Course Name: Architectural Approaches to Decarbonization of Buildings

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Lecture 1

Environmental impacts of building materials and components

Hello students, so in our last class we made a comparison of the embodied energy and its emission impact when we use conventional building materials and when we use alternate building materials which are primarily renewable building materials. So, we have seen the impact of renewable and non-renewable building materials on the emission of the building and as a case to the point we had compared a couple of case studies. Now what we will see today is we will see the embodied carbon and some environmental impacts of various building materials. And so in today's class we will see embodied energy and embodied carbon of certain building materials and embodied carbon value for various materials in the Indian context. Now we find that in general there is the environmental impact in each life cycle stage of the building varies. So, this picture shows the contribution of each of the three life cycles to the total environmental footprint of the building for the Here I have taken three environmental categories because the focus of the research of this class is not on environmental categories and therefore I have taken only three which we already have seen.

First is the energy, second is the GWP which is the global warming potential and ODP is the ozone depletion factor. Now out of the three life cycle stages which are material production so this indicates this stage This stage indicates material production, the contribution to each of the categories due to material production, transportation stage and this is the on-site construction stage. Now, out of the three life cycle stages, we have considered these three life cycle stages. We are considering only these three for now.

The contribution of the material production is highest when it comes to the either energy category. You can see here in the energy category material production stage contributes highest to the impact and so is the global warming potential stage. It contributes the maximum. Now to the total environmental footprint of the building and it varies between about 88% to 97%. So about 87% to 97% of the environmental impact happens in the material production stage and therefore material choices by an architect is very important in reducing CO2 emissions as can be seen from this part, the global warming potential

and in reducing carbon dioxide emissions and embodied energy.

And therefore, use of renewable materials, renewable earth friendly materials becomes very important and that decision becomes very important. So some studies show that steel, cement and bricks are major materials that contribute the most to the initial embodied energy profile. And especially now that we build a lot of apartments more than individual houses, when we build apartments it is stilt plus 4. So, it is a 4-storey apartment. And you can see that you know the amount of energy that is consumed by the building materials is extremely high leading to high emissions.

Now also what happens is when it comes to the ozone depletion, transportation stage also contributes equally high. See the transportation stage contributes to about 48%. Why does that happen? This is due to the high use of diesel for transporting the building materials to the site. Hence, it becomes very important to choose locally available building materials. And therefore, I reiterate as I did in the previous classes, if one has to choose the Say a flooring material, you have a choice to choose the flooring from a local place or from within the state or from outside the state or even outside the country.

Depending on your choices, this transportation energy can go anywhere between 47% to even 80% damage can happen. Because diesel is the contributing factor. And then the final on-site construction stage constitutes to about maybe 1 to 5 percent of the total impact of all the categories except in the ozone depletion stage. And why is it that in the ozone depletion stage, on-site construction stage, the damage happens more? That is primarily because of use of diesel, petrol and electricity. which is associated with the running of machineries.

You know you do excavation, you do watering for which you use diesel pumps, generators are used, for paving we need machinery, tipping and other on-site operations because of which the you know contribution due to the the diesel, petrol and electricity increases on-site construction stage emissions, especially in the ozone depletion factor. And hence we come to what we what we come down to is on-site construction stages must look at you know vernacular and traditional building practices which did not lay much emphasis on use of machineries. This is possible in some of the building typologies, not in all the building typologies. But it is important for an architect to understand how his decisions will impact the environment, how his decisions of choice of material will impact carbon dioxide emissions and energy emissions and global warming potential emissions simply because of the choice of building material. Hence, be wise to choose renewable earth friendly building materials.

Try to source the materials from locally, from local places adjacent very close to your

building site and try to use practices which are not energy intensive, construction technology practices which are not energy intensive. In the previous classes, when we were discussing technologies with renewable materials, you saw the jackarch roof and the pillar slab. These do not require very heavy machinery as compared to many other construction techniques. Next, we move on to material wise environmental impact. So, when it comes to embodied carbon, this is the major materials that contribute to the most to the total environmental impact of a typical building.

So, In one study, about 78 building materials were taken and the impact of which material contributes most was taken. You find that aluminum contributes substantially. Brick, one of the highest contributors to energy and cement is one of the high contributing factors to the global warming potential and you can see that steel in the form and used in the form of steel bars and these are other materials. So, Although dependent on which environmental category one looks at, the major building materials contributing to the environmental impact of the building are bricks and bricks contribute to about 40 to 55 percent of energy. So, 40 to 55 percent of Embodied energy is consumed by brick and that reflects directly on the emissions and you can see that brick also contributes humongously to the global warming potential.

Then cement is another big contributing factor between 20 to 35 percent of embodied energy contribution to a building is by steel, by you know cement. So, cement is used everywhere in the form of concrete and mortar. So, it is a big contributing factor and steel bars contribute to between 5 to 10 percent of you know embodied energy emissions, while aluminum sections contribute to about 2 to 4 percent and that is because the quantum of the quantity of aluminum is very less. If you increase the quantity of aluminum in a building, then the impact of aluminum in you know embodied energy and global warming potential releases is going to be higher. Aggregates contribute to about 2 to 4 percent.

Now, galvanized iron pipe and diesel use are the major contributors to ozone depletion factor. Though we are not considering that right now because that is a slightly advanced, another concept is getting introduced ODP, ozone depletion factor. So, we are not looking at it primarily now. But understand that diesel is a primary contributor to transportation of building materials to the site and also to the machineries. that we saw in the previous slide like hydraulic excavator or concrete mixer and things like that.

So, from this we can make out what we can conclude is that one needs to reconsider use of burnt bricks. Because the fuel used for burning the bricks is a major reason for increase in embodied energy as well as global warming potential. So, find out what could be the alternate to burnt bricks which would have less impact on the environment and

look at the binders that you use. Should the binders necessarily be cement? If you can have alternate binders like lime which are renewable and environment friendly, try to go for it because cement contributes to the embodied energy and global warming potential. Similarly, steel in reinforcements can be reconsidered.

Try to look for other renewable materials. As I had already said, bamboo reinforced slabs are now in vogue in many parts of the country, especially in Kerala. And therefore, if these three building materials, burnt bricks, any binder which is cement, I am talking of cement as a binder, burnt brick, cement and steel contribute humongously to the embodied energy and global warming potential. And therefore, one needs to relook at building material choices. Now, let us look at which fuel contributes most.

Now, the electricity mix is dominated by hard coal which contributes to about 57% of embodied carbon. Next comes lignite. So, the electricity mix is mainly you know the contributor is hard core with substantial fractions generated from lignite then hydro and natural gas resource. And smaller contributions come from nuclear, wind, fuel oil and biomass. And what is shown as other you know it is composed of say photovoltaic which is about 0.

2 percent in this. So, PV is about 0.19 percent, waste from energy, biogas, all these come together to come to 0.5 percent. And therefore, you can see that hard coal from electricity and lignite 14 percent and hydro 11 percent, these seem to be the major contributors. Now, the embodied energy per unit weight of building material is given here which is brick.

Now, what we are trying to see here is how the embodied energy of brick is based on the manufacturing kiln. Depending on the kiln or the fuel fuel the embodied energy per unit weight increases or decreases. So, here you can see that when brick is manufactured using high draught or zigzag kiln the embodied energy is highest in that quality of brick and next to that is Brick made with clamp kiln and bull's trench kiln, sorry, common brick or facing brick is the third contributor. The manufacturing process of the common brick comes third. And fourth is brick using bull's trench clean.

And fifth is the brick manufactured using Hoffman kiln. Compare this to rammed earth. Rammed earth has only 2 megajoules per unit weight. Hence, you can see that the common facing brick that we use is more than double. It is more than double of rammed earth and even this rammed earth- it is made up of stabilized soil.

It is about 2 mega joules per kg whereas if we use unstabilized earth, unstabilized mud blocks or unstabilized earth then it won't be that high. The rammed earth brick

contributes to the least when it comes to embodied energy. Hence First what we have seen in the earlier slide is, brick is a major contributor to embodied energy. Next the method of manufacture. Method of manufacture which is in the form of kiln that is used to burn the brick is the reason why the embodied energy of the brick may be high or low.

Hence try to choose brick which is burnt using a technology which does not make the brick a high embodied energy building material. Now we will compare the global warming potential of brick with respect to rammed earth. If you look at the global warming potential of bricks, which is primarily related to the carbon dioxide emissions, you can see that the rammed earth, global warming potential of rammed earth is in negative.

It is 0.0084. So, it is almost not releasing any carbon dioxide emissions. It is a very earth friendly material. While when you see the brick made with high draught zigzag thin that is very high that is 0.59 kg carbon dioxide equivalent. and brick kiln has a global warming potential of 0.57 kilogram carbon dioxide equivalent. And the third is, so this is the first, second and the third brick made with The common brick which is used for facing ranks third when it comes to global warming potential and carbon dioxide release. Then the bull's trench kiln and Hoffman kiln, they are more or less similar in their global warming potential. Now, as compared to rammed earth which is a carbon negative material, the bricks manufactured with other technologies in terms of baking the brick, burning the brick, the global warming potential rises significantly. The focus is more on brick, because it is one of the materials which is used predominantly in most of the building materials in most of the buildings in our country.

It is a conventional building material. Most of the residences are made up of brick walls with cement facing with cement plaster and therefore the choice of the brick in terms of the kiln where it is fired becomes very important in reducing the embodied energy and embodied carbon of that building. Let us now look at the contribution of different building item works to its total environmental impact. Now, Here what we have done is this research considers 12 individual items of work and it is found that brick work, brick work you know it contributes to about 50 to 60 percent of embodied energy and global warming potential is due to brick, due to items where brick work is involved. RCC contributes to about 20 to 30 percent of global warming potential as well as embodied energy release.

So, all the RCC work, all work involving reinforced cement concrete, while all works related to aluminum contributes to about 4 to 5 percent. So, this is concrete RCC, I would say not even concrete RCC. And this is aluminum. Finish work also contributes to about 4 to 5 percent because the choice of the material becomes very important there. And these

materials contribute the most to the total environment footprint of the building for energy and global warming potential.

The flooring, waterproofing, finishing, drainage and woodwork, they all put together contribute to 2 to 5 percent of the total impact the building has on embodied energy as well as global warming potential. And all the remaining items of work contribute to less than 2 percent of the total impact for embodied energy and global warming potential. Hence, it becomes in here. You can also see that the PVC and woodwork contributes to about 3 percent of embodied energy and not for any other category and hence it becomes very important for us to focus on which item of work in a building contributes more to embodied energy and global warming potential in combination to that building material? What we must do as architects and designers is reassess the building material used for that particular item of work so that the embodied energy component due to that item of work comes down. Here, we look at the embodied carbon of various building materials in the Indian context along with its global warming potential.

Now, the global warming potential was developed to allow comparisons of global warming impacts of different gases. So, we all know it is specifically a measure of how much energy the emission of one ton of a gas will absorb over a given period of time. Relative to the emission of one ton of carbon dioxide and therefore, we call it a CO2 equivalent, carbon dioxide equivalent. The larger the global warming potential, the more that a given gas warms the earth compared to carbon dioxide over that period of time. The time period that we usually use is about 100 years highlighting some of the materials with the highest and the lowest global warming values.

So, here we can see that which material has very high embodied energy. If we look at those materials and even here if we look at brick the way brick is manufactured, the global warming potential as well as the embodied energy changes. And we see that all these aluminum based materials which are aluminum extruded profile or aluminum ingot or aluminum cladding or aluminum sheet have extremely high embodied energy to the tune of about 300 megajoules. Then brick, this is for us to know in general. So, aluminum has about 300 and brick has anywhere between 5 to 3.

5 mega joules. And of course, based on how certain things are manufactured, if nylon is used in carpet, its embodied energy becomes very high to the tune of 130. Adhesives are another compound that is used in the building sector which has very high embodied energy. And if we look at the global warming potential, aluminum seems to have a very, very high global warming potential to the tune of about 30 to 35 carbon dioxide equivalent. That way at least brick does not have too much of global warming potential as compared to aluminum, but it is still significant considering the quantum of brick, the

amount of brick that is used in any building. That much of brick material as aluminium is not used in buildings.

But nevertheless in comparison to aluminum, global warming potential of brick is less because the primary material there is earth and all the damage that happens primarily is because of the fuel that is used for burning. So, high embodied carbon materials have high intensive raw material extraction process or the manufacturing process or sometimes both and that is the reason why aluminium has aluminium or carpets, or steel and PVC has such high embodied carbon values. Whereas low embodied carbon materials are usually the ones that are renewable rapidly. You know we can take it directly from nature and they do not involve too much of processing. For example, timber or using mud plaster, straw bales, bamboos, these are all low embodied, low carbon materials because they do not involve too much of energy for its extraction and processing.

Here are some of the other materials just for comparison for you to understand the embodied energy as well as the global warming potential. We see that some materials like copper have We see that some materials like copper have very high embodied energy as well as global warming potential. Both are high for copper. Expanded polystyrene insulation, the embodied energy is high as well as its global warming potential. If you look at steel anywhere that steel is used its embodied energy is high 51 and its global warming potential is also very high.

UPVC window frames the embodied energy is high and global warming potential is high. So, anything with PVC is high. Whereas, we look at materials which are from nature or which we call as renewable, the embodied energy and global warming potential is relatively less for gypsum as a raw material, for lime mortar and for mud plaster. We also see that rammed earth has very less embodied energy as well as the global warming potential is in fact negative.

It is a carbon negative material. And this gives us a a perspective about the various materials in the Indian context and their embodied energy and global warming potential. And what we should also understand is the you know here we have taken three of the most common construction materials and their relative carbon dioxide emission for one metric ton of the material product. Steel has the highest carbon footprint as there is a long process and lot of energy is involved in its extracting it from the iron ore and converting it into steel. Now, there are multiple methods of production of steel, but in general steel has a very high value. Now, you can use BOF or electric arc furnaces and based on which we have already seen previous classes based on the nature of steel.

Its embodied carbon and carbon emissions during its material manufacture process is

very high. Then wood, though wood is a naturally occurring material which can be used in the construction, it still has to undergo some processes in the form of being made into either planks or veneers or plywoods. If it has to undergo that process then it still has a considerable amount of embodied carbon emissions and most of this could come because of the adhesives that go into it. Concrete has a lower embodied carbon value as compared to the others because except for cement, the other raw materials used in it which is aggregate, water and sand, they do not need large amounts of energy to procure and process. But when it comes to reinforced concrete, cement concrete its embodied emission is very high because you need to factor in the use of steel.

So, this is the graphical representation to kind of have a perspective of which building material gives more of emissions. So, in this class we saw the embodied carbon and carbon dioxide emissions of various building materials, especially in the Indian context. We also saw the contributing factor, whether it was at a manufacturing stage or transportation stage or on-site stage of various building materials. And what we learn from it is, it is not just the embodied carbon and the carbon dioxide emission of a building material. But if we look at the quantum of the material used in the building, then even a moderately high embodied energy material would contribute extremely high to the entire building.

So, the where that particular building material is used that component is also very important and we have seen briefly those items of work also. So, with this I will stop today's class and we will continue with another topic in the forthcoming class. Thank you.