Course Name: Building Materials as a Cornerstone to Sustainability

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Lecture 02

Mycelium

Hello everybody, so today we will look at a very interesting building material called as mycelium composite material. This material is upcoming. Though it is not used in very many buildings, it definitely has a future because this material is giving a very organic dimension to the existing building materials which seem to have a lot of embodied carbon. So, today we will see what is mycelium? What are mycelium composite bricks? What are the properties of mycelium composite bricks? How is it manufactured? What are the factors that affect mycelium composite products? What is the life cycle of mycelium bricks? Mycelium composite bricks Its benefits and its drawbacks or limitations. We will look at a couple of case studies and conclude the lecture. So, mycelium is a root or vein like fungal network.

This can be found subterranean or below the ground or in other locations like tree trunks and rotting wood and organic materials. It is also the organism that mushrooms grow from. Mycelium is a dense network of thin strands called hyphae that grow and fuse together into a solid material. Mycelium growth forms self-assembling bonds and miles with tiny white fibers which invade and degrade the organic substrate gradually colonizing the organic matter and binding them into strong and 3D structure materials.

So here you can clearly see how mycelium actually looks and here you can see its reproductive structure. What interests us is the subterranean part of this organic material. Mycelia are already incredibly important to the environment, aiding in the decomposition of plant materials and in adding nutrients to soil. Scientists have been exploring ways to use certain funguses as vegan alternatives to food, leather and building materials. Mycelium is a fast growing organism and one of its primary use is to decompose organic compounds.

Let us look at mycelium composite brick. Mycelium composite is made by allowing mycelium to grow inside a mold. For example, a brick mold. This is filled with a substrate. This can be composed of a variety of organic materials such as rice husk and other agricultural waste and the combination of substrate materials impact the resulting strength, flexibility and other qualities of the final end product composite.

Once the mycelium has completely filled out the space within the mould, it is baked or fired to prevent continued growth. Mycelium-based composites are mainly used for packaging, thermal insulation, and other different furniture. The mycelium bricks are bulletproof and absorb carbon dioxide, making them a sustainable material for the construction of our future buildings. And this is how a mycelium brick looks. Now let us look at the properties of this brick.

The composite made of fungal mycelium and the organic substrate is emission free, non-toxic, low cost, organic and recyclable. This composite shows excellent thermal stability, hydrophobic properties and mechanical strength that can replace conventional construction materials which are non-biodegradable, high emission and high cost. Factors affecting the physiochemical property of the composite include type of substrate and strain, incubation time and fabrication process. Initial embodied energy per meter cube of mycelium is just 2 to 7 gigajoules per meter cube. carbon dioxide emissions as kilogram of carbon dioxide per meter cube of mycelium is just 20 to 50 kilograms of carbon dioxide per meter cube.

Just to give a small indication of how it looks for cement it is 288 kg per meter cube. Now, let us look at the mycelium composite brick manufacturing process. Now, lignocellulistic material which is a low cost agricultural or forestry byproduct or waste is used. This could be straw, cotton, husk, hemp, sawdust, it could be any of these. This after hydration or soaking gets into homogenization.

During homogenization there is increased growth in surface area, blender grinder and milling happens. After this what happens as an outcome is sterilized because this sterilization can happen in either an oven or with chemicals or it could be autoclaved. This removes the microbial competition. Then there is inoculation which is done using either spores, hyphal tissue or fruiting body tissue. Results in growth which could take days to month under ambient or controlled environment.

After this there is dehydration. Dehydration neutralizes the fungus. It makes the material stiff and it is done using air drying or oven drying or hot pressing. And here you can see a more detailed method of manufacture of the composite brick using mycelium. So, what goes in is ecology, lifestyle, local respond to damage, cell wall composition and secreting redox active enzymes.

This goes to the fungal species and the characteristic is there is reconnection, regrowth, there is filament which becomes thick at a particular growth rate using fungal biomass density giving structural integrity, compressive stiffness, increasing bonding and lignin degradation which we saw in the previous slide. This goes to inoculation. When there is sterilization, it is done using autoclave, pasteurization, chemical treatment, microbial agents resulting in thermal stability, defibrillation of fibers and a growth rate. When under inoculation, there is pregrown substrate, grain spawn and liquid medium resulting in a good dimensional stability, flexural modulus and compressive strength. Then this goes to packing.

It is packed inside a particular mould. That mould gives a void space This is pre-combustion, as a hyphal outer layer gives the fibers space for orientation and a direction where it should go owing to its surface. This results in dimensional stability, elastic modulus. We can measure the thermal conductivity, water absorption, its density and compressive stiffness. Once packed, This packaging has a void space in which the fungus can grow.

In order to have conducive growth conditions, we must monitor temperature, relative humidity, carbon dioxide concentration and luminosity resulting in a material of requisite density and tensile modulus. It takes time for the growth to happen within days and which gives us a material which is porous, has a water absorption capacity, thermal decomposition, elastic and shear modulus and compressive strength. Upon drying, in an appropriate temperature with correct moisture content and time we get a material which has good thermal conductivity and elastic modulus. Then post processing happens which is in the form of waterproofing strength and stiffness. Now this packaging material or insulation panel or it can be even used in acoustic tiles, it can be used as building blocks in load bearing components, can be used as floor tiles and as textiles.

So, this would be its applications of the mycelium composite bricks. Let us now look at the factors affecting mycelium composite production. The thermodynamic, physical and mechanical properties of mycelium composites depend on the composition and nutritive profile, the size and geometry of particles, porosity of the organic substrate as well as the characteristics of the growth medium. Let us look at the composition of the carbon substrate. The choice of agricultural, agro-industrial and forestry based for mycelium composite depends on the species requirements of the fungus used and its specific polymer degrading abilities.

Carbon is the most important macronutrient for all fungi. It promotes or it provides nutrition and promotes fungal growth, increasing the density of the mycelium network and thus improving the strength of composites made from this material. Fungal species selection is also important. The degradation ability of fungi influences the morphology of the mycelium network and must be considered when selecting species for mycelium composite production. The physiochemical properties of the growth medium also take significance.

The growth of this mycelium, its kinetics, and the morphology of the mycelium are dependent on various process parameters such as the composition, pH, humidity, temperature, and the growth medium. Let us quickly look at the life cycle of mycelium bricks. By manufacturing regionally and using local feedstock, transportation of raw and finished materials could be minimized, thus making the production process sustainable. After its use at the end of the life cycle, mycelium-based materials could be conveniently left in the backyard to get decomposed in a few weeks because such an organic material. Hence, the material is completely biodegradable.

Mycelium breaks down when exposed to the atmospheric conditions facilitating its decomposition. Being an organic, the material gets composed easily. Thus mycelium successfully follows a cradle to cradle life cycle. Let us look at the benefits of mycelium composite bricks. Now these are low cost material because they involve the use of naturally growing fungi.

They are low density materials. They have low environmental impact and carbon footprint. They are biodegradable and termite proof. These have good fire, thermal and acoustic insulation. Huge reduction in using fossil fuels can be achieved.

Bulletproof and absorb carbon dioxide. Mycelium traps more heat as compared to fiberglass. Dried mycelium is stronger than concrete and also it is much lighter in weight than concrete. If maintained in stable and favourable condition, the lifespan of mycelium brick is 20 years. Mycelium does come with certain drawbacks.

Mycelium has low structural strength and dries off when exposed to the environment and it becomes inactive. Water resisting capacity reduces over time leading the brick to exposure of mould and humidity and cannot be used for long term standing structures. Mycelium bricks, they expand, contract and relax. When mycelium touches the ground, it immediately absorbs the moisture. Let us have a small comparison between red bricks and mycelium bricks.

Red bricks is the regular baked brick that we use. In terms of composition, mycelium are the thin root like fibers from fungi. that run beneath the ground, and when dried it can be used as a super strong water, mold, and fire-resistant building material that can be grown into specific forms, thus reducing the processing requirement. Whereas the regular bricks are made by a mixture of clay which is alumina, sand, lime, iron oxide and magnesia.

Sand from locally available natural soil is used for production of bricks.

In terms of durability, mycelium materials are durable and naturally fire resistant and these can be moulded into any shape. Bricks too are strong, hard, and durable. Its compressive strength is 13.1 Newton per meter square whereas red bricks have a compressive strength of 3.

5 to 35 Newton per millimeter square. Water absorption, it should not be more than 20 percent of its weight for mycelium bricks and red bricks and it is achievable. Look at its thermal conductivity. Thermal conductivity is only 0.

78 to 0.081 watts per meter Kelvin. But red bricks have a conductivity of 0.6 to 1 watts per meter Kelvin. Let us look at its pest resistant comparison. Mycelium bricks do not spread termites and pests. Now these red bricks are not termite resistant as they are made from clay which is an organic material.

Looking at the breakage properties, mycelium bricks have negligible breakage. Almost 100 percent of it can be utilized. Whereas on an average 10 to 12% or even more breakage can happen on construction site depending on the quality of bricks. Let us look at the carbon emission properties of mycelium bricks as compared to red bricks. By using mycelium, there is a huge reduction on the reliance of fossil fuels, the embodied energy required for fabrication and a massive reduction in the building waste which is left at the end of the product's life as the mycelium product is 100% biodegradable and can be used as soil.

If we look at red brick, red brick is not a green product. Red bricks are made from the clay which is naturally available no doubt. But it reduces the fertility of the top soil. Hence the land available for agriculture gets reduced. More amount of CO_2 is emitted during the manufacturing of red bricks.

Let us look at cost. If we are actually going to do the mycelium brick, they can be low-cost and easily produced. Red bricks are cheaper as compared to many other masonry units. However, the overall cost is higher as it requires more mortar, both for joints and plaster. Let us look at the case study of a structure or installation using mycelium bricks. Now this case study which is called as the growing pavilion is at Eidehoven in Netherlands.

This growing pavilion is a temporary even space at Dutch design week which is constructed with panels grown from mushroom mycelium supported on a timber frame. The uniqueness of the pavilion consists in the large number of bio-based materials used such as wood, hemp, mycelium, cattail and cotton put together in order to form a building. The skin of the pavilion consists of 88 mycelium panels. Everything in the pavilion is built from plants and trees and used in agricultural waste. This is the material atlas of the growing pavilion.

So let us see how green this material is. Basically it uses a mould here along with mushrooms, the material on which it grows hemp, Cattail is being used, cotton is being used, rice straw and miscanthus is used, aspen wood and scots pine. All of these are organic building materials. Let us understand the process. The unique power of mycelium is that it can easily be molded into any desired shape. The best way to do this is to fill the molds with it.

These molds can take various forms from lampshades to chairs and facade panels. The molds are covered so that there is only minimum oxygen supply and they are placed in a very dark closed room. The moulds stay there for four to five days. The mushroom spores, they start to slow process of breaking down the residual flows.

You could say they actually eat them. The tracks create a natural network of connections through all plant remains. This way they glue everything together. The moulds are then removed after a week in a humid environment and these are baked at 80 degree Celsius for two days. The mushroom growth process is completely stopped before the mushrooms actually sprout. This completes the production process and the mycelium design is ready for use.

If we look at the CO2 calculations by the supplier crown.bio, it shows that when producing 1 ton of mycelium, 2 tons of carbon dioxide are captured from the atmosphere. The production of mycelium therefore makes a very positive contribution to environmental issues. Certainly compared to its conventional material equivalent such as styrofoam where between 1 to 6 tons of carbon dioxide is released into atmosphere during production. It seems that mycelium bricks or panels are extremely green materials.

The calculations of Primum have shown a total emission of 15,943 kilograms of carbon dioxide for the production and final settlement of the growing pavilion building. If conventional building materials were used, this emission would have been 40,710 kgs of CO2. This is two and a half times more emissions. The growing pavilion not only has lower emissions, in fact its carbon dioxide uptake from the atmosphere is higher than the total emissions. With the production of the pavilion, more than 26,000 kilograms of carbon dioxide were captured and stored in the building materials.

The pavilion therefore has a negative carbon dioxide balance of more than 10 tons of carbon dioxide. Finally, the analysis shows that the structure is 95% circular. From the seeds of the grown materials to the final processing when the pavilion is no longer used, the materials do not disappear as waste or end up in landfills, but they can be reused without losing value. Totally the growing pavilion therefore has not a negative but a more positive impact on the environment. So the growing pavilion becomes a very famous and popular tribute.

to materials derived from plants. So, this award winning pavilion is distinctive in that it demonstrates the potential and fresh aesthetic of bio-based materials while utilizing a significant number of bio-based elements to construct a building. The 10 ton carbon dioxide negative and 95 percent circular structure is made by growing five core raw materials. Wood, mycelium, residual flows from the agriculture sector, cattail or bulrush and cotton. It showcases each material as raw as possible and the pavilion has a very distinctive visual identity, organic texture and also colour. Inside, within the pavilion, it offers visitors a storytelling experience taking them on a bio-based journey of what is already possible but also what the near future will bring.

The growing pavilion is a catalyst, starting, sharing and driving the conversation about bio-based building that is essential to achieve the desired change in our thinking and doing. And in order to reinforce the story of the growing pavilion, daily harvesting of edible oyster mushrooms that grow from the mycelium was organized which does not grow anymore because dryness has already set in. But when it was initially built, it did have this story also. The second example we will take is the Hy-Fi Tower. Now, this Hy-Fi Tower is located in Queens, New York, in the United States by a firm called The Living.

Hy-Fi commissioned by the Museum of Modern Art, MoMA. It is the circular tower of organic bricks. It offers a captivating experience for the museum and a new paradigm for sustainable architecture. The structure is an extension of the natural carbon cycle with a revolutionary new construction material that grows out of living materials and returns to the earth through composting at the end of the structure's life cycle. In contrast to typical short-sighted architecture, it is designed to disappear as much as it is designed to appear. In conclusion We can confidently say that bio-based materials combine many mitigation strategies such as low embodied energy and carbon, low cost, they are recyclable, they use locally available materials and are available as waste and byproducts.

As a result, they can be easily integrated with the prefabricated constructive system. Raw material availability and ease of production for microbe-based materials results in cost minimization. Using biomaterials can reduce costs about 80 times lower than conventional materials. Biological materials have also indirect advantages in organic waste reduction because most of these raw materials used for the production of microbial based materials are locally available organic waste. The cost was the prior advantage of mycelium based block over conventional materials.

Mycelium based blocks are 80 times cheaper than cement and gypsum based blocks. Hence, we can clearly see that mycelium based blocks are organic. They are green building material. These are the indications of a sustainable building material. It is up to you as architect and designers to experiment further with these materials and also have a good balance between building the buildings using appropriate carbon negative building materials and setting an example of sustainable architecture.

With this, I will stop today's class and we will again have an interesting building material to deal with in our next class. Thank you.