Course Name: Architectural Approaches to Decarbonization of Buildings

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Lecture 01

Choice of building materials for carbon neutrality - Part 1

Hello all. So, last class we saw a very important topic and the topic was - 'what are the strategies to reduce embodied carbon'? We will continue with the same topic and today we will see some of the other aspects of it. So, last class we saw the strategies for reduced carbon emission would be to advise the client on the necessity of the building, whether you really need this building or not. And then if you have to eventually decide to build it and if there is an existing structure, should you demolish the structure or can we retrofit the structure? And if at all, yes, we have to go ahead with building, what should be the scale of the building? Should the building be so huge? I mean, such a large scale building if the client is suggesting or can we advise the client that we can go for a smaller scale and so on. This is what we saw last class and we also saw that we have to consciously decarbonize the building. Let us take this topic further.

Now, how does these decisions impact a building from becoming high carbon to low carbon to even becoming carbon negative. Let us take the case of three buildings. One building is a cement based building. So, let us take a cement based building.

Let us look at the design decisions of this building. In this building, suppose the internal pavement is made up of ceramic tiles of say, 0.009 meter thickness, 9 mm thick ceramic tiles. Last time itself, I had given you an example of how decision on tiles can impact the embodied emission and the embodied carbon. In this building, the pavement is made up of ceramic tiles.

Now, you need to understand the embodied energy and embodied emission of tiles. The repercussions of this, you need to understand how much energy goes into its manufacture. So, how much energy goes into its extraction of raw materials and manufacturing process, not to mention its transportation. In comparison to that, suppose the client is advised to go for something like a softwood. So, 20 centimeters softwood.

What is the embodied energy repercussion of using 20 centimeters of solid wood. So,

how much energy would go into its extraction? What is extraction here? Extraction would be to get a natural product. Wood is a natural product, but wood also has some life. There is some more sequestration left in wood. So, you need to understand what is this extraction and at this stage is extraction is say felling of a tree, maybe a mature tree and then its manufacture.

Yes, it does involve some energy in its manufacturing from a wood to becoming a pavement. And third is its transport. Yes, some amount of transportation would be involved. But not to the extent of a ceramic tile which is a high carbon material. Because it may be probably transported from the next state, adjoining state.

Whereas the transportation of this solid wood would be within the state. Let us assume so. Let us look at the third decision that could be made on the same aspect of internal paving. Suppose we go in for bamboo flooring 15 centimeter bamboo flooring. Now bamboo as a material we will delve into it in the forthcoming class very very briefly or rather we will delve into it In slight more detail in a next course.

In another course. But for now. Bamboo is a material which you will have to eventually harvest. There is no point in leaving bamboo unharvested. Because it will not be of any use.

It will just dry up and have a silent death. So it is imperative to harvest it. So what is the energy required in extraction? Only the labor component- because anyways you will have to mandatorily extract bamboo which is nothing but felling the bamboo. Then next is manufacture. So, in its manufacture, some amount of embodied energy is involved- because you could end up with resins, or sometimes even embodied energy is involved.

But only thing that is involved is the human energy of making bamboo strips and weaving it. Of course, some embodied energy is involved in its processing- making it termite proof and so on, which can also be done in a very humane way by using cashew oils and so on. One need not use chemicals. Look at the manufacturing energy involved in the bamboo flooring. And third is- transport .

Transportation energy- where it is from -if it is from the adjoining state it would be almost same as the timber based building. But if it is from the local place, (because bamboo can also be a very local material). Can you imagine for just one decision of flooring in a cement based building where ceramic tile is used, in a timber based building where solid wood is used and in a bamboo based building bamboo flooring is used. The amount of emissions can fall drastically. Let us look at the second decision of this cement based building.

Now, internal finishes are imperative and therefore, let us look at the decision on finishes in all of these three buildings. Suppose the internal finish of wall and ceiling is a mineral based plaster. So, mineral based plaster. Suppose we go in for a cement plaster. Now, cement is a very carbon intensive material.

Its extraction has humongous repercussions on the environment, and its processing using of clinker and things like that which we will see in the forthcoming classes also, it is extremely high. So, cement is a very energy intensive material. Mixing this cement with sand makes it even more a energy intensive material. And cement is not a local product. Cement has to be brought from longer distance.

So, the extraction energy is very high. The manufacturing energy is extremely high. And transportation energy is also high because it is not a local material. In comparison, let us look at the decision that is taken on the internal finishing wall and ceiling of a low carbon building. If it is just gypsum plaster board, its extraction, yes, does have some amount of energy, but definitely not as high as cement plaster.

So, its extraction is not as high. So, I will say extraction is medium energy consumption. Its manufacturing further is only medium. Its transportation and erection is extremely less because you are already using it in the form of a plasterboard. So it makes transportation energy also medium to high.

Medium to high. But its erection or construction energy is very less. Whereas for a cement plaster all this is very high. The same thing you consider for bamboo. For bamboo you need clay plaster.

The plaster is clay. Imagine the extraction or retrieving energy for mud. It is very very less. Manufacturing, hardly any manufacturing goes into it. There is nothing to manufacture.

It's very less. It's transportation. Mud is a local material and therefore that is also very less. Hence, the decision taken to use plaster- whether you want to use a conventional cement plaster or you want to use a low carbon plaster such as a gypsum plaster board or you want to use an extremely low carbon almost zero carbon material, like mud or clay plaster makes a lot of difference. You can see in the total embodied emission of that building. Now let us look at another one component which we do not talk more about because it's quantity in a building is less.

Nevertheless, it is also very important contributor to the overall embodied energy of that

building. And that would be windows. Before that, let us look at the ground structure, the masonry. Depending on whichever masonry structure you want, suppose in a cement-based building, I am just giving options. You use burnt brick or you use RCC, reinforced cement concrete for the ceiling and you use burnt brick whereas in a timber based building you use something like CLT for ceiling.

And for the walls, you could use any of the low carbon material. Say you can use CSEB. Think. Think for a moment. And for bamboo? Talking only of walls and ceiling, you can have bamboo reinforced ceilings.

Quite used in Kerala. And for wall, you can use bamboo itself for the wall or you can have mud stabilized walls, you can use either. So, this itself shows how much embodied energy reductions can happen when you use alternate materials to high carbon building material. By high carbon, I mean reinforced cement concrete for the roofing, burnt brick for the wall and for low carbon you can go for compressed stabilized earth blocks. Then for the walls, you can use coconut laminated timber for ceilings and for a bamboo building, If you use bamboo reinforced ceiling or bamboo walls or stabilized mud walls or unstabilized mud walls, then so much difference will make to the carbon emissions and you will get a carbon negative building. Another important component which I wanted to talk was about windows and doors.

We tend to avoid to address this, but that is also a very energy consuming thing. Suppose you have a PVC frame and triple insulated triple glazing see PVC becomes a very synthetic material. And it humongous amount of energy is required in its extraction and manufacture. Insulated triple glazing involves a lot of glass as well as the manufacturing process is also very energy intensive. Whereas in a low carbon building you could choose to have wood aluminum frame a combination of wood and aluminum and insulated triple glazing.

Whereas in a bamboo based building just wood frames would do and there is no need even for a glazing. You can avoid this glazing and have timber or bamboo windows leading us to carbon negative. So, Just our choice of building material is so important. In making a building either high carbon, which is a conventional way of material selection and construction or low carbon which is finding some clientele in a very niche area, and a carbon negative which is the most ideal situation and this is what the world needs today if we need to meet our emission goals.

So, we need to shift slowly. So, this shift is very important. Just to give you perspective, let us look at the embodied carbon of some of the insulation materials. Now, you look at cork slab. Now, this comparison shows the difference in embodied energy that can be

achieved by shifting towards a natural material. So, if you look at the sequestered and embodied carbon per meter square of the wall.

Just look at polyurethane unfaced or even expanded polyurethane., its embodied energy and look at the embodied energy of some other materials like as we go up- probably cork slab or cork board. The embodied energy is so less, but you should also understand that there is no sequestered carbon. It does not hold any carbon in this polyurethane expanded or polyurethane unfaced, whereas humongous amount of carbon is held or sequestered. So, sequestered carbon is very high in natural products such as cork slab or cork board or wool board or flax.

So these are natural products and therefore even though they may have some amount of embodied carbon by virtue of their manufacturing process, they have very high amount of sequestered carbon which is a very also an important criteria for us to consider. So these are natural fibers. So, this was actually based on a study that was done and that study considers the various building materials and for particular density and thickness to achieve the same U value of 0.15 watts per meter square Kelvin. How much of each of this material is required? That is what the study is based on.

And you can see for achieving the same result how much energy is required by materials which are extremely high carbon consuming, materials which are high carbon consuming and materials which are low carbon consuming. I would name these materials as medium carbon. So, what I am trying to say is and this is high carbon. What I am trying to say is to achieve the same impact in terms of indoor thermal performance, our choice of building materials for just one item which is insulation can have so much of impact on the environment, because of the amount of embodied energy it holds. Now these are choices which you will have to make very early in your design Along with your client.

So sitting with the client, and talking to them, and going for natural products. The point being- Even if you have to maintain, after some time, the embodied energy for maintenance is not going to be too high. But if you have to maintain high carbon or medium carbon, the embodied energy is going to be very high. And the bonus of having natural products is that you still have a lot of carbon sequestered, carbon to be sequestered. And therefore, I am going on reiterating that it is very important to have the appropriate building material choice.

Now, I would just like to give you a perspective about what happens when you start using recycled materials. Aluminum is the most recyclable and the most recycled material in use today. Aluminum has very high initial embodied energy, but in fact, it is one of the highest, but if you are using recycled aluminum that is the least you can do for

the material choice you had you have made. Now, you see- for reprocessing, The embodied energy used say energy savings is very very high when you start using aluminum as compared to steel. And for glass the embodied energy savings is very less.

We will come to this graph a little later. Let us understand some basics, that aluminum recycling involves remelting the metal which is cheaper and more energy efficient than its production from raw bauxite which is done through electrolysis of aluminum oxide. Already in the previous class we have discussed about how aluminum is extracted. Bauxite being a very spongy ore is found in virgin forests and therefore to extract aluminum itself means that you will have to destroy some forest area. You may go for replantation that is a different thing but what do you do first? A part of the ecosystem is destroyed. Whereas if you are going to recycle the aluminum then that process can be avoided.

The process of having to destroy the forest land can be avoided. And therefore it is melting or it is recycling is a much better option if you have decided to use aluminum. Now recycling scrap aluminum requires only 5% of the energy that is used to make aluminum from the raw ore. And therefore it becomes a very important choice to use recycled aluminum. But steel is also continuously recyclable without any impact on its properties.

The property does not get degraded. Steel scraps are collected and they are sent to foundries where they are melted down in a furnace that runs at very high temperature probably around 3000 degree centigrade and then it is purified to get rid of the contaminants. This steel which we melt is again solidified and it is sent as raw materials to various factories. Now this can save up to 75 percent of the overall energy used in the production of steel from raw materials. However, we should note that compared to aluminum, the savings for recycling of steel is less. But its savings as compared to having to manufacture a completely new product is very high.

That's up to 75%. Now glass is also 100% recyclable and you can endlessly recycle. Once you recycle the glass you use it and then it's of no use again after some years 30 years 50 years you could again recycle the glass and there will be no impact on its quality. The major source of embodied carbon in glass is the energy to heat the furnace to melt the raw materials. Now this process anyways has to be carried out even while recycling. Hence recycling of glass does not save as much embodied energy as aluminum or steel as you can see from this graph.

Therefore, if you want to consider a recycled material, aluminum is a much better choice as compared to glass or as compared to steel. We will quickly see materials with carbon

sequestering properties because I had been talking multiple times about carbon sequestration when we were discussing about use of core products. So, carbon sequestration is the process of capturing and storing atmospheric carbon dioxide. So, it is like the inherent property of the material.

Because it contains the biomass. So the carbon is not yet released from the material but it is held in the material itself and therefore all natural products will have carbon sequestered in them. These products- they absorb more carbon dioxide in their growing phase than they emit during production. Therefore, it is assumed that these products have a negative global warming potential value. Here I have shown some materials which have sequestered carbon and what is their renewable feedstock energy. So, you can see air dried sawn timber or bamboo flooring has very high sequestered carbon which means it consumes more carbon in its growth phase and holds more carbon than the carbon that is needed to make it into any product.

And you can notice it is a natural product. So, even amongst natural product, bamboo seems to have a very high sequestered carbon. As much as timber, we can well imagine that timber also has more carbon in it. And again, you can see cork, all cork products, they have large amounts of carbon sequestered in them. Now, look at products which are if you look at any of the natural products whether it is straw bale or timber or wood any wood based product you can see that the carbon sequestration is high in them.

The carbon sequestration is in the range of 1.5 to say 1.75 kg carbon dioxide per kg of the product. If you look at products which needs some kind of manufacturing- say fiber cement board. You can see carbon sequestration is almost 0, it is 0.06. Whatever little carbon sequestration happens is because of the natural fiber that is used as an additive in the cement board.

Otherwise it would definitely have no carbon sequestered in that. And so this gives us a perspective about which materials have more carbon sequestered and therefore are kinder to the environment and therefore support decarbonization by having reduced embodied carbon emissions. They are all made up of natural fibers or they all have some natural material in them. And another thing we have to be careful is which component consumes most of the embodied carbon. Based on that we can decide for an alternative building material for that particular component in such a way that the embodied carbon will be reduced. So, we already know that embodied carbon emissions- these are associated with materials and construction process through the whole life cycle of the building not only at the initial stage.

Now our choice of low carbon materials become important because there are certain

components in the building, which can consume a lot of embodied carbon. They can hold a lot of embodied carbon and therefore we need to identify this when that is where early design stage is important. Catch it young. At an early design stage make your decisions about what building materials you want to use, how you want to manufacture and or rather from which part do you want to bring those building materials. So those decisions become very important in ensuring that we have a low embodied carbon building and that is what was our topic today and this will be one of the important ways to reduce embodied carbon in buildings.

So, I will leave you with this and of course, the gist of this- we have seen how our choices of building materials will result in either a high embodied building a high embodied high carbon building or a low carbon building or a negative carbon building an extremely green building and these choices are definitely in the hands of the architects and designers, taking the client into confidence. So, we will close this lecture now to continue with further ways and strategies of how we can reduce embodied carbon. Thank you.