Sustainable Materials and Green Buildings
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Lecture 07 - Calculation of ecological footprint

Hello, so welcome to lecture four. Now, if you recollect in the last class so we were talking about, lastly we were talking about embedded energy and talking about, before that we talked about (eco), yeah, that is the energy we talked about but right in the beginning we talked about eco footprint. And I said that we will look into the calculation sometime, so let us look at today first the calculation part of it, then again we will go back to the material, right? And we said it is cement which is the major contributor to greenhouse gas emission after fossil fuel.

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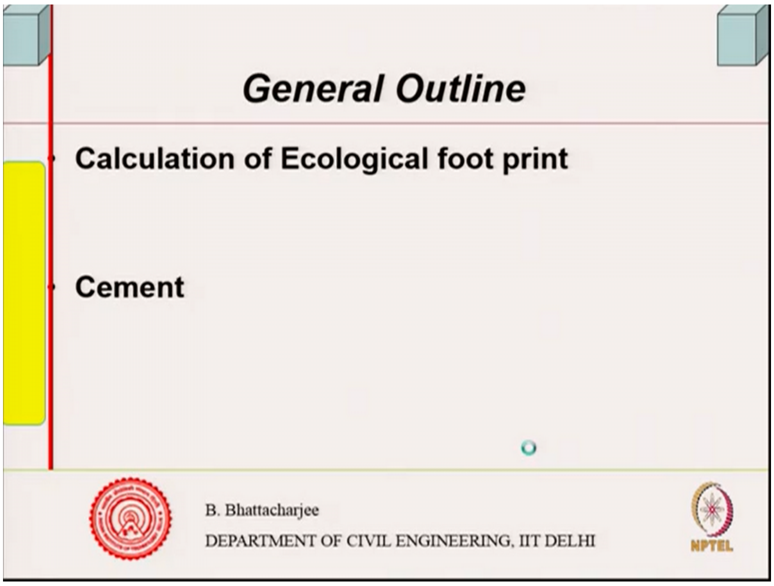

So we will start with cement, right? So this is what we will discuss today: Calculation of Ecological footprint, how do they do that? And cement.

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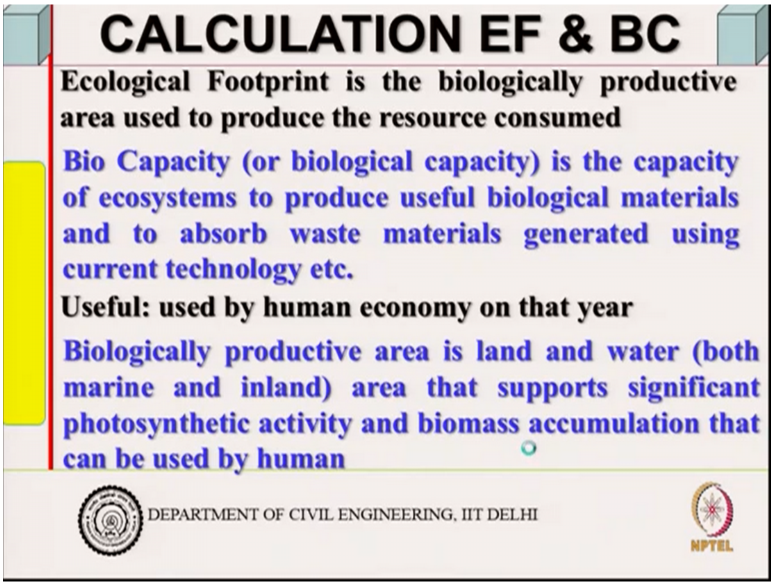

Because if you remember it is done for it can be done for individual but to a nation or for the whole world. So essentially basically, it is a biologically productive area used for produce, used to produce the resources consumed total, that is what we defined it earlier, I am just giving brief again. And we defined something like bio-capacity, recollect that we talked about bio-capacity as well or biological capacity which is the capacity of ecosystem to produce useful biological material and to absorb waste material generated using current technology, right? And this ratio gives you basically this ratio gives you I mean how many planet equivalent you are using, you know number of, if you collect we talked about that sometime earlier.

So, bio-capacity is something, ecological foot print is the other thing, this is what ecological footprint, footprint of all the activities that you do and bio-capacity is what is available. So, remember that we said that you might require three planets, right? In 2050 if you go in the same manner as you are consuming. So, this is you know this is for, this is based on basically bio-capacity for useful using current technology etcetera, used for human economy of given year. If you recollect it was given year also because it will change from year to year.

You know both bio-capacity or technology will change and I gave example of Malthus you know population, agricultural food generation is in I said it was in AP series, population growth in GP series but then he thought that the society is not sustainable but the food production went not in AP series it improved much better because of agriculture you know technological change and all. So, also new land might have been brought into agricultural fold and so on.

So, biologically productive area is essentially the land and water both marine and inland that supports significant photosynthetic activity, remember I said that it is plants which capture the carbon, right? Takes the carbon dioxide form the atmosphere, convert them into carbon which is a courier of energy. So, it is mainly the plant, therefore those area where photosynthetic activity goes on, right? Which supports significant photosynthetic activity and can cause biomass accumulation, carbon you know it captures the carbon, so therefore creates a biomass, it accumulates biomass that can be used by human being.

I mean obviously we are talking mostly because we said that in this calculation we are not even thinking about the wild life and such things. Whatever is captured even if we can human being consumes all, you know that is what we are looking for. Basically, biomass area which can accumulate biomass that is what is the biologically productive area, biologically productive area. So there is an equivalence of everything.

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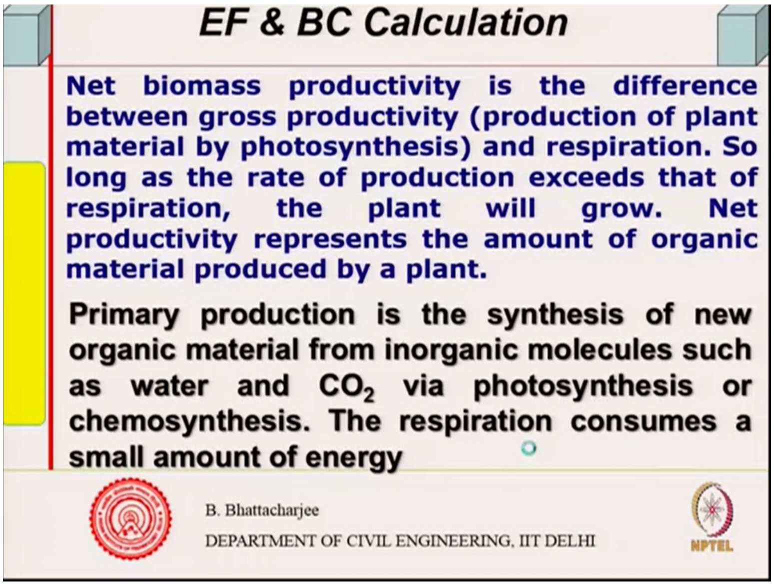

So, net biomass productivity is the difference between gross productivity, that is production of plant material by photosynthesis but then some of the energy is used up by the plant itself, right? Some of the carbon dioxide is released by the plant itself, alright? Because of its respiration process. So net is the difference between the two. So long as the capture or the carbon dioxide it you know captures through photosynthesis is more than that is lost by respiration, plant will survive, right? Plant will grow. So net productivity is a difference between the difference between the two.

And primary production is the synthesis of new organic material, that is what it does, from inorganic molecule such as water and carbon dioxide, that is what it uses, the plant uses or chemosynthesis. You know photosynthesis or chemosynthesis, respiration consumes a small amount of energy. So therefore the area which is bio-productive that we can identify, right? And that is what goes in calculation.

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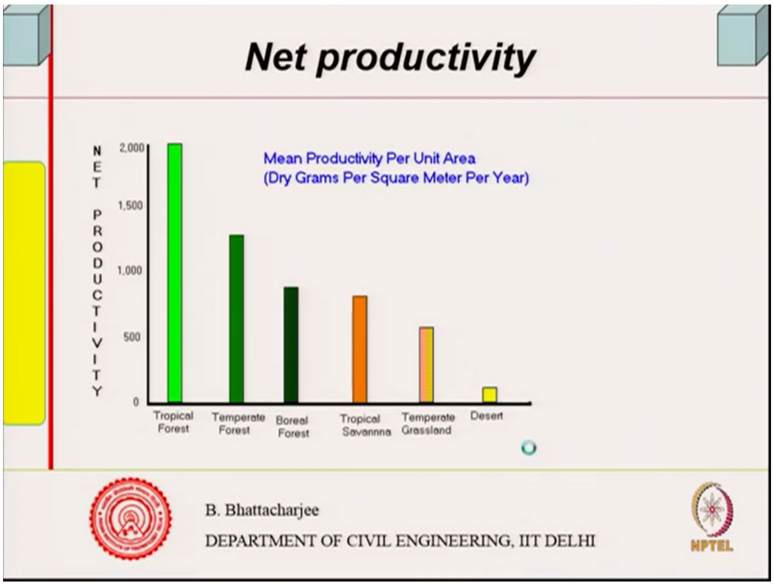

So, that is what for example net productivity if one looks at, tropical forest that has got very high value relative to let us say desert, let us say a desert, temperate grassland, tropicalsavanna, temperate forest, boreal forest et cetera, et cetera. So different types of forest and such lands can actually their net productivity we know and they are essentially the biological product. Other things are converted into equivalent of that. All other things are converted into equivalent to that, right?

So, mean productivity per unit area that is what this is given in dry grams per square meter per year. This one is given in you know dry grams of the biological material that is carbon, biological material that is you know carbon that is what is given, grams per square meter so biomass generated per meter square per year. So that is one example.

Both terms we are going to define, one is called equivalent factor and these values which I will give you, some data I will give you, this is form 2003. I gave you some data of 2008. So, this is various agencies actually, they do these statistical calculations and like United Nations agency, various agencies they do this and obviously individual researchers also do.

For example, I could lay hand on papers from China, some from England and so on. So they did for their, you know and I am sure there must something available if not research article or something must be available on the Indian data too. Because you can get the data but somebody has to may have to analyse. So there is something defined as equivalent factor.

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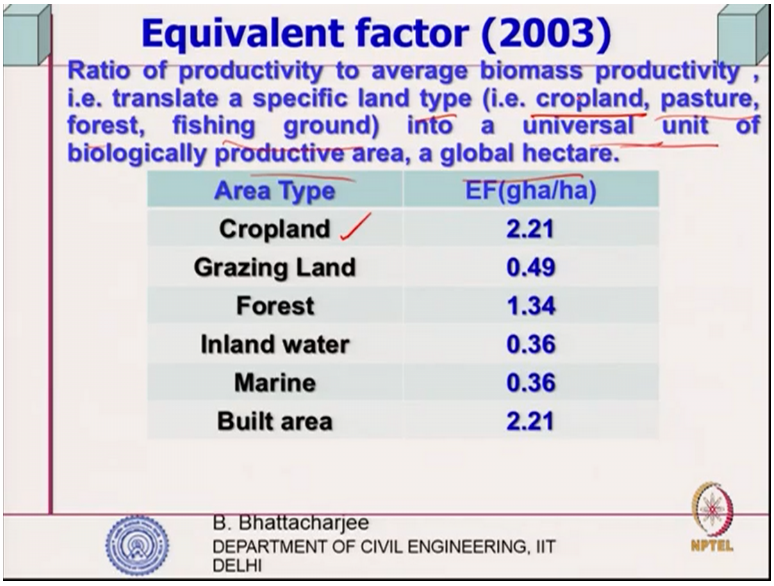

Now what is equivalent factor? It is a ratio of productivity to you know ratio of productivity to average biomass, ratio of productivity to average biomass productivity, that is translate the specific land type. So it considers five type of land. When you look at the bio-capacity we consider five type of land. What are those? Cropland, pasture, forest, fishing ground, these are the four but there are for example this will have marine and inland water. So, we will break this into five and this is you know, this ratio gives you, this ratio gives you universal unit of biologically productive area in terms of global hectare.

Ok, so it is productivity of a particular land or particular type of land area divided by average productivity of all types of landmass, for all type of landmass. For example, if it is a cropland, this area type, right?

If I divide for all the land area, find out the productivity of biomass, productivity of all the types of land area, divide by the area then I get average productivity per unit area, average productivity per area and now I take productivity of cropland alone.

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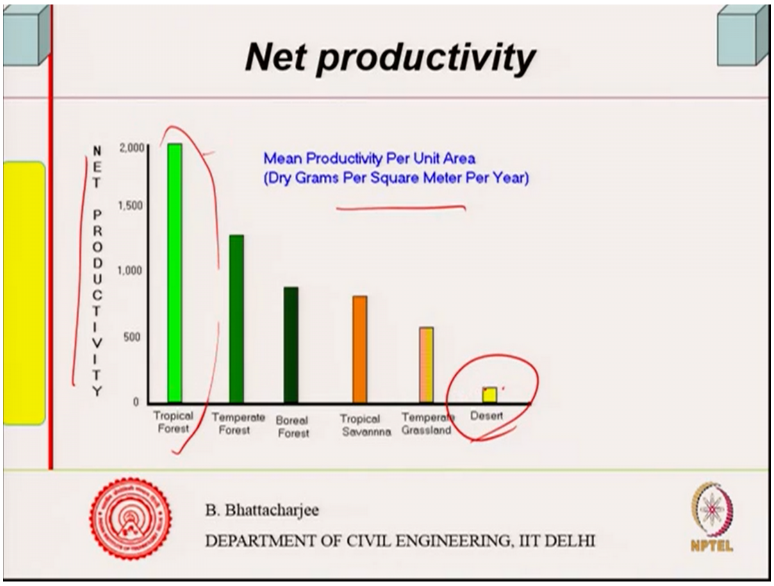

Because we have seen the productivity varies with the type of type of land. For example, there is in tropical forest, this is somewhere in desert, so its productivity is in terms of grams per square meter per year is much higher, biomass productivity compared to desert which is very less, right? It is of the order of 2000 where this might be of the order of around less than100. So, biomass productivity of the land varies. Now I want to convert them into a relative factor and that relative factor is equivalent factor that relative factor is equivalent factor.

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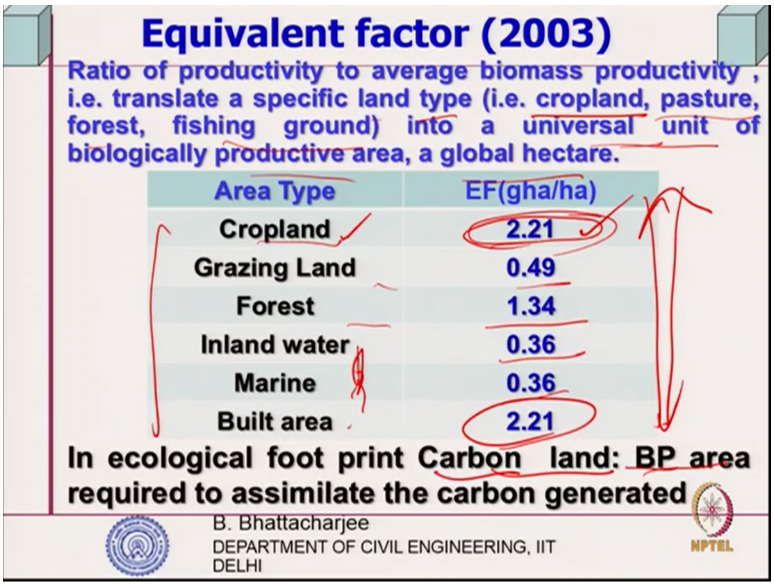

So, equivalent factor is the productivity to average biomass productivity, biomass productivity to of that particular type of land to average biomass productivity of all types of lands that we have, right? So, this all specific land type it converts into a number, some factor. For example, then if I know how much cropland I have in the country, how much desert I have in the country, I will multiply by that factor to get the you know weighted area.

So, cropland et cetera, et cetera, so this is how it is. So, a crop plant is 2.21 global hectare per hectare of overall, because average it was you know it is the ratio, biomass productivity, so global hectare per hectare.

So one hectare average corresponding to for cropland it will be 2.21. 2.21 times of the average one hectare productivity. Grazing land: 0.49, forest: 1.34, inland water; 0.36 because you know that aquaculture, fish and also, I mean basically biomass we are looking at. So as far as the algae and such thing whatever grows there, this is what we look into. So marine, same and built area taken is also same as this.

An assumption is made here that built area would have been constructed on cropland you know that kind of fertile cropland only. Civilization, why? Civilization grew you know civilization grew mostly in the near the river, fertile land et cetera, et cetera. So it is thought that it is the crop land which was converted into built area, so built area is given the same. So, as far as this is the equivalent factor, right?

Now this equivalent factor of course are only for five types of land, 5-6 types of land. This is what is taken into account. I mean these two are together but they are divided into two parts, they are also similar. So this used in calculating bio capacity, bio-capacity of a country or the urban area or whatever you consider, some area bio-capacity, obviously urban area this will be maximum.

So, bio–capacity, we calculate it for bio-capacity for you know any area, country or a globe as a whole. While ecological footprint is, what we are consuming? Bio-capacity and ecological footprint. So ecological footprint takes into another type of land into account which is called carbon land, carbon land right? Now carbon land means this gives you the actually the bio-productive area required to capture all the carbon dioxide that is produced, right?

All the carbon dioxide that is produced that is what is a carbon land because carbon dioxide is generated, that would be captured or assimilated by the plants, so you need some bio-productive area. So, one can calculate out because you know on an average basis of course this I am just giving you introduction, this could be a very several things are not done. If you want to do actual calculation for a given country, several things are also to be done because you are importing, exporting, tourism; these are some details and there are more complicacy involved.

So, I am giving just an introduction because it is not a course exactly on ecological footprint alone but this introduction is important because to understand that carbon issue is absolutely important. So, you can see that ecological footprint involves carbon land. If you are generating carbon dioxide how much land because there is a natural cycle, beyond that there can be imbalance of carbon dioxide which I talked about sometime earlier, right?

So, how much land do you require biologically productive land which can, which can be used you know which can be useful for photosynthesis to capture all the carbon? So carbon land required for this area geographical or political geographical area nation et cetera, et cetera you can find out. So, biological productive area required to assimilate the carbon dioxide, general carbon generated, so that is what it is.

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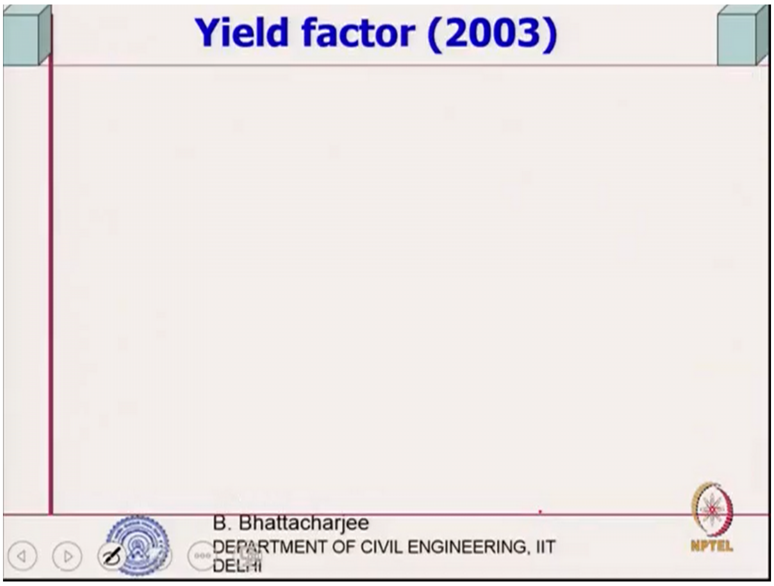

Then we define something called yield factor. So we define something called equivalent factor, we define yield factor now, what is yield factor?

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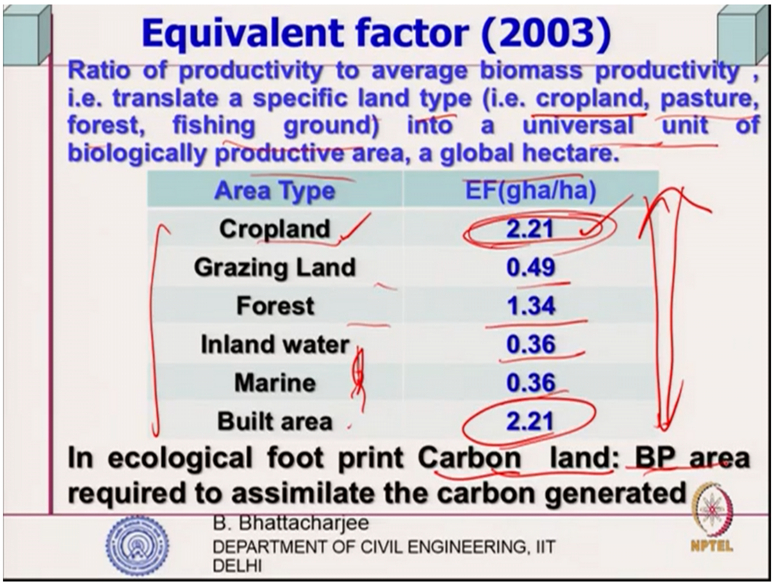

Not you know, not all the lands have, all the cropland do not have the same kind of, same value, 2.21 was an average for the whole globe, but some country's cropland may produce somewhat less compared to another country or some country's you know grazing land might produce more compared to other country. So, yield factor takes account of that sort of situation.

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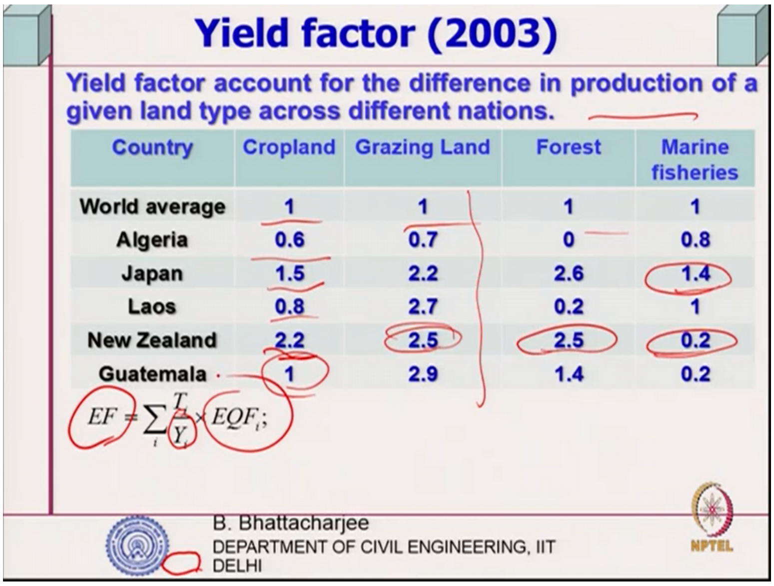

So yield factor account for different production of given land type across different nations, across different nations, right? For example, same type of land in two different parts of the world might be more productive or less productive. Relative productivity of two different same type of land in two different countries might be different and this is taken care of through yield factor.

So, for example this is what is the, excuse me, yield factor for certain countries. Obviously, how it is defined? World average is taken as 1 for everything, right? Word average is taken as 1, for cropland world average is 1. Some country will have 0.6, that means for the same area it produces only 60 percent, you know it is 0.6 times of the yield for the same area or per hectare production biologically or production of biomass is 0.6.

It would depend upon climatic condition, also technological scenario as well depending upon all. So for example Japan is 1.5; Laos, I did not have the Indian data available. New Zealand, they have 2.2 and Guatemala is 1, so it is close to 1. And if you see the grazing land you know New Zealand is 2.5 because they produce milk and maybe Switzerland if you look, all your chocolates come from there. So, grazing land, their milk production is very, very high milk.

So grazing land, they utilize it and the productivity is higher. Forest, the forest also this is what they utilize but the marine and fisheries they are very low, whereas Japan is relatively high, 1.4. So country-wise then yield factor is related to country-wise situation. So based on that one can calculate, right? So the equation would be something like this: eco footprint would be this is yield and this is equivalent factor, right?

This is a total amount of ith type of product that you are considering. Now difference is when you are finding bio-capacity you would not take the carbon land. Bio-capacity you would not take the carbon land. In eco footprint you will take the consumption, bio-capacity you know the land area and find out the total bio-capacity available, right? Eco footprint you will also take the carbon land area and you also take the consumption, right?

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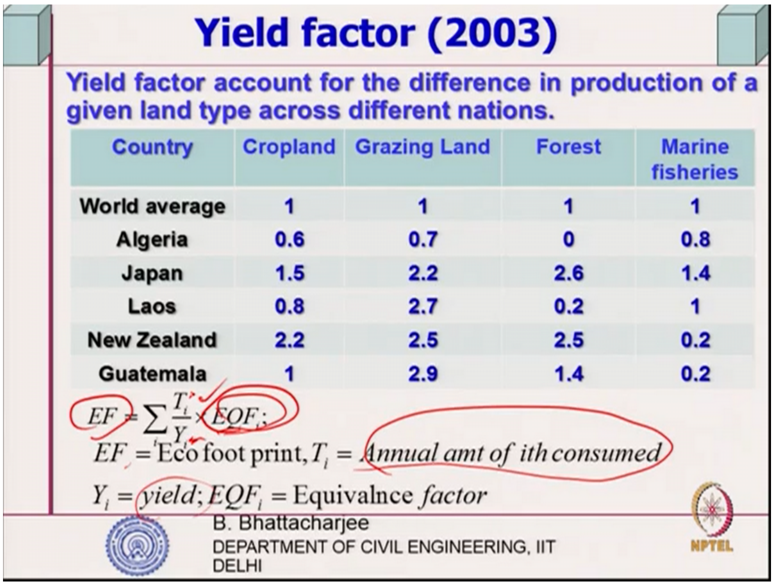

So T i is the consumption, eco footprint, EF is the eco footprint, TF is the annual amount of ith product consumed, right? Y i is a yield factor because for the country we will have a break, so we will have break sometime, then we will go into bigger discussions, right? No problem. Yield factor is one for the world. Ecological footprint should be lower, is not it? Ecological footprint I am not talking about capacity I am talking about the ecological footprint. If I have a higher yield that means my land is more productive, eco footprint is less, that is why it is divided, multiplied by equivalent factor.

What is equivalent factor? Because of type of land I will take it, production of a given type of product in a type of land I mean corresponding to those type of land how much I am producing annually? As I said that I might import something, export something. There are more complicacy involved, this I have not taken into account. I mean they are bigger, the mathematical treatments, algebraic treatments are much elaborate. I am just trying to give you simple examples or simplest situation.

So T i divided by Y i into equivalent factor, sum up for all the things, right? So that will give you the ecological footprint, it is the consumption that I am looking at. Annual amount of ith consumed ith product consumed from a given type of land and summing that for all because there are 200 types of products that is being, lot more, large number of products that has been there. So it becomes more elaborate, I am just trying to show you the simplest of the formula. So, that is how one calculate out the eco footprint, right?

So, what all you got to know is for example you got to know the yield factor for the given country and equivalent factor for given type of land, product, land and so on. So therefore it is taken, so this is what, equivalence factor that is what we had, equivalence factor that is what we had earlier. So, this, this is what we talk of.

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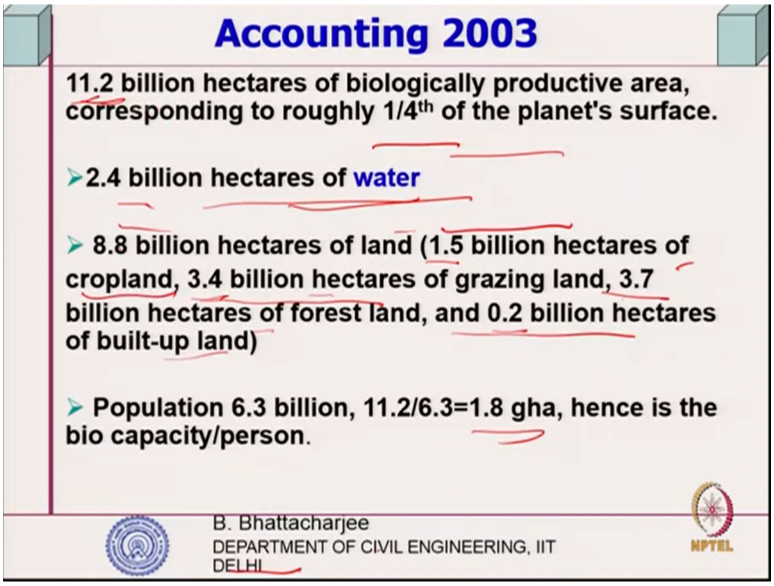

Now if we take example of 2003, that was available. There are 11.2 billion hectares of biologically productive area in the world, corresponding to roughly about one-fourth of the planet surface, we know that three-fourth is see marine environment and all that.

Actually out of which 2.4 billion hectares of water, useful water was there and 3.4 billion hectares of grazing land, 3.7 billion of, 8.8 billion hectares of land in the you know that 11.2, 2.4 billion hectares of water inland water, 8.8 billion hectares of land which involves 1.5 billion hectares of cropland, 3.4 billion hectares of grazing land, 3.7 billion hectares of forest and 2 billion hectares of built up land. So, you can sum this up, 8.8 plus 2.4 makes it 11.2, right? And 1.5 plus 3.4 plus 3.7 plus 0.2 make it up to 8.8 because this is 7.1, 7.3 plus 1.5, 8.8, so this is what, right?

Population of the world was 6.3 million I mean billion at that point of time, therefore 11.2 divided by total biologically productive area is 11.2, population is 6.3, so this ratio is 1.8 global hectare is the capacity per person, right? Capacity per person and this capacity is fixed, this capacity is fixed. As opposed to that the eco footprint would be different, that depends upon consumption. So you know this is biologically productive, productive area was this much, right? Per person was available was this.

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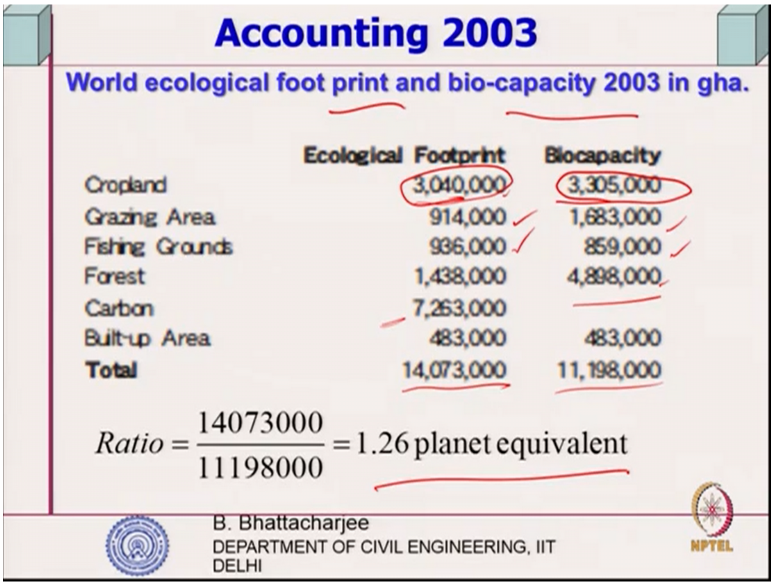

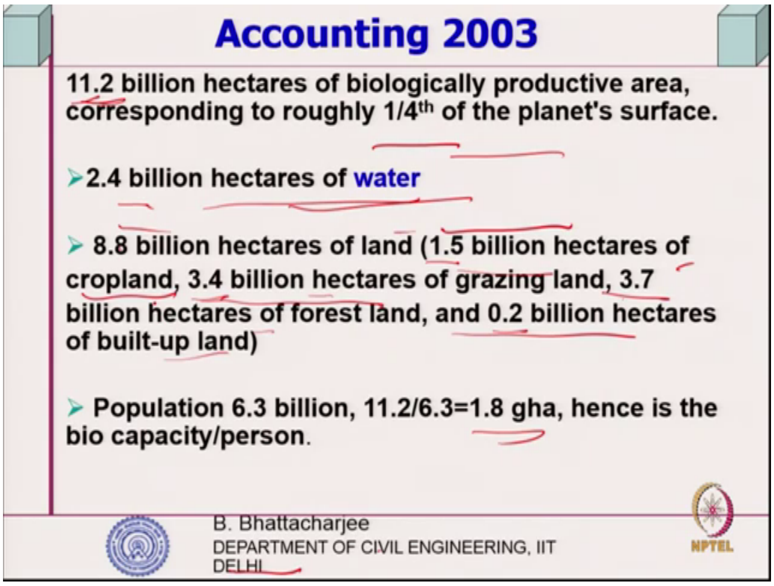

So if you look at world ecological footprint and bio-capacity in 2003 in giga hectare, we had cropland which was, how much was the crop land? (1.) billion hectares. 5 billion hectares of cropland multiplied by the equivalent factor, right?

Because how much compared to the average, that is, so this you will get from the bio-capacity, ecological footprint of whatever you have consumed, how much cropland? You know from that you can actually find out consumed divided by yield et cetera, et cetera for all. So, this grazing area was this much and as far as footprint is concerned this much. Carbon, of course it is not there, it is only here and sum total comes out to be fourteen zero et cetera, et cetera. I mean more or less because some rounding is there, so it comes out to be this and ratio therefore is 1.26 planet equivalent.

So, I just showed you a graph, I am just showing the simple way to calculate this. If you want details, there of course literature available, lot of literature available on this aspect. So this is how they actually arrived at different planet equivalent I was talking about, that we are spending around 1.5 planet equivalent in 2010 and the rate it goes out 2050 it will become three planet equivalents, alright?

So, that is what it is. So that is how we do the accounting, that is how we do the accounting, right? That is how, that is how we do the accounting. So after that now having looked at that, we can now look into materials back again. So, I just want to show you an example calculation because I told you the theory idea earlier but the example calculation I just wanted to bring in.

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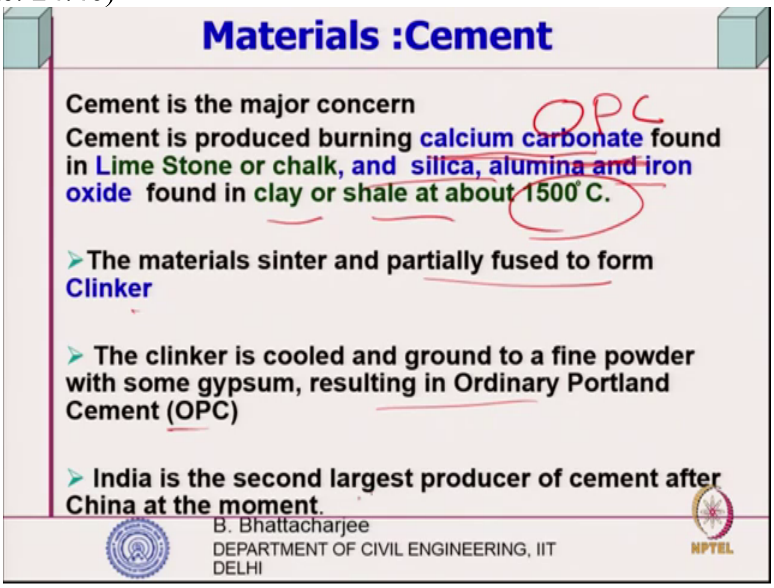

So now the materials, first of all because we said that embedded energy, operational energy all this we have discussed in the last class and we said the carbon issue is important, life cycle issue is important, that is what we look into. And, now further we understand why carbon issue is important because more carbon you generate, you know you need more bio-capacity to absorb it which is not there. So if you want to live within the means of the planet and make it sustainable, you know we have also defined sustainability earlier, then you need to you need to look into these carbon aspects. Cements, obviously carbon aspect is one of the more important thing.

And because we are looking at those material, so cement produced, cement of course is main, then we look into other materials like machinery unit, bricks, clay bricks particularly, this is a serious problem. So, several, we look into other materials and obviously as we shall see today the cement is not the same cement what we understand let say about 50 or 60 years back because today there are n number of cements, not one, n number of combinations of cements, right?

So therefore you have the options of handling in a right manner as you wish. So, ordinary Portland cement when I am talking about this I am talking of ordinary Portland cement, you know it is produced by burning calcium carbonate and then with clay found in clay or shale nearly about 1500 degree Centigrade. Materials sinter and partially fused to form, what you know clinker.

So some other course also we talked about this and this clinker is cooled and ground to a fine powder with some gypsum resulting in ordinary Portland cement. This you know, so you can see right form here itself, there are two things you are doing. You are calcinating this as we called it calcination and you know which will require some temperature, then you are fusing them to form this, right? So of course this I have mentioned earlier.

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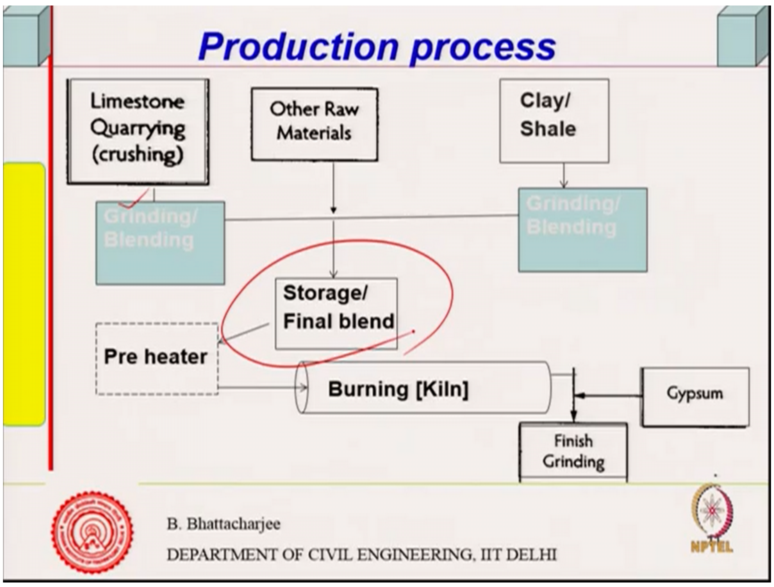

So production process, limestone quarrying and crushing that would be there, other raw materials, so first I think I was mentioning this that you will actually select the quarries based on appropriate composition of limestone and clay, you cannot bring them from different sources and mix, the cost goes higher.

So this is what it is. Then it goes to crushing, and then other raw materials then you add, fluxes you may have to add. Clay and shale, so that makes you, you know after crushing, grinding and then blending, grinding and blending of all these materials that gives you final blend, blend that is stored and then this goes to the pre heater and then to a kiln where it is burned, gypsum is added then the finishing grinding is done. That is the production process of cement, that is the production of cement, right?

So that is the production process of cement. So, let us look at some issues related to how much material I require. And what I produce? First, let us look at that and then we look into how much energy I will require, right?

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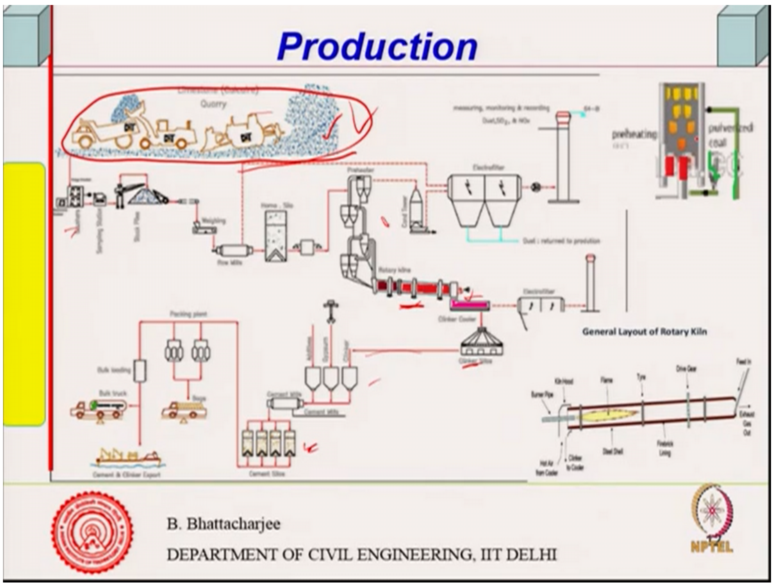

So, this is of course schematically the this is what it shows is a quarry. This is actually collected, transported through the dumper, so you see every stage you have. You may have to do blasting air, you may have to do blasting here depending upon the situation and then of course you know this is basically this is collected loader which will load it and dumper truck this goes to the basically grinding unit from where it would be stacked somewhere or some hominization would be done, then stacked then it would go to the grinding units, right?

And then these are the pre heaters, calciner, kiln and final product would come something else, you might be adding somewhere the flow gases, and then the silos where it would be stored, the tucks loads it, transports it et cetera, et cetera. Or ship it or whatever it is. So this is a process that we are talking about, this is showing the pre heating process and this is a kiln details, the burner is on the this side, downstream side and as you know the hot gases go like this, clinkerization occurs here. So here of it is comes from the top, hot gases go from the bottom and so on.

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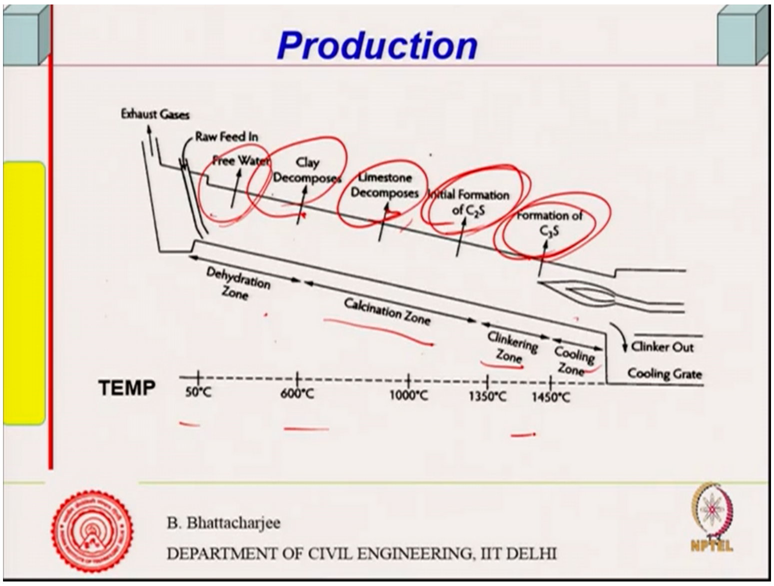

So, this is a production, so this is the kiln, it shows there the burning occurs here, formation of compounds of cement C 3S, C 2S limestone decomposes and sorry, the raw feed comes from there, raw feed comes from there. So this is higher temperature, this is lower temperature, free water will move away. Clay then decomposes, limestone decomposes, C 2S and then C 3S forms, right?

So this is cooling zone, so dehydration zone, calcination zone, clinkering zone and cooling zone, so that is what it is and the temperature is shown 50. So that is the process basically that is the process of cement production, that is the process of cement production, right? That is the process of cement production, ok? Ok, so that is typically I think I might have, it might be there in another course or something that is basically the control room.

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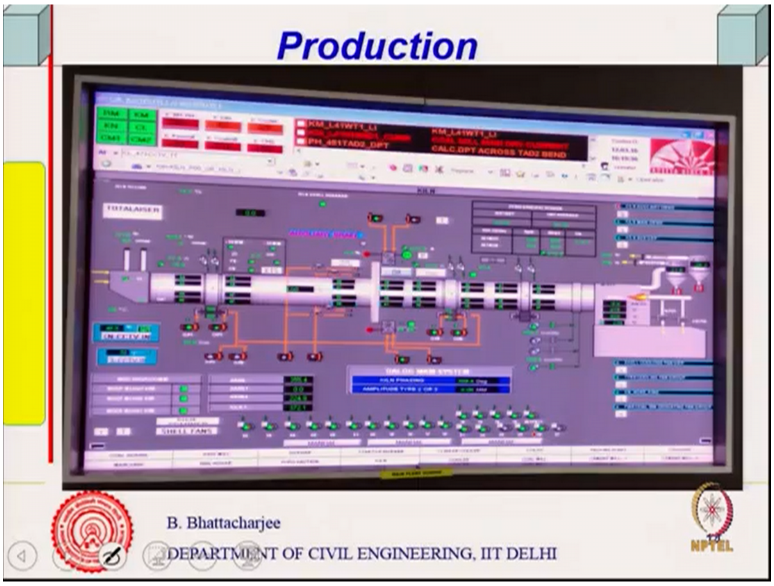

You see something of this kind, in the control room you see the screen of this kind. It is all automated, computer controlled and all that. They can see what is happening in every point, any chemical plant you go it will be like that.

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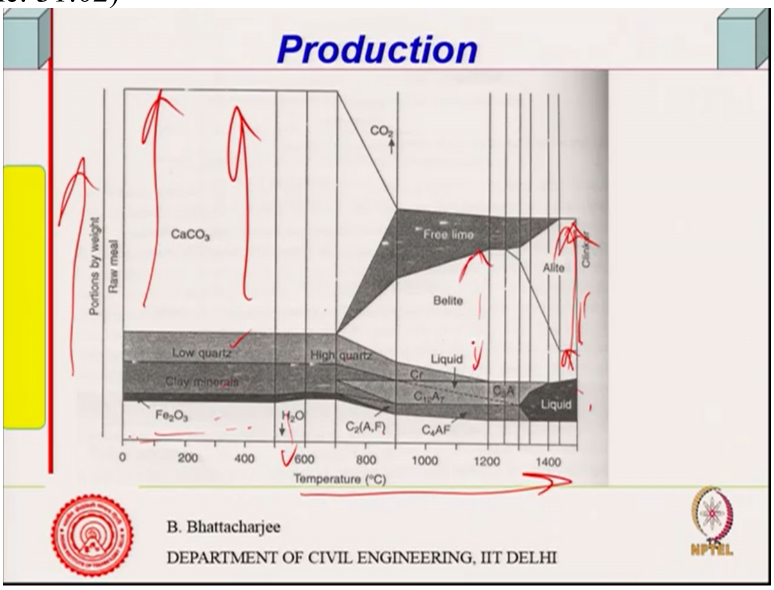

So this is a phase diagram of cement, this is temperature, this is proportions by weight of the raw meal, you have initially calcium carbonate, quartz, clay minerals et cetera, et cetera. So this is clay minerals will have low pores and this combinations, iron oxides, so the moistures goes away, right. So, moisture goes away, so it becomes little bit dry, then somewhere here this gets changed to high quartz another crystalline form and then these are the compounds formed at different stages, liquid stage, finally cool liquid solidified. That is why the clinker is, this is at this stage that is C 3S forms this is C 2S belite formation occurs or C 2S formation occurs here, some free lime. So, that shows the process again.

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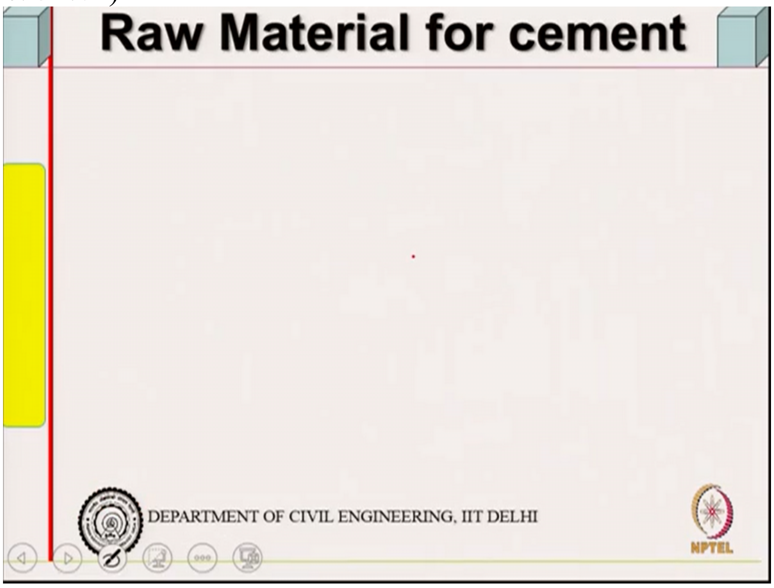

So think we will break here and look into the, more into the raw material of cement for a while, right? So any questions if you have, I will take it right now.