Course Name: Architectural Approaches to Decarbonization of Buildings

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Lecture 03

High embodied carbon building materials

Hello students, in our last class we saw building examples of renewable energy materials, buildings that were used with that were built with renewable energy materials. Today we will see high embodied building materials. We have seen low embodied building materials and now we will see high embodied building materials, high embodied energy, embodied carbon building materials. The first one we take is cement. Concrete is one of the most consumed material in the world and it is responsible for over 7% of annual global anthropogenic carbon dioxide emissions. Concrete is comprised of aggregates and binders and Portland cement is a binder which is primary binding material in vast majority of cases and that alone is responsible for 90% of concrete's emissions.

Nearly 95% of cement's emissions come from clinker. which accounts for 91.4% of the material substance of cement. Clinker is produced by heating limestone plus clay at 1450 degrees centigrade, which precipitates a chemical reaction called calcination.

Energy emissions from heating the kilns account for 35% of concrete's emissions. The calcination process releases carbon dioxide in great amounts resulting in 53% of concrete's emissions. According to International Financial Corporation database, embodied energy of cement is 6.4 megajoules and its global warming potential is 0.91 kg carbon dioxide equivalent.

Looking at the processes and embodied carbons of cement, we can see that this clinker is caught by heating this limestone at 1450 degree centigrade along with nearly 2000 degree centigrade along with silica, gypsum and some alumina. So, this itself is responsible for a lot of carbon dioxide emissions and therefore, it becomes one of the most, highly carbon intense building material. Next building material, high embodied carbon building material we will see is steel. Steel is made with a mix of primary raw materials which is the ore and recycled materials if available. Mostly it is available.

So, this is ore plus old steel used for recycling. Primary steel is made by processing ore in a blast furnace or basic oxygen furnace system or in a direct reduced iron plant. The basic oxygen furnace it burns coke which is a coal based fuel to up to 1300 degree centigrade. So, what was 2000 degree centigrade in concrete now is 1300 degree centigrade to get pig iron. Now, this utilizes a reducing gas such as hydrogen which reacts with iron ore at lower temperature to make sponge iron.

Secondary steel is made using electric arc furnaces to melt existing steel scrap and recycle it into new. So, basic if you look at electric arc furnace then there is 50 percent less CO_2 emissions as compared to basic oxygen furnace. So, this seems to be a much better option. So, that is because 97% of what goes inside is recycled content. And 29% of global steel is made using this procedure with electric arc.

And 71% of global steel is produced using the basic oxygen furnace which is highly energy intensive. The third building material we see is gypsum boards. Now gypsum board sometimes is referred to as plasterboard or drywall. It is commonly used building finish material for walls, ceilings and partitions. The gypsum used in gypsum board comes from both natural which is from mines and synthetic sources like flue glass, gas or desulphurization etc.

as a byproduct of coal fired power plants. Gypsum board is an energy intensive product to manufacture and there is a significant amount of gypsum board waste disposal as a result of over ordering, incorrect specification, damage and off cut during construction. People need to realize that wasting a high embodied energy, high embodied carbon building material is equivalent to adding that much more carbon to the usable building material making it even more further high embodied carbon. The exteriors and gypsum cores of gypsum board can be made from high percentage of recycled materials but this result is limited to no energy saving because it must go through the manufacturing process again. So, compared to cement where clinker has to get heated to 2000 degree centigrade and steel where the furnace is heated to 1300 degree centigrade, chip sim is heated to 300 degree Fahrenheit And it involves the process of gypsum which is heat dried plus water fibers and additives faced with paper and the boards get heat dried resulting in a product which is high in carbon.

It is a carbon intense product. Carpets can sometimes be very high embodied carbon materials. It stands out as a high impact material in interior projects, renovation projects. The carbon impact of carpet is driven by the extraction and processing of oil and gas into the different petrochemicals and plastics in various component layers. The production of nylon fiber from crude oil is the largest source of embodied carbon emissions for most carpet.

Natural fibers such as wool can also have significant embodied carbon impact from industrial processing. Actually, wool is a natural material and therefore its inclusion in carpet should make the carpet low carbon material. But when you start industrializing it the processing makes it carbon intensive. Final manufacturing of carpet uses substantial quantities of energy specially thermal energy typically from natural gas or other fossil fuel sources to evaporate water and melt plastics into backing. So, various materials that can be used in carpet are nylon, polypropylene, polyester, wool and recycled carpet resulting in various nature of or various intensities of carbon in the carpets.

The next material we see is aluminum. India is currently the fifth largest consumer of aluminum in the world. Aluminum based products, they are extremely carbon intensive because highest carbon emission is involved in its manufacture. Bauxite is the ore. It's a reddish rock and comprises of 15 to 25 percent aluminum.

And after its extraction, which itself is a process involving a lot of sensitiveness to environment because forests have to be destroyed to procure bauxite. Refining bauxite into alumna is moderately carbon intense and usually occurs in coastal refineries. But you should understand the impact of coastal refineries on coastal life. The Bayer process operating at 150 to 200 degree centigrade contributes to these emissions. The energy intensive smelting process transforms alumina to aluminum and is the most carbon intensive step demanding 15.

37 MWh of electricity per ton equivalent to 5 times of UK households annual consumption. Smelter locations vary in emissions intensity depending on electricity sources like low carbon hydro or high carbon coal. India is currently the fifth largest consumer of aluminum in the world. Aluminum based products have one of the highest level of carbon emission. So, before using aluminum in buildings, one needs to rethink its usage.

The biggest advantage with aluminum however is its recyclability. Aluminum can be recycled along with the new product and the percentage of loss during recycling is very very less. In fact, it is the least. However, you can see how smelting alone accounts for a huge amount of emission during the smelting process. Now, let us look at bricks.

Bricks are considered high embodied carbon material if they are burnt bricks. Now, they are most widely used in construction materials. So, the bulk or the quantum of brick used is humongous. It is used for structural and non-structural purposes. The brick production process includes clay extraction and processing, brick forming, drying and firing.

The process of brick production begins with clay extraction using diesel fuel machinery.

Once clay is processed and the bricks are formed and dried they are fired in a brick kiln. Depending on the fire used fuel used to fire the kiln the embodied energy of brick gets increased or decreased. The kilns primarily use coal but also use firewood and other biomass fuels. It is estimated that the Indian brick industry consumes more than 24 million metric tons of coal annually in addition to several million tons of biomass fuels.

According to the International Financial Corporation database, embodied energy of common phased brick is 4.4 megajoules and its global warming potential is 0.39 kg carbon dioxide equivalent. Let us now look at another high embodied carbon material which is glass. Now the raw materials for glass are silica sand and sodium oxide from soda ash, dolomite along with feldspar.

Glass from the furnace gently flows over the refractory spout onto the mirror-like surface of the molten tin starting at 1100 degree Celsius and leaving the float bath as solid ribbon at 600 degree Celsius. Coatings that make profound changes in optical properties can be applied by advanced high temperature technology to the cooling ribbon of glass. Despite the tranquility with which the glass is formed, considerable stresses are developed in the ribbon of the glass cools. As seen from this picture, the first step of converting raw material into molten glass requires the highest amount of energy. Now, this can be reduced to some extent by adding further broken glass called collet in the mixture.

Fine grained raw materials closely controlled for quality are mixed to make a batch which flows into the furnace which is heated to 1500 degree Celsius. This temperature is the melting point of glass resulting in glass being a highly energy intensive material and high carbon material. Now, here is a small inventory of the embodied carbon and the quantity produced. So, even though embodied carbon of a particular material may be extremely high, one needs to consider the bulk of material that is used, the quantity of material that is used. So, along with embodied energy of every material we must consider the quantity of material in which these materials are produced to understand its full impact on the environment.

Here we see that even though the embodied energy of aluminum is very high in comparison to some other common building materials the amount of aluminum used is negligible when compared to say concrete. So, if you see aluminum has embodied energy of 9.16 kg carbon dioxide equivalent, but its consumption is abysmally low compared to concrete. So, but the concrete's embodied energy is pretty much low.

it is the same with copper. Embodied energy is high, but consumption is low. For iron ore embodied energy is high, consumption is not so much and so on and so forth. So, it is very important that we target first the alternate to building materials whose embodied energy is high and is a material which is consumed on a much larger scale. So, in a study done in Sri Lanka on the life cycle carbon emission assessment of a multipurpose building, this graph shows comparison of percentage weights and embodied carbon of major building materials. And you can see that ready mix concrete has the highest percentage of embodied carbon As well as the weight of the material that is used.

Sand too the embodied energy and the embodied carbon is considerably very less. But the consumption is very high. It could net effectively result in products using sand to be highly carbon intensive. You can see steel reinforcement, the carbon percentage is very high but not so much of consumption whereas clay, bricks, the embodied energy or embodied carbon is also very high and the quantum of material used in the building industry is also very high. So, with this we come to the end of non-renewable building materials.

We saw some of the examples and we also saw which process in its manufacture, which part of the process results in high consumption. We also saw that it is not sufficient for us to just look at which building material is very high in carbon. We must simultaneously also look at the quantity of material that is used in the building construction industry to understand its overall impact. So, we will meet next class with yet another interesting topic. Thank you.