when compared to sawdust. A substrate combination of 25% coconut residue plus 75% sawdust accelerated the mushroom growing processes and gave the highest in both mushroom yields.

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Figure 2.4 Coco Peat

5.Sugarcane molasses

The binder in the produced bricks is from mycelium. The materials used for the development of mycelium are rice and sugarcane molasses. Sugar Cane Molasses was utilized to act as the mycelium in serum form for the researchers to securely handle and later add the mycelium to the substrate mixes.

Figure 2.5Sugarcane molasses

V. METHODS:

1.Collection of material for colonizing of mycelium

Firstly, we have collected the mushroom seeds from the mushroom farm. Also, we have bought the agriculture waste from the farm. And we also taken some saw dust from the factory of wood cutting. We have taken the saw dust, coco peat and other agricultural waste and have meld it into two separate moulds.

Mixtures:

Ratio	Materials	Outcome
5:3:1	Mycelium Fungi of 250g +Sawdust of 150g+ Coco Husk/Peat of 50g+Approximately 150ml of water till the mixture becomes like dough.	The 5:3:1 mix which was kept in a dark room for about 15 days to set and harden which grew to about 1 inch from the initial level and growth of fungi took place which needs to be killed in oven and testing of the brick will take place.
5:2:1	Mycelium fungi of 125g + Rice bran of 125g+Sawdust of 100g+Coco Husk/Peat of 50g+200 ml of water till the mixture becomes like dough.	The 5:2:1 mix which was done a couple of days ago needs to undergo the change in the mould and further the same procedures of growth of fungi and testing of bricks will be done.

Table 1 shows the two different mixtures done

Testing on mycelium brick:

1. Compressive Strength Test

After hardening of the brick, the compressive strength test on hardened mycelium bricks were performed on the compressive testing machine as shown in figure 3.1. Two bricks were tested of different sizes.

Fig 3.1Compression testing on mycelium brick

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Purpose:

This test is done to determine the compressive strength of burnt clay building blocks. Brick are mostly subjected to compression and rarely to tension. The usual crushing strength of common hand melded well burnt brick is about 5 to 10 N/mm2(50 to 100kg/cm2) varying according to the nature of preparation of the clay. Pressed and machine melded bricks made of thoroughly mixed clay are much stronger than common hand mould bricks made from carelessly prepared clay

Compressive Test Results:

Tests show that the unit weight of the mycelium brick is lighter than the standard tile brick. The tile brick compressive strength test carried out as per IS 3495-1992 part 1.

S.No.	Compressive strength of mycelium bricks in N/mm2	Compressive Strength of tile brick in N/mm2
1.	12.2	7.2
2.	13.5	8.0

Table 2.1 Compressive Strength of mycelium brick and standard tile brick

2. Efflorescence Test

The efflorescence test was done on the test sample. This test was done to check the concentration of the salts of magnesium, Calcium, Sodium and Potassium on the brick.
It is the white power that is covered on the brick when it gets reacted by water and sun.

As efflorescence alone is not a problem but it is the reason of many problems like water intrusion, Structural damage and health problems etc, Efflorescence can be removed by dry brushing and washing repeatedly. To check which brick has less efflorescence mycelium brick or Standard brick we have tested both the bricks for the efflorescence test.

Figure 3.2 Efflorescence test on bricks

PURPOSE:
This test is done to determine the efflorescence of burnt clay building blocks.

Efflorescence Test Results:

Test shows that there is slight efflorescence in case of mycelium bricks. In case of Normal AA class Bricks the efflorescence is slight. Table 2.2 shows the efflorescence test on mycelium brick and standard tile brick.

S.No.	Efflorescence of standard brick	Efflorescence of mycelium brick
1.	Moderate	Slight

Table 2.2 Efflorescence test on mycelium brick and standard tile brick

3. Water Absorption Test

The water absorption test was done on the mycelium bricks. This test was done to check that how much amount of water the mycelium brick can resist. For this test we have done water absorption test on both bricks. And Note down the reading.As if the brick absorb more water than the weight of the brick increased which also increases the dead load of the building. Also, it can cause the problem of seepage from the structure.

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Figure 3.3 Water absorption test on bricks

Purpose:
This test is done to determine the percentage of water absorption of bricks

Water Absorption Test Results:
The water absorption on the plastic bricks is 10.50% but in Normal brick this value is up to 11.56%.

S.No.	Water absorption on standard brick	Water absorption on mycelium brick
1	11.56%	10.50%

Table 2.3 Water absorption of mycelium brick and standard tile brick

VI. CONCLUSION:

This project presented a brief overall review on mycelium bricks using mycelium the root part of mushroom. The strength depends on the content of mycelium. And also, this project has social benefits also like if it is used to grow leather than no longer need of animal skin to make leather. Also, if it used to grow synthetic wood than the deforestation will be very less as it is stronger than wood The economic benefits and contribution of mycelium bricks for sustainable development are also been outlined.
Since the mycelium brick is a whole new concept of bricks with new technology no Indian Standards are available, so a detailed study on the chemistry behind the mycelium bricks is needed. Now a detailed study thereafter should be needed for making of bricks cheaper and useful than that of standard brick so it can be introduced into the market. Also, there a detailed study is need on a method to grow mycelium faster.

Research needs:
The Mycelium brick is new concept no Indian standards are available hence detailed study of Mycelium brick is needed. Also, the study is required to grow Mycelium faster, and to increase the range of application of Mycelium brick.Updating ourselves in this field also plays a vital role as newer techniques might bloom at any time.

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IS Codes:

1. IS Code 1077:1992 for the Compressive strength classification of Bricks
2. IS: 3495:1992 part 1 to part 4 for the Testing of Bricks
3. IS: 5454:1918 for Classification of Bricks