Advanced Topics in Science and Technology of Concrete
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Environmental impact and life cycle assessment (LCA) - Part 2

We talked about cement, the greater system or finally the product that we are going to use is concrete. So, we have to do the same thing for concrete in order to understand what is the environmental impact and here we have a typical process flow, a ground to gate system of making concrete. So, for the concrete you will need cement, you will have to know where the cement came from, what went into the cement. So, you have here this part which is related to the cement production what we saw earlier. Then we need aggregates, we need coarse aggregate and sand, we have to know what is the impact of the mining, the production of the coarse aggregate sand. See what are the distances for all of them, how much distance does the cement have to travel, how much the coarse aggregates and how much the sand.

We also need water, so the water also has certain carbon footprint and embodied energy. The fabrication itself, we will need electricity for the production of the concrete for the mixing, transportation and so on. So, we will need to know how much that is, where is it coming from, is it coming from the grid or is it being produced locally, where, what is the source of the electricity also needs to be known and all the distances and the embodied impacts of each of these components are put here to get the final value for concrete. So, this is what we can do for the calculation of the carbon footprint and embodied energy of concrete.

Let me show you some examples, values, so that we remember the numbers. For energy, three different sets of concretes have been considered, a 30 mega Pascal strength, 50 mega Pascal strength and mixes which have the same amount of binders, ordinary Portland cement, Portland pozzolana cement and limestone calcined clay cement. We find that when you have blended binders like PPC and LC3, the energy consumed goes down, we see this in all the cases. Let us look at carbon emissions. Again, we find that as you have, just like we saw in the case of cement, here also quite drastically you have a reduction in the carbon emissions if we have blended binders.

So, from about 350, the carbon footprint could come down from about, so if you just have an OPC concrete, in this case the carbon footprint is about 350 to 400 kg. It comes down to about 250 and less than 300 if you use blended cements. We find here that the aggregates play a role, but a very small role. We are talking in this lecture series on aggregates. We find that the aggregates have a small part to play in this overall system.

Nevertheless, due to the volume considered if we can focus on it, try to eliminate the need for pristine aggregates, it is always good. So, to reiterate, in concrete the major part of the impacts come from the cement. A small part comes from the aggregate. And when we are focusing on this, we are trying to make sure that this is becoming as negligible as possible. So, let us look at some assessment that we have done of aggregate production.

So, we went to a crushing unit near where we are Chennai, we went to this aggregate crushing unit in Kanchipuram and we made the process map. So, we can have different process systems. We look at the ground to gate, which is the overall system as I mentioned before, everything from the quarrying, obtaining of the raw materials up to the plant where the, up to the gate where the aggregates are leaving the plant. The ground to gate system is only what happens within the crushing plant. So, what happens that what are the different processes that we have to take care of? First, there is quarrying.

Quarrying could involve drilling, blasting, reduction of sizes from big boulders to smaller material that can be loaded. So, this often happens outside the plant. So, when we are doing a ground to gate analysis that has to be included, but then that may be excluded when you are looking at the gate to gate system. In the gate, within the gates, in the plant what happens? The material is unloaded into say a feeder which takes it to a primary crusher. The primary crusher breaks the material down to smaller particles say 15 centimetres, then it goes to a secondary crusher, the size reduces, a tertiary crusher and finally a separator which provides the different fractions of aggregates.

So, for all this, obviously we need an infrastructure. The infrastructure has a carbon footprint. Infrastructure meaning all the crushers, the conveyor belts and all the feeders, all of these have a carbon footprint. They need consumables, lubricating oils and other things, spares which also have to be taken into account. So, there is a carbon footprint of the infrastructure, there is electricity required and there is some wastage.

So, all this has to be taken into account in the gate to gate system. Additionally, when we are talking about the ground to gate system, we have to go back to the quarry. See what is the electricity required there, what is the diesel for your transportation, the excavators and what is the wastage at the quarry. So, all this comes together when we are looking at the impact of the aggregate production. So, if we look at some values for this particular plant that we were discussing, if you have the gate to gate system, just what is happening within the crushing plant, the impact of the carbon emissions associated with the production of one ton of aggregates is about 5 kilograms.

Now, compare this with about 400 kilograms per ton of concrete or per cubic meter of concrete or 800 kilograms of CO_2 emission per ton of cement. So, it is much, much less, but still it is significant enough considering the volumes that we have to work on reducing it. Now, suppose I include upstream processes like extraction of fuels, quarrying and so on, then we have a higher carbon footprint that has to come in when we are looking at the ground to gate system. So, from 5 it goes up to 12, because we are including more processes, we are looking at more what has happened outside the plant. Similarly, the energy consumed for a gate to gate system is about 600 mega joules, in ground to gate system is about 200 mega joules, that is the energy consumed, much less than concrete and cement, that is why we use so much of aggregates to make concrete and cement, because of the lower cost, lower energy requirement and so on.

What we also see is, the transportation affects the values significantly. So, from one plant to the other, depending on what is the distance they are located at from the quarry, the values will change significantly. So, transportation becomes very very important and since it is often something that will vary a lot from plant to plant, when we are comparing plants, it might be useful just to look at what is happening in the crushing plant, when we are looking at the processes that can be improved for the crushing and so on. So, let us see what we have learned from waste crushing plants. We have now the benchmark values that we looked at just now for pristine aggregates.

Now, what we want to know is, if you recycle, are we use emitting more carbon dioxide or less than just taking natural aggregates. We looked at the advantages in terms of landfilling and so on and another major advantage that I have not talked about until now is that of the avoided quarrying that we can do when we are recycling concrete as aggregates. We use up a lot of land, we are using up a lot of raw material when we are quarrying digging holes in the crust of the earth. So, to look at all this, we have to do a proper analysis. Here, I am talking only about the life cycle assessment leading to carbon footprint and the embodied energy, but to look at it holistically, we have to see the avoided burdens of the landfill as well as quarrying to get the true benefits, the complete benefits to the environment of recycling concrete.

So, we looked at different plants, we got data from different plants in India. We got about data from about five plants and I will show you some of the results. We also got some data from South Africa, from CEDEL near Cape Town and I am going to include those values also in the comparison. So, typically similar to what we have seen for pristine aggregates, we have a process flow. So, in the gate to gate system, we will have the waste material coming in loaded onto a hopper or into a bucket with a through a feeder that goes into the primary crusher, then the secondary crusher, a screen and then we have separate stockpiles.

Before the material comes in here, it has to go from the demolition site and get transported to the crushing plant. Obviously, we are avoiding the two major aspects that I discussed, landfilling and quarrying. So, this is the advantage and now when we look at the process flow, we have to look at all the materials which come in to giving us one ton of recycled concrete aggregate at the end. So, our functional unit would be one ton of the recycled concrete aggregates. So, we have to look at all the things that go into giving this to us in terms of the infrastructure, the consumables and the electricity that goes in.

The diesel that is used by the trucks and the moving equipment also have to be considered. So, let me give you some typical numbers for certain centralized recycling plants, this one is in Surat. So, here the waste is all collected from the city transported about 16.5 kilometres by trucks, then the C and D waste is segregated and we can imagine that concrete is somehow separated which will be crushed and recycled. The size is reduced either by crushing or using jackhammers and so on to about 50 centimetres.

This is now loaded on to another crusher. For this, you need some amount of diesel and lubricating oil for the machinery. For the crushing, we have an electricity requirement, some water is also used to control the dust and lubricating oil as a consumable and finally, we get the recycle aggregate. Compare it to other plants, we will find that the process is very very similar. Say for the CEDEL plant in South Africa, again the waste is collected, transported over a certain distance here 23 kilometres, then it reaches the plant, gain size is reduced.

For this, we need some equipment to be used and therefore some fuel for the equipment. Crushing happens, again we have the values here and finally we get the aggregates. Note that the electricity consumption in these two plants, one in India and Surat and the one in South Africa very similar. So, what we find is the crushing itself is very similar between different centralised recycling facility. So, if we, once we have done few and understood which are the exceptions, I will show you one case where the value is very different and we will have to see why that data is different instead of just averaging out the values.

We could also have mobile crushes. So, instead of a plant where, which receives the waste and processes it, the plant could go where the waste is being produced. Suppose you have a large demolition site which is going to later have construction of a new structure or project, then it would be ideal to set up a mobile plant there itself. You take the demolishment's, segregate and crush and provide the aggregates for that, for the new project at the same site. So, there is a plant which we could visit of L&T in Chennai.

So, here you have the mobile crusher which obviously needs fuel and it takes the material from the demolition, breaks it down, the little bit of water is required other than electricity and obviously here we are avoiding the landfill. The advantages as I mentioned, transportation distance is less because you do not have to move all the material, you are taking the crusher near the site itself. All the landfilling problem is not there or even stocking temporarily the material is not there like usually these landfills will charge a gate fee even for temporary usage. Better handling of waste, the movement of waste produces a lot of dust, health hazards for the workers and so on all this is reduced if you take the crusher to where the demolition is happening. No uncertainty in material availability.

The parent concrete decides the properties of the recycled concrete aggregate and here if you are at the demolition site there is no uncertainty. You know where what material was originally used, we can test it and then we can see how to have recycled concrete aggregates which are of a certain quality, consistency in quality. So, some numbers here obviously the distance is 0, we do not have any transportation, major transportation of the demolition waste to the plant because the plant is now brought in and we would get certain values after going through this process, we segregate the waste again reduce the size, crush, sieve and to get the recycled aggregates. So, from these values then we can calculate how much is the carbon footprint and the energy requirement for a ton of aggregates. So, we are here comparing different values.

Suppose I look at emissions per ton in terms of kilograms of CO2, we find that 4 out of the 5 plants in India have very similar results, very similar values in the range of 3 to 5 kg per CO2. So, this if you remember is less than the 5 kgs that I got for pristine aggregates. So, it is less than or similar. In one case, it is much less because this is the mobile crushing unit. The mobile crushing unit we save the transportation part and we save a lot of electricity and diesel in the transportation.

So, the values come out much lesser. In terms of the ground to gate system, the values are more than the gate to gate because we are including upstream processes. So, the values are slightly higher, but still much less than the 12 kilos that I got for the pristine aggregates. So, here in it is in the order of about 4 to 7 kilograms instead of 12. Again, when you have a mobile crushing unit, it is much less. Now, interestingly, the values for the CEDEL plant in South Africa fall very much into this range.

So, this tells us that the process of production of recycled concrete aggregates can be made very systematic. Most plants seem to have the same type of equipment and require the same type of energy and fuel. So, we can now understand, we can even generalize that this would be the range of carbon footprint and embodied energy that we will need for recycling of aggregates. This is the embodied energy. Again, for a gate to gate system and ground to gate system, again, much less than what we had for pristine aggregates and again, the value for CEDEL falls very much within the range that we have for these three plants in India. Obviously, the mobile crushing unit requires much less energy overall. Let us look at only crushing. Only the crushing, if we want to understand how much of carbon footprint and energy is required, we have taken only those values. So, we find that three of the plants had very similar values. One plant, which was the Godrej plant, had much less energy consumption and therefore, lower carbon footprint because they had the material brought to them from projects that were only demolishing concrete.

So, they saved a lot through the segregation at source itself. All the other plants had to segregate, clean up the construction demolition waste before they could process it. In this plant, they could get concrete directly without other contaminants if I can say so. So, the concrete was brought in chunks that did not have to be reduced much in size where only concrete and when they were crushing, they were not too worried about the fractions because they were using it in their own plant and they did not need so many fractions of aggregates. So, you find that the crushing in this case came down much compared to the other C and D waste processing plants.

So, again if we can segregate at source, make sure that only concrete is being used by these plants for making recycled concrete aggregates, the energy decreases significantly. Again, the values in the CEDEL plant, the CEDEL C and D waste processing plant in South Africa is within the range that we have for these three plants in India. Embodied energy, similar story. We have a certain range 20 to 35 mega joules per ton in the gate to gate system, little bit higher in the ground to gate system. The CEDEL values fall within this range and the Godrej values are much lower because of more efficient way of segregating, transporting and processing.

So, this exercise gave us certain values, some ranges of values. We could compare these values with those of pristine aggregates. We are clear that the processing making of recycled concrete aggregates is better in terms of the carbon footprint and the embodied energy than pristine aggregates other than the two major benefits of avoiding landfill and quarrying. If we are just looking at the impacts due to carbon emission and embodied energy, we are still better than using natural aggregates. So, to conclude the recycling of waste concrete has major benefits because we avoid the burden of landfilling and quarrying for new aggregates.

When we look at the carbon footprint and energy demand through life cycle assessment, we find that the values are lower or at the worst similar to the production of pristine aggregates. So, in all indications point that we have to push for recycled concrete aggregates to be used in new concrete rather than pristine aggregates from the environmental point of view. Thank you.