Course Name: Architectural Approaches to Decarbonization of Buildings

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Lecture 04

Renewable building materials

Dear students, in our last class we discussed at length about the strategies to lower carbon and in that we discussed how use of renewable materials gives you one clue about how the embodied carbon in that particular material is very less. So, now we will look at what are renewable materials and some of the examples. If you look at the history of building material use, prior to 4000 BC, The primary building materials were soil, stones, reeds, thatch, sun dried bricks or adobe construction and unprocessed timber. Today, we call these materials as zero energy materials. While in around 4000 BC to 1800 AD, The primary building materials were burnt clay bricks, lime, some cast iron products used in very minimal amount and lime pozzoluna cement. Now burnt and these today we call as medium energy materials.

Why how come burnt clay bricks come under median energy materials is because by virtue of the nature of fuel that was used to burn the clay bricks. Depending upon the fuel, bricks can become very high energy material or it can be it can remain as a medium energy material. Puzzolona that was used at that time was a form of a volcanic soil. In 1800 AD, from 1800 AD to date, we use aluminum, steel, glass, Portland cement, plastic and many other smart materials like phase change materials- .

nanomaterials etcetera and these we deem as high energy materials. There is not so much of significant information on which of these materials adds longevity to the buildings because we see a 100 year mud house standing tall and we also see a 20 year conventional contemporary modern house getting cracks and falling prey to weather. So, construction is also very important criteria along with history of building material use. So, we can generally say that mud, stone, wood, thatch were used prior to 8000 BC while sun dried bricks came up in around 6000 BC. Pottery products came between 4000 to 8000 BC.

Burnt bricks in its preliminary form came up in 4000 BC, while lime was used in 3000 BC. glass came in 1300 BC while iron products also came along that time. Lime pozzolina cement came in the 80s while the modern so called modern materials like aluminum, Portland cement, glass, steel, plastics came in around 1800 ADs and is a result of industrialization. This is a small and a brief history of building materials. Let us briefly look at some of the examples of renewable building materials.

Now, let us look at timber. Now, forests are an excellent source of renewable material. But without a sustainable approach to forestry, we cannot guarantee that they will be able to provide for future generations. The yearly growth of each individual tree cannot be detached from the living plant. Rather, new wood is added inseparably to pre-existing growth until the entire tree is harvested.

after a waiting period that varies widely depending on intended use of the wood. For example, it's 2 to 3 years on energy plantations where biomass is produced as fuel for power generation and it is 6 to 8 years for pulp wood like eucalyptus. It is 12 to 15 years for fast growing hybrids and 30 to 50 years for fast growing pines and 100 years or more in temperate and tropical forest producing wood of large dimensions like say the banyan. So the embodied energy of timber depends on timber production and it requires less embodied energy as compared to non-renewable materials. Timber also uses less fossil fuel for manufacture.

If you see in this picture, the fossil fuel energy in megajoules per kg, rough sawn timber is only 1.5 while steel is 35 and aluminium is 435. So, compared to sawn timber which is 1.5, aluminium is 435. So, you can imagine the quantum of fossil fuel energy used in the manufacture of these building materials.

Whereas, if you look at the carbon released and stores in the manufacture of these building materials, you can see carbon is released in extremely high amounts in steel. Whereas, in rough sawn timber, it is just 15%. While 15 kg per meter cube of carbon is released for timber and 5320 kilogram per meter cube of carbon is released in the manufacture of steel. So, you can imagine the humongous amount of carbon released and why steel is considered a energy intensive material. If you look at carbon storages, rough sawn timber stores carbon up to 250 kg per meter cube while concrete and steel do not store any carbon at all.

And therefore, we talk of what is called as carbon sequestration. The next renewable material we will see is cork. Now cork comes from the outer bark of a tree. The bark is an agglomeration of cells filled with a gaseous mixture similar to air and lined with alternating layers of cellulose and suvarine. Cork has remarkable properties that are unmatched by any other natural material which provides for an expanding range of practical applications.

Even in our previous slides, as we were comparing the carbon sequestration of cork and other products, we saw that cork has more sequestered carbon as compared to other materials. The initial harvest of cork is done when the tree reaches its maturity, which is at around 25 years. The bark is stripped of two-third of the tree. But a thin layer of protective inner bark gives the cork its unique ability to survive and regenerate itself after the debarking process. Cork bark regenerates and is harvested every nine years making it extremely and rapidly renewable.

So the tree remains and the cork bark just keeps shedding and therefore it is 100% renewable. It is a natural raw material and it is easily replenishable. It has reduction in greenhouse gas, it is extremely low embodied energy, it is environment friendly and because it is a natural product obtained as a bark, it is a biodegradable product too. A very important building material in India is bamboo. India supplies a large percentage of the total world's bamboo forest land.

It's actually a grass that is hollow stemmed but firm, is woody, is enduring and is perennial in nature. It just keeps growing. The shoots develop on its own. If you plant a single bamboo shoot over a period of time, that shoot gives rise to what is called as kid and further bamboo regenerates. Due to the peculiar rhizome dependent process, bamboos are one of the most rapidly growing plants and their growth is three times more rapid than a number of other plant species.

It is imperative that you harvest the bamboo after particular time. depending on the quality of the bamboo. Otherwise the bamboo will perish. The primary harvesting often takes 3 to 5 years considerably quicker than wood forest which usually takes about 25 years. It produces 12 times more green building material than wood and provides a great variety of functional commercial item for eco-friendly daily use along with shelter and transportation, thus decreasing the rate of timber consumption.

Whereas timber takes 25 years to harvest, bamboo takes a maximum of 5 years to harvest. From that dimension bamboo is a even more low carbon material and it is a renewable material too. As a construction material bamboo has a very solid fiber and its compressive strength is twice more in comparison to concrete. Its tensile strength is almost equivalent to that of steel. No wonder we find a lot of bamboo reinforced slabs in certain parts of our country.

Experimental studies have shown that the ultimate tensile strength of bamboo and mild steel varies between 140 Newton per millimeter square to 280 Newton per millimeter square. It is a sustainable material that requires very less energy to nurture. restrains soil erosion, supplies biofuel, it extends wildlife refuge and manufactures a wholesome food source for both humans and wildlife. It offers crucial restoration from the consequences of global climate change by producing oxygen a lot more than other species of plants and traps high quantities of carbon dioxide. The next material we will see is hempcrete.

Hempcrete is an agriculture fibre based material. Hempcrete is used, the hemp in the hempcrete. actually an agro based material and when you use it in certain combination with concrete a block can be produced which is a biocomposite building material made from the inner woody core of the hemp plant with a lime based binder sometimes cement based binder. During its growth, the hemp plant absorbs carbon so that even allowing for the production of the binder, transportation and construction, it can be considered to have offset more carbon emission than it has produced. The materials used to create hemp root biocomposites absorb carbon dioxide during the curing process because it contains lime.

The amount of carbon dioxide sequestered from 1 pound of hempcrete varies but it is generally estimated to be between 1.2 and 1.5 pounds. Thus, hempcrete is a very effective way to sequester carbon dioxide. Carbon dioxide is absorbed and offset during the life cycle of the industrial hemp plant.

Hemp is a fast growing plant that requires minimum water and has no pesticides or herbicides. Hemp sequesters carbon dioxide from the atmosphere during its growth making it a carbon negative material. Any composite material made with hempcrete is bound to be carbon negative. It is also hygroscopic, meaning that in very high humidity conditions, it will absorb moisture from the air, releasing it again when the humidity levels drop, allowing buildings to breathe and avoiding damp problems because dampness is a big enemy of buildings. Hempcrete is a lightweight material often used as insulating material and is suitable in most climates as it combines insulation and thermal mass.

Using hempcrete thus helps in the reduction of cooling loads and thereby reduces operational energy. Next we will see straw. Straw is an agriculture fibre based material. Straw bales can be load bearing or used to fill a timber frame and rendered with earth or lime. During its growth, the straw will have captured carbon dioxide which will continue to be stored.

Straw is also very cheap and can be locally sourced. When compared to conventional building materials like concrete and steel, straw bales have much lower embodied energy. They require minimal processing and manufacturing resulting in significantly reduced greenhouse gas emissions. They are highly renewable and abundant around us. Specially we belong to the agrarian community and therefore straw which is a by-product of grain harvest is readily available and considered as an agricultural waste.

Utilizing straw bales as a building material prevents its disposal as waste and reduces the reliance on non-renewable resources. Buildings built with straw bales are extremely light in weight and sometimes are very suitable in places which are prone to earthquakes too. So straw as a waste product from a variety of grains but not limited to only wheat, oat, barley, rye and also rice. Straw can be pressed into structural boards that replace standard western platform framing or 2 feet by 4 feet construction. The product is extruded under heat usually around 200 degree Celsius and pressure.

The process uses minimal energy to produce the highly dense fiber resistant board. The compression releases natural resins that bind the straw together. The straw must remain dry during storage, transportation and installation. While here in this picture you can see a house made with straw as a filler walling material. A very interesting renewable building material is mycelium.

Now mycelium bricks are fiber based material and a mycelium brick is an organic brick that is formed from organic waste and the mycelium of fungus. Mycelium are the thin root like fibers from fungi which run underneath the ground. When dried and naturally connected in a man-made mixture with fibers, it can be used as a super strong water, mold and fire resistant building material that can be grown into specific forms. Mycelium naturally absorbs carbon dioxide. If more mycelium were produced and utilized as building materials, it can absorb more carbon dioxide instead of adding more to the atmosphere making the particular component a carbon negative material.

The material has very high fire and UV resistance, but is performing poorly when it is exposed to water. Weatherproofing mycelium bricks without destroying their essential composability is possible by penetrating natural oil into the bricks. The mycelium bricks are not considered very durable yet as in their current form they won't be applicable to last for over 50 years. Non-treated mycelium bricks do not degrade without exposure to living organisms such as that found in soil biota and moisture. Being exposed to this the material will degrade like a soft unfinished wood and that is the drawback of mycelium today.

We need more research to be done using mycelium so that we have a carbon negative building material. Then material sourcing is very important. The focus is on prioritizing sustainable and locally sourced materials to reduce the carbon footprint associated with transportation. This not only decreases environmental impact but also supports local economies and ensures adherence to sustainability certifications. Alternatively, we can also look at some other materials which we call as alternate materials.

One amongst that is use of construction waste. Implementing responsible construction waste management strategies is crucial to minimizing the environmental impact. Now this involves reducing landfill contributions, conserving resources through recycling and ensuring compliance with environmental regulations. Now what can we do about this? For material sourcing we can look at materials like stone which is locally available, we can look at granite We can look at random rubble. When it comes to binders, we can look at natural binders such as lime. Mixing it with kadukai and jaggery or natural gums.

We can also look at mud which is taken from site from a digging pond or trenching a pool. with which we can make dry mud bricks or mud wall, cob, compressed earth blocks or rammed earth. We can look at salvaging wood from old buildings. Bamboo is a very versatile material. We could look at that and bricks or terracotta which come today in the form of hollow bricks which have insulation because they have air cavities within it.

And we can look at interlocking bricks which will avoid use of too much of mortar and therefore binders. So, using appropriate building material by sourcing a environmentally friendly, eco-friendly material is also a way out. Construction waste management is a specialization by itself and architects and designers and civil engineers, builders must be open minded about incorporating construction waste management as products or byproducts in their buildings. Because ultimately the construction waste goes to the landfill for dumping. The land is also polluted and it's such a waste of the entire embodied energy.

You remember the amount of embodied energy that a building consumes and the gas it emits. Instead of letting it waste in a landfill, this can be recycled and converted into useful products and it can be used in buildings. So, in conclusion, if you see Renewable materials, their characteristic is they are natural. Their origin is natural.

For example, mud, timber, bamboo, mycelium, hemp etc. So, they are found in nature and they are renewable because as you use it, it regenerate itself. In that capacity mud can be left out but all of these materials are renewable and if you see all these materials that we talk of also sequester carbon. They sequester carbon dioxide. Now these renewable materials are robust.

Some natural insulations claim to be highly robust. So they are strong because they are found in nature. But we must be prudent enough to have an appropriate application for each of these. All renewable material are low embodied energy and therefore low carbon. Sometimes negative carbon materials. Their construction efficiency they can be constructed with on-site methods as well as off-site methods.

So, offsite methods are like for example, hempcrete blocks are made offsite or any of the agro-based boards are made offsite. When you see their moisture buffering capacity, many natural insulations can help to regulate humidity. by absorbing moisture and releasing the moisture at the appropriate outside temperature. Most, if you look at their indoor air quality and breathability, most natural insulation helps with good IAQ.

They have odor absorbing capacity. Recycling, some include recycled and waste material. So, it could be a combination of agro-based material plus recycled material making them an extremely green material and a material which is low on carbon. When we look at their thermal mass, most natural material contains varying levels of thermal mass which improves thermal performance. So, we need to choose the material based on thermal performance requirement.

requirement. If we look at their durability they are much more durable because they can survive in moisture not wetness but moisture whereas for most other modern material moisture is a very big enemy. If we see their acoustic performance, they have superior ability to absorb sound and hence in many of the sound insulation and acoustic material, the renewable and natural materials are used. End of life disposal and pollution, there is nothing much you need to do. You just need to sit and watch if the material decays. falls apart it will get absorbed in earth and because they have sequestered carbon they will add nutrient to the soil after their lifetime.

Ozone depletion they have no or low negative effect because they are natural products and And they can go back to nature once they decay. In conclusion - these are the renewable materials. And today we saw the characteristics of these renewable materials. And some examples of renewable material.

And what composites could arrive out of that renewable materials. So, we will stop our class with this and we will continue our next class as a continuation to this same topic. Thank you.