Admixtures And Special Concretes

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Lecture -51

Life cycle assessment of concrete - Part 2

Methodology for sustainability assessment:

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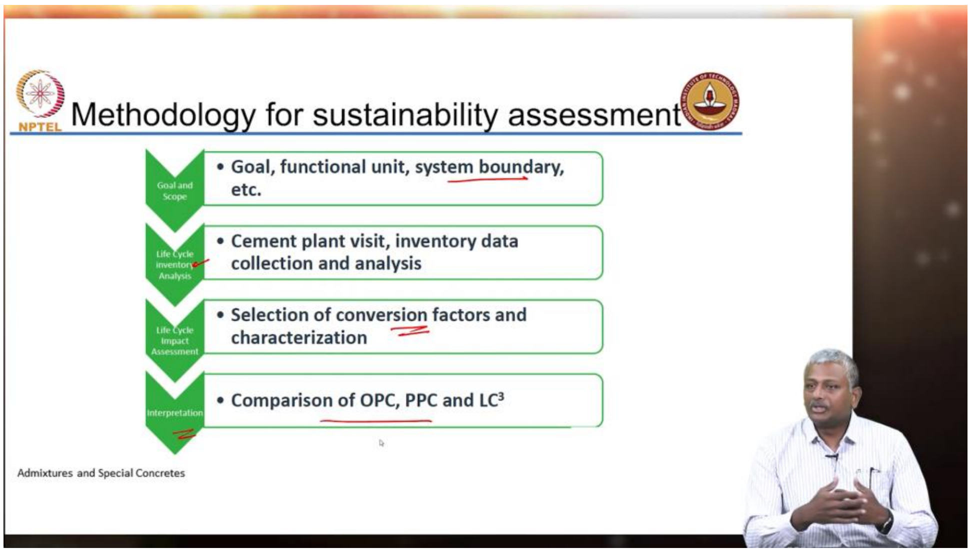

We have been talking about mineral additives and the need to actually quantify the sustainability impact and we were talking about the methodology that can be utilized for sustainability assessment. The first is obviously to define the goal and scope, what is primarily the goal of the sustainability assessment. The unit which describes the kind of assessment that we are performing, for instance, CO_2 reduction per cubic meter of concrete could be one of the aspects we are looking at. System boundary, what are we describing as the range over which we are actually conducting the analysis, are we talking about the production of cement, are we talking about production of concrete, do we consider extraction of raw materials also into the boundary, do we consider the remaining life and reuse of constructed structures also into the life cycle, so you can actually do sustainability impact assessment across a range of different system boundaries. But whenever you do the assessment it is very important to describe very clearly what is the boundary that you are looking at. The second part involves the inventory analysis, trying to get an assessment of what are the values associated with specific processes and technologies that we are adopting.

So this includes possibly visit to cement plants, inventory data collection and analysis, we also then need to figure out what are the conversion factors that lead from that specific data into CO_2. For instance, let us say we are using on a monthly basis certain tons of one type of fuel, but what does it mean with respect to CO_2 and energy, what does 1 kilogram of that fuel contribute in terms of CO_2 and energy, that is the kind of conversion we are looking at. And finally, we do a comparative analysis, in this case the example that I have looked at is a comparative analysis of ordinary Portland cement, Portland pozzolan cement and LC3 or limestone calcined clay cement.

Life cycle of concrete:

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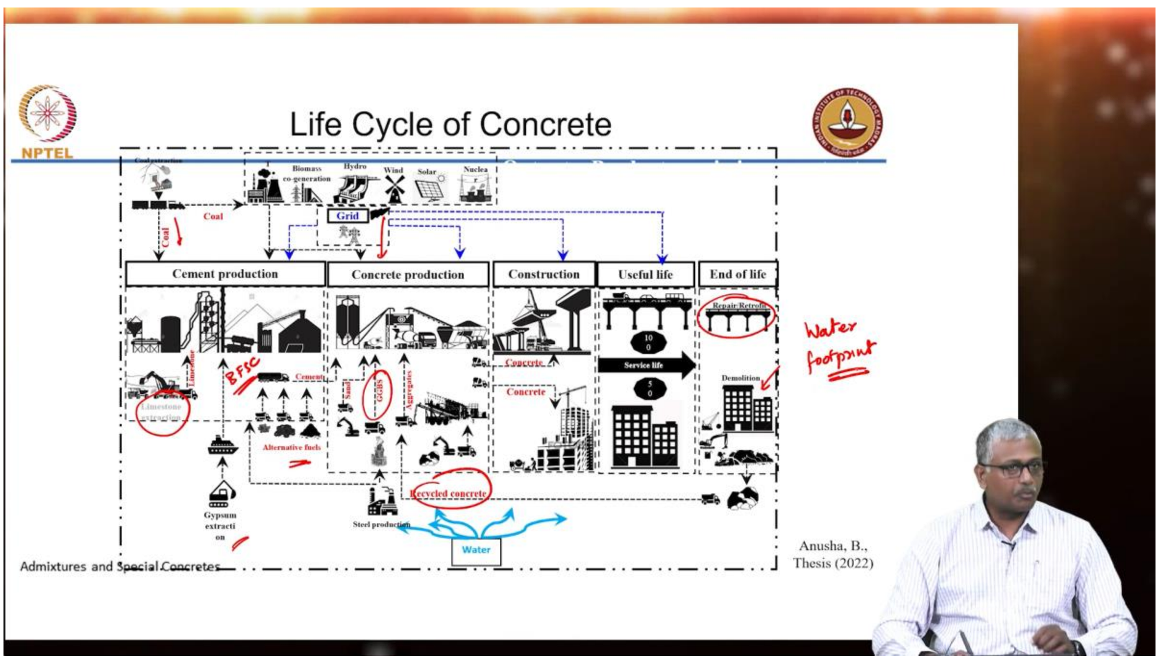

So, let us look now at the life cycle of concrete, much of the work that I am showing here is from the PhD thesis of one of our recent graduates Dr Anusha.

So, here if you look at cement production as a process there are inputs coming in obviously, first, you need coal, coal is obviously needed to fire the calcination in the kiln, rotary kiln process of cement manufacture. You have other processes also of course coal is being brought in from wherever it is getting extracted, so extraction of coal involves some CO_2 and energy, transportation of coal to the cement plant also involves the same. You also have gypsum which is extracted and brought to the cement plant because gypsum is required for functioning as a set controlling material added in the final stages of cement manufacture. There may be some alternative fuels that you may be using also, in the mix of fuels that you put inside the kiln, apart from coal there could be alternative fuels depending on how your fuel mixture is going to be, these materials will be variable and we consider within the cement plant limestone extraction because obviously the cement plant is going to be located right next to the limestone mine. So, limestone mine is considered to be part of the cement plant and all your processes that happen in cement production are within that boundary.

From the cement plant the cement gets shipped to the concrete manufacturing unit or the ready mix concrete plant or batching plant as the case may be. Other materials that are going into the concrete for instance sand, aggregate, your ground granulated slag or other mineral admixtures they are also forming as part of your entire system making up your concrete. Now steel production, why is that coming into the picture here? Because steel is contributing slag, steel production contributes to slag, steel production could also contribute to the slag to make your blast furnace slag cement. In case the cement manufacturing involves the production of blended cement, the slag could be contributed into the cement production also directly by the steel industry. From this you produce the concrete of a given grade and that basically is taken to the site wherever construction is actually happening.

Now after the useful life of the structure, let us say a service life of 50 years or 100 years, there will be a stage where any further repair of the concrete structure may be more expensive than actually demolition and reconstruction. So, that is basically the end of your useful service life. And from then what you could also do is either design a repair and retrofit strategy in case it is economically viable or take up a demolition. When you do demolition you can produce recycled concrete and feed that back into the concrete production. So, now if you really consider the overall life cycle of concrete it has to encompass all of these activities that have been looked at individually.

So, if you have, to let us say keep a system boundary as concrete considering its entire life cycle then it becomes a very complicated process obviously. So, very often we have system boundaries defined either just within the concrete production unit that means you receive all the raw materials into the concrete plant and then churn out concrete. For every cubic meter of concrete that is shipped out of the gate of your concrete production unit, you can then calculate the net CO_2 emission, net energy and so on and so forth. But for that you also want to know what would be the background in terms of the raw materials and the energies involved in their extraction processes. So, all that has to be taken care of.

So, it is a little complicated to really put this together but then you need to have a very good overarching view of the entire process and outline each and every activity that is involved in the process if you really want to do a good job with life cycle assessment. Now, all of these processes also involve the use of electricity.. So, that further complicates your entire process. So the electricity basically could be from coal, fire, thermal power plants, it could be from biomass, from hydro sources, from wind sources, solar, nuclear and so on and so forth. All of that is being fed into the grid and from the grid all of these processes are drawing electricity to complete all the processes.

So, again that is also another component that will actually come in, electrical energy that is required for all of these activities. On the other hand, you also need water. For all of these processes, water is absolutely required to really take up the process. Only thing is water or its use directly does not really involve a CO_2 or an energy footprint. Unless of course, you need to pump water.

So, there will be some energy or CO_2 release associated with transportation or pumping of water. But on the other hand, when you start doing sustainability impact analysis, these days as far as construction is concerned it is also important for us to look at water footprint. We often define sustainability analysis in terms of CO_2 and energy but it is also important for us to start considering water footprint because that is a very important ingredient of your overall life cycle estimation. Because increasingly we have shortage in good quality water and the more optimal utilization the better for the construction project

System boundaries- Processes considered:

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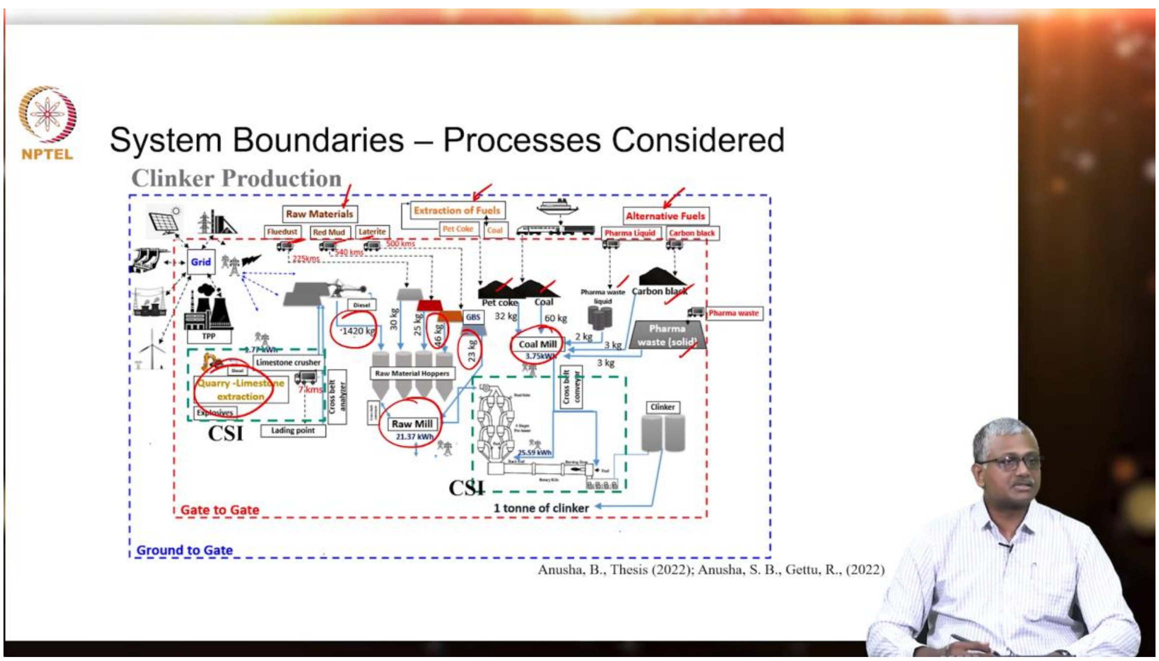

So, again system boundaries have to be defined properly. For instance, if you are talking just about clinker production as the process then you can define let us say a ground-to-gate system or a gate-to-gate system. Now, gate simply means the gate of the cement production plant. Ground to gate implies something that involves the extraction of the raw materials also in addition to the processes that take place within the cement plant. So, let us look at all these processes that are taking place here. So, here the raw materials are getting extracted this is outside the gate of the cement plant.

There are fuels that are getting extracted which are then getting supplied to the cement plant to actually produce the cement clinker in the kiln. Alternative fuels are also getting extracted or obtained from other sources and coming into the cement plant. So, here all of these are basically fuels your pet coke, coal, farmer waste liquid, carbon black, farmer waste solid all of these are basically your alternative fuels that are coming in. So, entire fuel mixture then goes in the coal mill and has to get ground to a size which is easy to fire. You do not work with coarse materials this is actually needs to be milled down to a size which is easy to fire.

On the other side, you have the raw materials which are contributing all of your cementing materials for instance the limestone extraction that actually happens in the quarry. From the limestone crusher, you are actually getting the limestone and storing it in individual silos. You may require different quantities of other materials to make up your necessary composition in terms of aluminium oxide, iron oxide and so on and so forth. Then you have a raw mill which basically grinds the material into a size which is small enough to produce your material which can be blended together and fired in the cement kiln. So, again the details of each and every process that are actually undertaken need to come in along with the quantities of these materials in order to do a comprehensive analysis of the CO_2 and energy impact.

LCA of cement- goal and scope:

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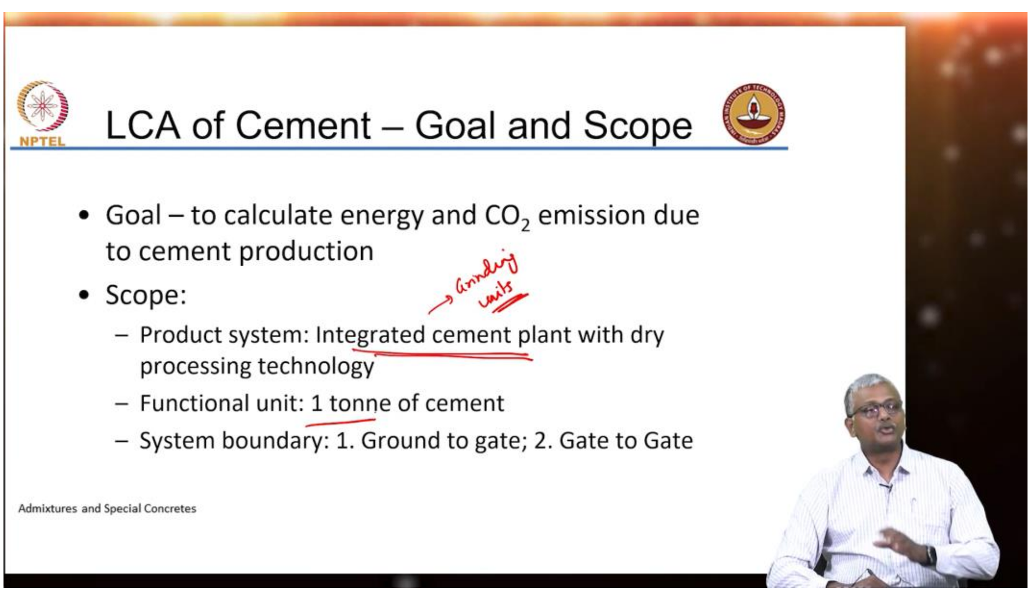

Now in this case for the example that I have chosen here we are trying to do a life cycle assessment of cement. The goal is to calculate energy and CO_2 emission due to cement production. So, it is defined in such simple terms just to calculate the CO_2 and energy emission due to cement production. The scope, the product system is an integrated cement plant which has a dry processing technology. What is a dry process plant? In the old days, people were using wet process plants.

Wet process plants were used to blend the raw materials together in a much more uniform fashion. Today we do not do that. We have raw materials which are essentially having less moisture content. Then we send them together into a pre-calciner or a pre-heater and then from there the material goes in the kiln. In the wet process plant before the pre-calciner or pre-heater process or before the kiln process there is actually a blending of the materials that happens in the wet state.

So, lot of waters involved in the process but these plants are not really existing in large numbers nowadays. Most plants today are integrated cement plants with dry processing technology. You have to distinguish the integrated cement plant from other plants which are also known as grinding units. Apart from integrated cement plants which are located next to limestone sources, it may be worthwhile for cement companies to set up grinding units in several locations where they ship all the materials which are required to produce the cement including clinker, fly ash, limestone etc. And then all you have to do in the grinding unit is simply grind everything together and produce as a Portland cement or a Portland pozzolan cement or a Portland slag cement as the case may be.

That is called a grinding unit. When the cement plant has limestone extraction and limestone processing, the kiln burning and everything then it is called an ICC or ICP or integrated cement plant. The functional unit across which we are calculating the CO_2 emissions and energy emissions is 1 ton of cement. So, to produce 1 ton of cement so much CO_2 is evolved, so much energy is required. And system boundary is defined here in two ways, one is ground-to-gate, the other is gate-to-gate.

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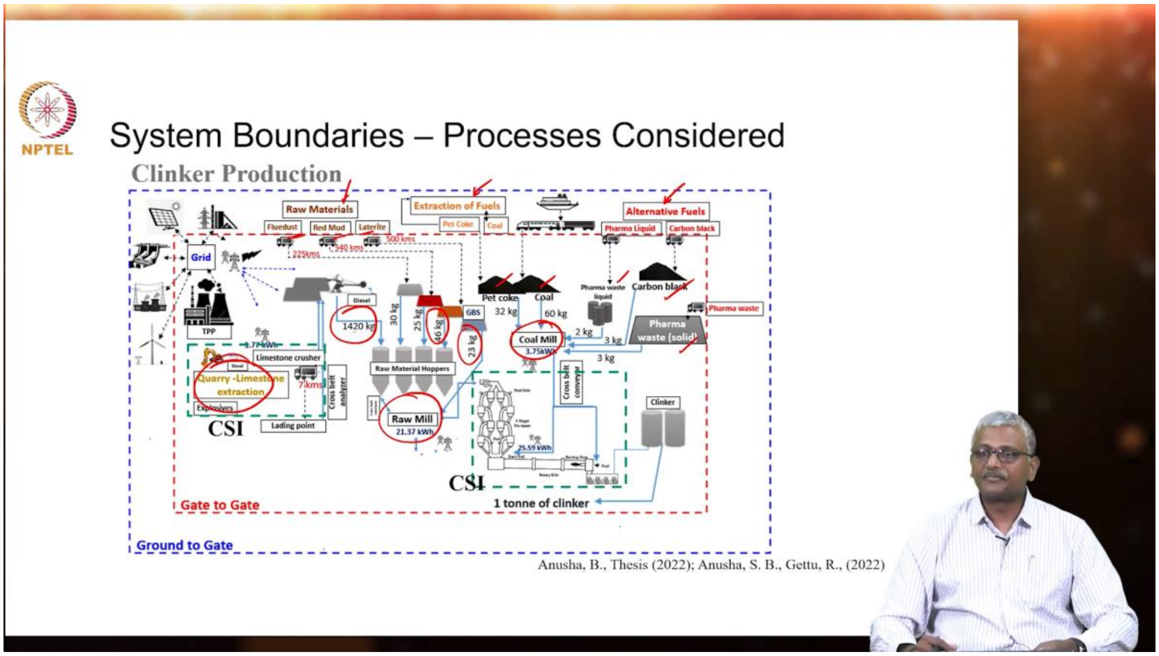

Again, coming back here, ground to gate also involves extraction of fuels and raw materials. Gate to gate simply means that these are already inside the system, now can you define a CO_2 and other sustainability impacts.

Process map- OPC:

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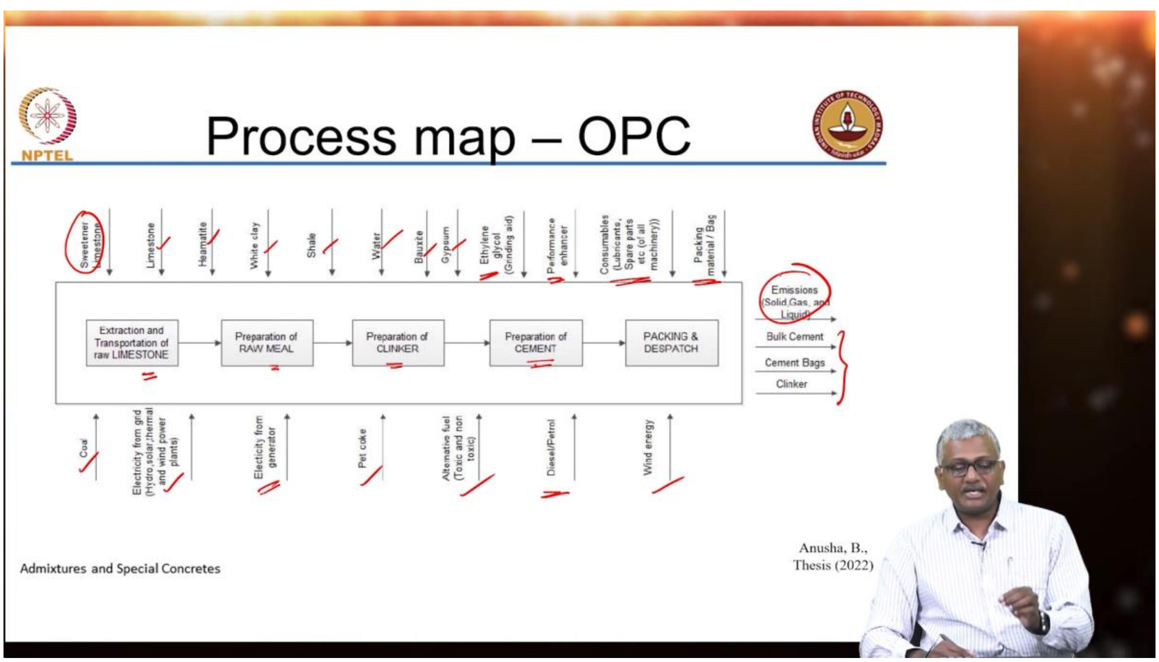

So, let us consider the process map in the case of a plain cement that is ordinary Portland cement. So, we have various raw materials that are coming into the process, we have limestone, sometimes they use a very high purity limestone called sweetener limestone, high purity calcium carbonate. Just in case the limestone available in the quarry is of an impure kind, they have to mix it with a very pure calcium carbonate which is also called sweetener to ensure that their mix has the right level of calcium oxide content.

Hematite which is iron source, clay, shale, these are silica sources, some water may be coming into the process also required for cooling and other systems and so on. Bauxite, gypsum, these are also raw materials that are coming in. Sometimes you may also be using what are known as grinding aids in your process. Grinding aids are basically used in the final ball milling process, final grinding process because they help in actually achieving fineness at lesser energy. They also have additional properties, we have not discussed that grinding aids are also increasingly important today as construction chemical additives, but we have not discussed that in big detail, but yes grinding aids are regularly used these days in cement plants.

Performance enhancer like limestone or fly ash and then your consumables in terms of lubricants, spare parts and so on. Then your packing material, the material like bags, liners and so on which are required to do the packing of the cement. On the other hand, you have coal and electricity that is coming into the process, electricity that is probably from diesel generator also, then you have alternative fuels petcoke, all kinds of alternative fuel, you may have diesel and petrol, maybe wind energy also, all of these are basically the fuels. So, raw materials on one hand, fuels on the other hand and then you have different processes. One is the extraction and transportation of limestone, that is the first process obviously.

Preparation of raw meal, before the clinker process all the ingredients are blended together to make what we call as the raw meal and this raw meal basically goes into the kiln and comes out as clinker. So, the clinker then is processed as a cement by inter grinding with your gypsum, performance improver like limestone or fly ash and so on and then it is extracted as a cement and packed and dispatched. Now what you have is a dispatch can happen as a bulk cement in bulkers, you would have seen some of these bulkers which go to rare mix concrete plants, then you have cement bags of 50 kilograms and sometimes a clinker also may be getting shipped out of your plant to go to a grinding unit where it is then produce a cement. Then of course you have emissions which are coming out from this entire process, the solids, gas and liquid.

So this is the entire process map. So it is very important to do this because then you go to each and every element of this process and look at closely the inputs required to do your life cycle analysis. How do you calculate this CO_2 impact? By looking at each and every component in this process.

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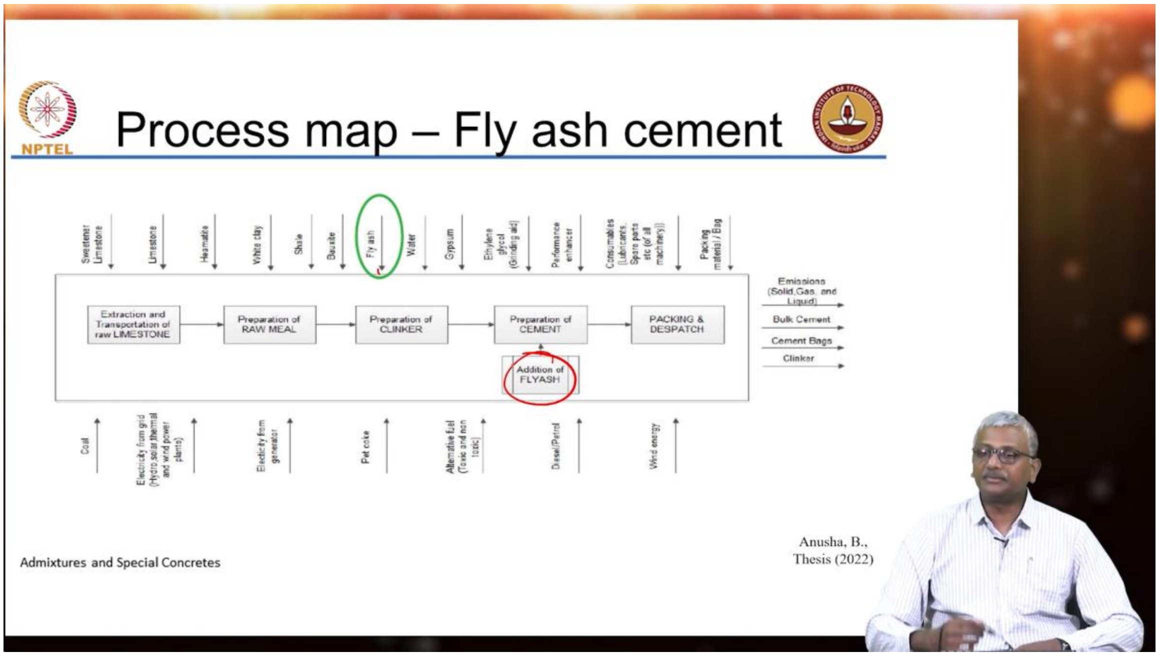

Now when you do fly ash cement, more or less everything is the same except that you have now fly ash also as a raw material and then you have addition of fly ash happening during the final ball milling stage. All the other things are just the same except that you have fly ash as a raw material so it will also bring in with it some internal sustainability impact and your process of grinding is going to change because fly ash is being added into the system.

All the other processes are the same. So once you do an estimation of the other things, all you need to do is plug in this extra which comes in because of fly ash. The only place where you will have some differences will be the final grinding process where the energies and emissions may be a little bit different as compared to what you have with OPC clinker.

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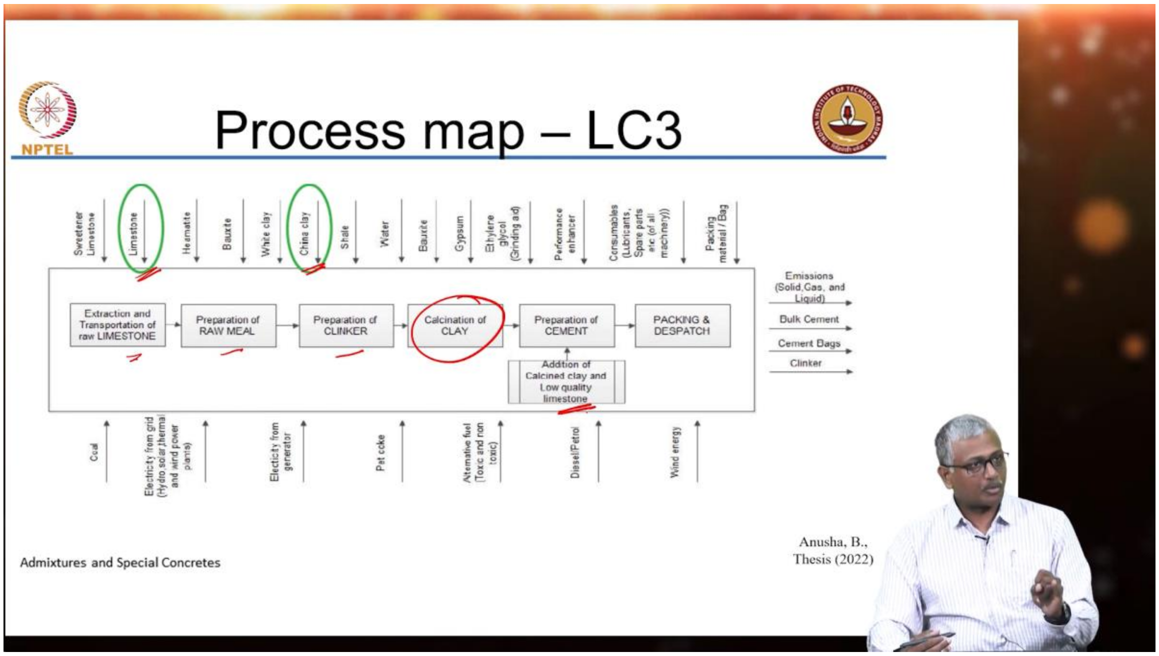

In LC3 you have instead of fly ash being one ingredient now you have two other ingredients, one extra limestone and extra calcium clay. So, here extra processes are involved, again limestone extraction and transportation fine. Then you have preparation of raw meal, then you have preparation of clinker, then you also have to include the calcination of clay.

Calcination of clay is an extra process. So that is going to contribute a little bit additional CO_2 and energy into your system. And then you have this process where again you are seeing a change, your addition of calcium clay. You can make do with low-quality limestone but addition of calcium clay and limestone in the final process of cement manufacture by inter-grinding with the clinker. And then you are packing and dispatch, everything else is just the same.

Alternative fuels are the same but raw materials are different and one extra process has been introduced. So, when you go to a cement plant where possibly all these three types of cement are getting produced, the only variable that you will see is because of the addition of the additional raw materials and the process especially in the case of LC3 is the calcination of clay and your final process of cement inter-grinding, that is where the numbers will change when you change the blend that is going in for final cement manufacture.

Sustainability Assessment:

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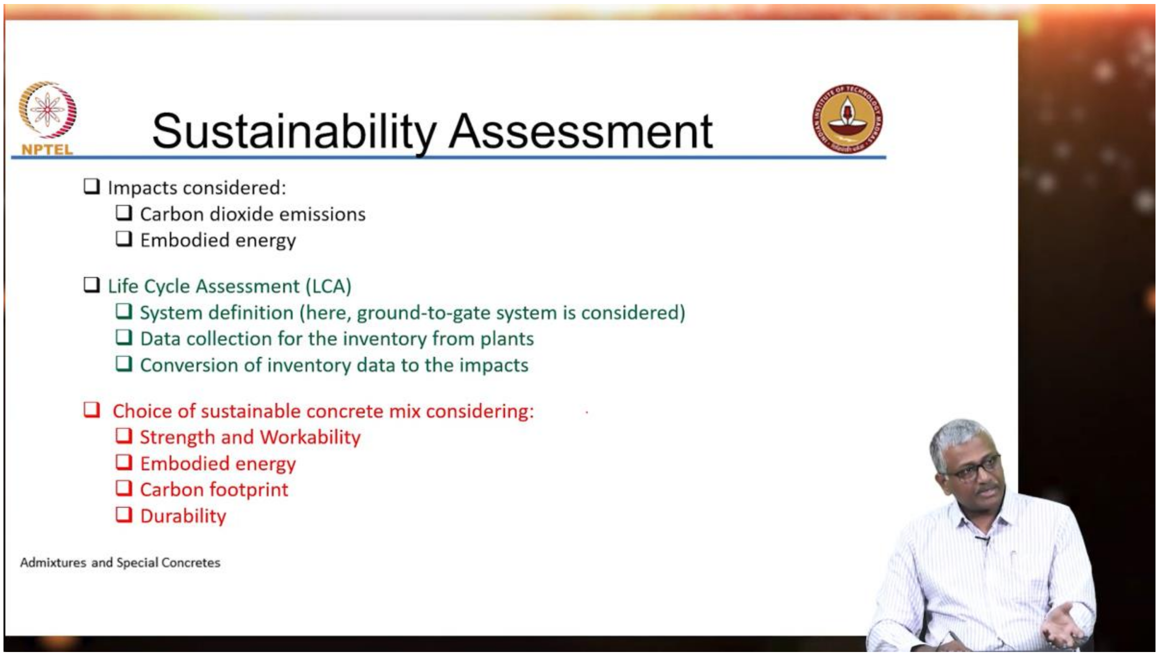

So, now let us do a sustainability assessment with this. The impacts that are considered are CO_2 emissions and embodied energy just like we defined in the goal that was set out in the beginning. So, you need to define obviously the system boundary and in this analysis ground-to-gate system is being considered that means extraction of materials also is required.

Gate implies the exit of the cement from the gate of the cement plant. It does not involve the transportation of cement to concrete plant and so on. Data collection for the inventory has been actually done from plants. The conversion of elementary data to the impacts was done by additional laboratory studies. Now, in the second step, we will also look at how we can do an analysis for the concrete which has been prepared with the help of these cements where we consider not just the strength and workability of the concrete as well as the embodied energy and carbon footprint but we try and normalize that with respect to the durability of the concrete that is achieved.

So that is the last part that we will see in this lecture.