Course Name: Architectural Approaches to Decarbonization of Buildings

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Lecture 01

Renewable building materials and technologies

Hello students, as part of understanding decarbonization in buildings, in the last class we saw some of the renewable building materials as well as their characteristics and we found that renewable building materials are in no way inferior to conventional building materials when it comes to either their strength when used in appropriate places and for appropriate uses, acoustics, thermal performance and ability to withstand moisture. Today we will have a look at some of the renewable building materials and the technologies which we can use for those building materials giving us an overall low embodied buildings with low embodied carbon. So, today we will have a look at some of the building materials part 2, the properties of these renewable materials, some examples of these. So, renewable materials are derived from natural sources and can be replenished over time. These materials are those which can be manufactured or generated quickly enough to keep pace with how fast they are used up. They can be made from natural products or synthetically produced and they often include recycled products.

By utilizing renewable materials, we reduce our dependence on non-renewable resources such as fossil fuels and minerals. Renewable materials are plant derivatives or agro-based and thus can be regenerated over again after the initial crop has been harvested. Though not all renewable materials are plant based and agro based because some of the materials could be like earth, clay, lime. A renewable material must not be consumed more quickly than it can regenerate.

With the help of technology, construction companies are utilizing waste materials with recycled commodities such as mining waste, glass waste, burnt clay to develop renewable materials for construction. The output is a low maintenance and long lasting renewable material for construction. Manufacturers are designing these materials while keeping in mind the entire construction life cycle composed of structural design, parameters, production techniques and maintenance methodologies. Regenerative plants like bamboo are a good example of renewable building materials as we saw in the last class. Rapid regenerative properties along with low cost make it a favorite for manufacturers in the

market.

Sugarcane is another example. Sometimes banana fibers also is a good example of naturally grown regenerative raw material which can be used to create bagasse which is a renewable material used in construction. Besides, being composted in a short period without causing environmental harm, bagasse is used as a biofuel for producing energy and heat along with electricity. These multifaceted benefits pile up its demand in the market. Now we will again go through some of the properties of renewable building materials.

Renewable materials are natural. Most of them are agro-based. So they are agro-based most of the times. Natural found in abundance. They are replenishable.

So, they are self generating in a way. For example, bamboo. They are indigenous. So, they have local adaptation. because they are indigenous.

They are lightweight because they are mostly made up of dry agro based and they have low embodied energy because they are natural. They are fit for on-site and off-site construction. They have low carbon emissions because they are natural and they have carbon sequestration again because they are natural products. So, carbon sequestration has given natural renewable materials an edge over synthetic materials as they can be seen as carbon negative. The overall environmental burden is reduced by the fact that plant-based materials have locked up carbon when growing which synthetic materials can never do.

Studies on the embodied energy consumption in buildings which have been carried out by UNCHS in the year 1991, have indicated that a high proportion of the energy used (Almost up to 90% is used) in the production and transportation of building materials before they are brought to site. Only 10 to 20% of the energy use takes place in the on-site construction process. Thus, renewable materials which are natural have less embodied energy. So carbon sequestration which is a very important part of any renewable material has given natural renewable material an edge over synthetic materials as they can be seen as carbon negative. Hence agro-based renewable building materials need a lot more research to be done in order to be brought into mainstream building industry.

In our case, we will also consider mud as a renewable building material since it is a natural material and there is no dearth of mud. If you look at the characteristics and properties of renewable material, mud follows almost all of these except for being say lightweight or self-generating except for that it abides by most of the characteristics of

renewable building material. Now, Encouraging adoption of renewable material is a very key component in decarbonizing buildings. Recent government regulations encourage adoption of renewable materials. In the mission to transform the construction industry into a sustainable sector, various renewable materials in the construction market have been identified which hold the potential to replace the existing construction materials.

The major objective here is to save energy, water and various non-renewable resources to gain and reap long-term benefits. In order to propel such initiatives leading to sustainability, recognized organizations such as LEED are encouraging the construction companies by avoiding green building certification. Also, the CII Confederation of Indian Industry awards green certification to the products itself through Green Pro as an organization. The growing trend of such recognition has been increasing the supply of renewable materials in construction industry. Let us now look at few of the materials and the construction technology which makes the combination of building material used with that particular technology to give rise to low carbon buildings.

Let us look at burnt bricks. Now, if you look at burnt brick masonry, for the per meter cube, burnt brick masonry has 2 to 3.4 gigajoules of embodied energy. Whereas, if you look at composite blocks, it has half or less than half of the embodied energy which a burnt brick masonry processes because it has 1 to 1.

35. Burnt brick is manufactured by casting mud blocks and firing it in kilns. the process of firing the burnt brick in kilns using certain type of fuels. Sometimes the fuel (mode) is just straw, hay. It could be anything. Sometimes it is coal.

It could be any of those and that is what increases or decreases the embodied energy in burnt bricks. If we look at the embodied energy of stabilized mud block, it is almost one-fourth of that of burnt brick. The stabilized mud blocks are nothing but masonry and burnt bricks are basically manufactured by burning the bricks at high temperature. So you process the clay and the clay minerals the minerals that are found in the clay they undergo irreversible changes which gives strength to the brick. But in this process it uses high energy.

Here conservation of energy as well as clay mineral resource become important from environmental and environmental angle where, when it goes back to the soil, will we be able to retrieve the minerals becomes a question mark. But SMB (stabilized mud block) they are energy efficient eco-friendly alternatives to burnt clay bricks. These are solid blocks which are manufactured by compacting a mixture of soil, sand and some stabilizer. Normally that stabilizer is cement or lime. If it is lime it becomes even more environmentally friendly with of course a mixture of water.

After 28 days curing these blocks are used for wall construction. So this becomes a combination of mud plus stabilizers which are mostly cement and lime. Whereas if we look at fly ash Fly ash blocks are a mixture of lime plus fly ash along with the crusher, crusher dust. This is compacted into high density block. Now, lime reacts with fly ash and the minerals in the fly ash form a water insoluble bond and that gives strength to the block.

So, if the embodied energy of brick masonry is 2 to 3 gigajoules per meter cube, stabilized mud block is And fly ash is 1 approximately. So, you can imagine how much reduction in embodied energy can take place by using renewable material or composite renewable material. Now, we will look at stabilized rammed earth and unstabilized rammed earth. The term rammed earth refers both to a material which is a mixture of sand gravel and clay and to the construction procedure whereby walls are built using this material rammed in layers between formwork. That is when a cementing material is also added to the material is known as stabilized rammed earth.

So rammed earth actually is a technique and this is with forming solid walls by compacting compacting processed soil in progressive layers in a temporary formwork. So you have formwork within which you start compacting soil in layers like this. Once this layer is laid and compacted next layer is laid and so on and so forth and then the third layer is laid leading to this kind of. Once the formwork is removed, this is how we see it. So, there are two types of rammed earth construction.

One is stabilized rammed earth and unstabilized rammed earth. Stabilized rammed earth is made from mainly soil, sand and gravel. Whereas, stabilized rammed earth contains additives like cement or lime along with soil, sand and gravel. But unstabilized rammed earth walls are nearly zero carbon options. So, rammed earth is a technique which uses earth or soil.

This along with binders or stabilizers is called as stabilized rammed earth whereas this is just soil. So, alternative options like stabilized mud block masonry and rammed earth walls have considerably lower embodied energy values when compared with energy of burnt clay brick masonry. Energy content of stabilized mud block masonry and stabilized rammed earth wall is about 20 to 25 percent of the burnt clay brick masonry energy. Fly ash block masonry shows reduction of 40 to 50 percent in the embodied energy values when compared with energy in burnt clay brick masonry. If you see or if you rather compare then Burnt brick as we saw in the last slide has embodied energy of 2 to 3.

5 gigajoules whereas stabilized mud block has 0.45 to 0.56. Let us assume for

convenience 0.

5 gigajoules. Whereas, unstabilized mud block, unstabilized rammed earth has 0 to 0.18 gigajoules of embodied energy. That is the extent of how low embodied carbon and low embodied energy material these two are. We will quickly see a small gist of techniques that can further lower, technologies that can further lower embodied energy.

Now, the first case is a RCC slab. RCC is reinforced cement concrete slab. We will take an example of flooring or roofing systems. We will look at four systems and we will see their embodied energy. The first one is RCC. If you see RCC has an embodied energy of 0.

8 to 0.85 gigajoules. Whereas composite stabilized mud block masonry jack arch roof is a system which is made up of arches with a filling material. This shows 40 to 50 percent reduction in embodied energy when compared with RCC slab. Now, the use of stabilized mud block filler slab results in 20 to 25 percent savings in embodied energy when compared to the energy in RC slab. Now if you look at the composite stabilized stabilized masonry jack-arch roof this is comprised of concrete channels like these in which arches are used with composite. These are filled with composite stabilized mud blocks as you can see here.

So, this jack-arch is classically defined as a structural element in masonry construction which provides support at openings in the masonry. Its other names are flat arch or straight arch. Unlike regular arches, jack arches are not semicircular in form. Instead, they are flat in profile and are used under the same circumstances as lintels. This name has also been used to describe another roofing system that involves a series of smaller sized yet elongated vaults that are supported on intermediate beams.

And these are called as jack arch slab roof type. So, there are a series of vaults, mild vaults placed next to another and on RCC beams. And if you see by virtue of using stabilized mud blocks as the fillers, their embodied energy is almost only 50% of RCC. Let us now look at the filler slabs. What is a filler slab? Filler slab roofs are basically solid reinforced concrete slabs with partial placement of the concrete in the tension zone by a filler material.

The filler material could be something cheaper or lighter. So what happens is when you have a roof like this as shown here Some parts of the RCC is scooped out or replaced with either voids or terracotta tiles or pots etc. It can be filled with or replaced with anything. So the unreinforced masonry here, this part, it's not reinforced. What happens is where the zone does not need too much of strength, that part is scooped out and refilled

with any one of these.

And when you do that, the embodied energy is 0.6 to 0.7. Whereas if you look at composite stabilized mud block masonry vaults, so this vaults, what happens? There is no reinforcement. It is just stabilized brick masonry.

And this is actually a very old technique. And these vault and dome constructions are very old techniques and that too using unreinforced masonry. This is due to the advent of steel and RCC that these techniques were abandoned during the British period. So they are very aesthetically pleasant, beautiful, they are cost effective, they are durable, they show savings in energy. And these, if we revive these vaults and dome systems wherever appropriate or necessary, a lot of embodied energy can be saved because you are going to avoid steel completely. Probably avoid concrete completely depending on what material you use to construct your vault.

So, using appropriate construction techniques in combination to lower embodied energy can reduce dramatically the embodied carbon as well as embodied energy in the system or in the buildings. So, with this we conclude that Embodied energy component in various wallings and roofing system is a combination of the building material that is used and the construction technique that is followed. If we take a comparison burnt clay brick masonry has an embodied energy of 2 to 3.5 gigajoules per meter cube.

Whereas, stabilized mud block masonry has only 0.5 to 0.6 gigajoules per meter cube. Fly ash block masonry which is composite has half the embodied energy as that of burnt brick.

while stabilized rammed earth wall has 0.45 to 0.60, 25 percent of embodied energy of burnt brick. Whereas, unstabilized rammed earth wall could even have 0 gigajoules of embodied energy per meter cube. If we look at the roofing system, If the RCC slab has embodied energy of 0.8 to 0.85 gigajoules per meter cube, composite stabilized mudblock masonry jackarch roof system has about 0.

45 to 0.55 gigajoules per meter cube. Whereas, stabilized filler slabs have 0.6 to 0.7 gigajoules per meter cube and could get further reduced or increased based on the nature of the elements that are placed in the filler component, in the void component.

Unreinforced masonry vault roof has 0.45 to 0.6 gigajoules per meter cube and could get lesser because there is no reinforcement involved here. So, in today's class we saw how if we consider mud as a renewable material when you use various technologies. in construction techniques whatever techniques you used for construction based on that we

can further bring down the embodied energy per meter cube of the walling and roofing system. We will meet again with yet another interesting topic to discuss all aimed at decarbonizing buildings in India. Thank you. Thank you.