Sustainable Materials and Green Buildings
Professor B. Bhattacharjee
Department of Civil Engineering
Indian Institute of Technology Delhi
Lecture 05 – Role of materials and embodied energy

Ok so, last class what we did? You know last sequence of classes what we saw was there because of the current civilization, technological development and all that there was population growth. There is a population growth, and as a result we are technological processes which we are using, we are consuming more than what the earth can produce in a given year and also we are generating a lot of waste. So, resource consumption is one of the issue, resource is of course materials, energy, everything.

And, then we define sustainable development. What is sustainability, right? What it means is in simple sense that you will be consuming as much as possible, leaving the resources for the future generations, right. So, followed from there we saw that carbon issue is one of the issues. Because, carbon dioxide, carbon is a major courier of energy and in the process carbon dioxide is generated which is absorbed by the plant et cetera. There is a cycle and if there is an imbalance then excess carbon dioxide might go to the atmosphere which will have negative effect in term of increasing the temperature or global warming and so on.

There can be issues related to depletion of ozone, so ultraviolet radiations can come. And therefore, we shall now see followed from that how we should tackle this kind of situation. And that we have seen a part of it, of course we have seen, we have said that recycle, reuse et cetera and make system efficient and realize that sustainability is an important goal. So, followed from that then, we will look into some of those issues, some of those energy issues.

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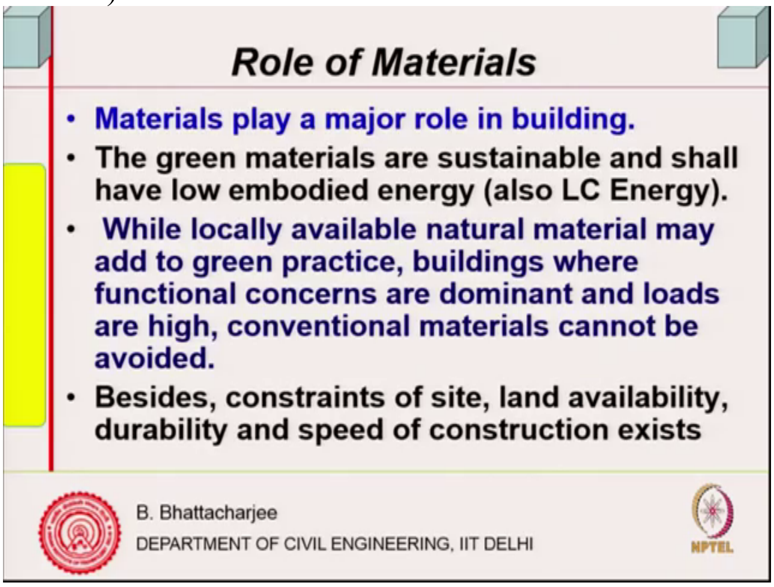

For example, in resources material plays a major role. Material plays major role not only that, they are also it plays major role is one thing. Second thing is that you know materials are consumed, processed and in the process we might generate waste. So, therefore we have to see the materials. You know one issue is minimization of the resources, natural resources utilization. Other issue is least waste generation as much as possible and obliviously there the greenhouse gas is an important, carbon dioxide issue is important. So, that is what we look into today.

Now, they should have there should be, shall have low energy consumption. Now, the energy when talk of, there are energy involved in the production of material and then on the system, last class I think at the end I was just talking about example, given you the example of cement production. So, we choose the queries first of all, right. The queries which will have right kind of proportion of the limestone and silica or clay, rather alumina system, and then you do some homogenization, therefore some energy is consumed there, some energy is consumed there.

And then might be transporting within the plant itself to a crusher, where you will do crushing. So, transporting those would have some energy involved. Crushing would have some additional energy involved. And, then you burn it, clinkerization and there also energy is involved because you have to heat it up to 1200, 1300 degree Centigrade. And, therefore there is lot energy that goes into in the production of the cement itself. So, similar is the case with almost all other materials.

Therefore, we talk those, we will just discuss this today in terms of what we call as rather, they are embodied energy. They are already in the in it, although you may not add anything. Some of it might get dissipated in the process of hydration of cement because it is an exothermic reaction. But then, as per as we are concerned you know this is still embodied in a system itself. So, this is one thing.

Locally available material or natural material for example, you know say 500, 600 years back people would have used only natural material, right when they did not know use of let us say the use of technology did not come, the science and the technology did not come into. So, stone would have been used. Even if now you go in where stones are available in plenty, let us say Rajasthan or some places in the Madhya Pradesh or those areas, you will find that stone slabs are being used but their span will be very small. And, you will have possibly timber beams supporting them. So, they are natural material.

Now, such natural material their energy required is very little. Similarly, in the rural housing people are using mud. So, locally available only the human energy would go into it and then produce possibly thick wall depending upon the climatic scenario where you need massivity in term of thermal performance, where you can store heat, wall should store the heat. There you would find the wall is made of mud. Some other places you will have stones used. So, these are natural materials and their energy embodied in them is relatively less, right. So from that point of view they are sustainable.

As long as you use naturally and locally available material they are more, their embodied energy will be less and therefore they are sustainable. However, if you consider functional buildings, let say this is institute or similar bodies like major office and of course there are today commercial centres. So, these ones loads are also different compared to a residential building right. And, then various other concerns are there. For example you might need a column free space or a space, unsupported space, large unsupported space.

So, such materials which are naturally available and just you can pick from the mother earth and put it in some little bit of processing, they are not useable all the time; you cannot use them. Also you got to look into the duration for which you will we be using them. In term of what you call the life, right. So, they should have sufficiently, last class I was talking about life cycle issues, life cycle energy or similar sort of thing. So, you have to see that they are sustainable for long life. You know maintenance free service life they should have.

So, in such cases it is impossible to avoid engineered material right. There would be constraints of size, production, land availability, speed of construction. All this put together you cannot avoid using modern engineered material. So, therefore you should use them more judiciously, one should use them more judiciously.

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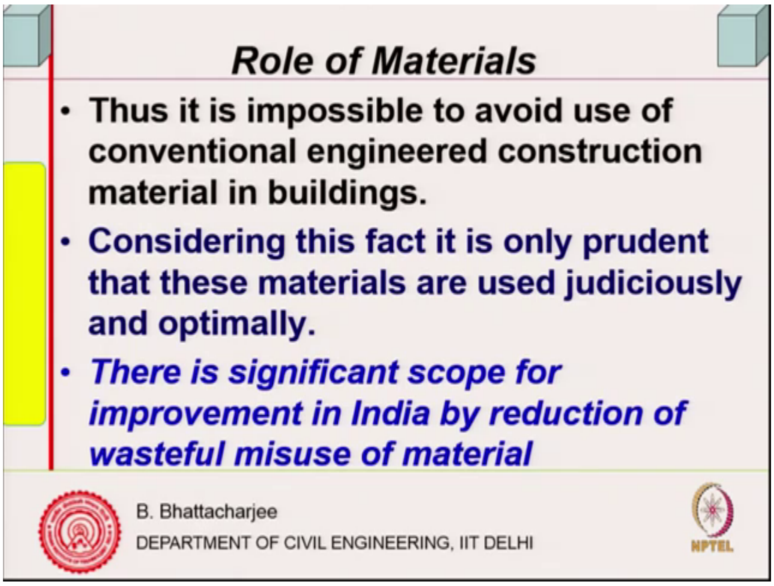

So, it is impossible to avoid conventional energy, I mean conventional constructional material. And, therefore it is prudent that materials must be used more judiciously and with more efficient process. So, of course it is not, I mean although I mentioned here in terms of India but it is not India, many other countries we have scope for you know reduction of wasteful misuse of material.

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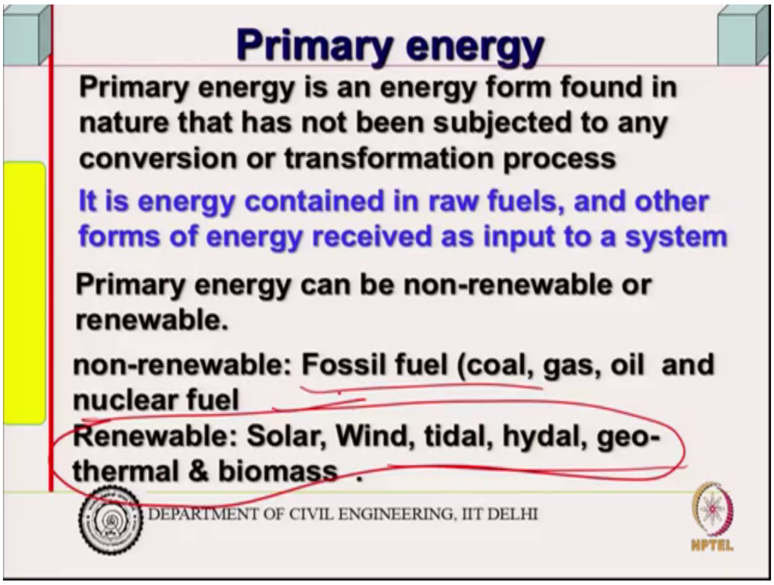

Now, let me define some energies, energies are primary energy is one which come from let us say coal, right. So, the energy found in nature that has not been subjected to any conversion or transformation process. So, energy coming from fossil fuel, they are primary energy. Similarly, direct sun's radiation if we are using that will be also primary energy. Straight away from nature but, if convert them into electricity that is secondary because there it has gone from transformation from one type to another, one form to another.

So it is energy contained in raw fuels and other forms of energy received as input to a system. So, primary energy can be non-renewable or again renewable. Now, fossil fuel is not renewable right, so non-renewable are fossil fuel they are not renewable: coal, gas, oil, nuclear fuel, they are not renewable, right. Renewable is solar energy, wind energy if you are using that is a renewable, tidal, hydal, geo-thermal and biomass et cetera. So, if you see the second one, renewable one you know second one if you see, and these ones if you see, you are not going to, it would be definitely more sustainable. Because it is renewable, right, while these ones if more and more you use of this in a system or in a process it actually would mean that you are consuming the resources stored in the mother earth.

So, non-renewable energy should be used more efficiently than renewable energy, obliviously you should use efficiently. But, then non-renewable you should be conscious about it because you are consuming the stored resources in the earth.

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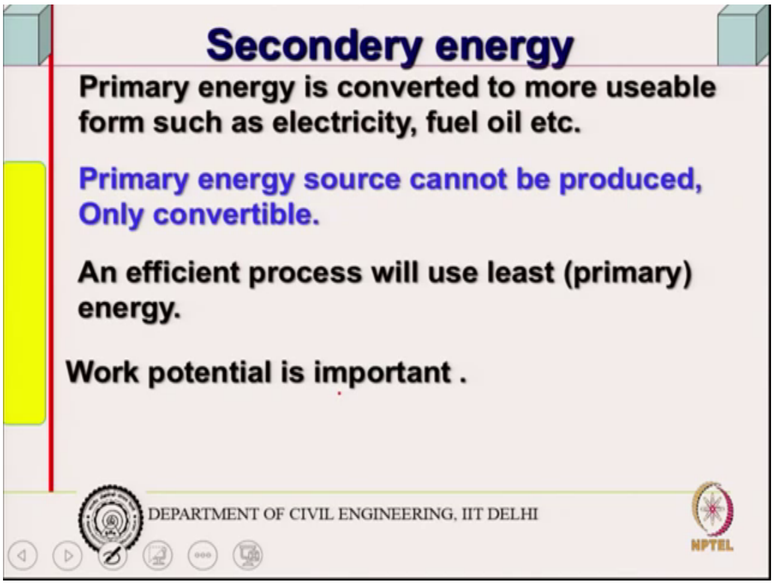

Secondary, primary energy is converted into more useful. Such as electricity, fuel, oil etc. So, you cannot produce the primary energy source, energy source cannot be reproduced, only convertible, you can convert. So, you cannot produce primary energy as such but you can convert. So an efficient process will try to use least of the primary energy, right. Ok and well one term we use is called work potential. But, I do not think I will discuss too much onto it because always you are able to convert it into some useful thing.

Work potential is slightly different than energy because thermodynamically speaking, whenever you are converting energy from one form to other or converting into work there will be efficiency can never be 100 percentage. There will be generation of disorder which we call entropy. Therefore, capability to do work for a given energy it may not be same for all processes, for all systems and it will be differ. And, as it differs that efficiency of the work potential you can increase, that is better. So, that is very important for all the industrial processes. As much as energy you can convert to the work, that is better. Efficiency of the system, so we will into that sometime maybe little bit.

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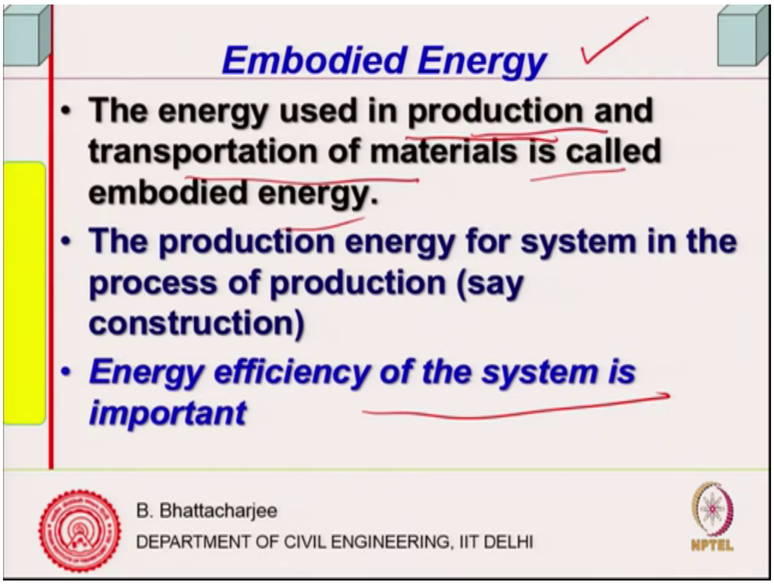

So, let us define embodied energy. Embodied energy is as I already explained, the energy used in production and then transportation of the material is called embodied energy. Because, you have to transport it. Transport it to the site where you will be using it. So, therefore both put together with embodied energy. Now, that is for material I said but even it for the elements this will be same. You will have several components as I say, structural system. And, then we will look into just mentioned about a functional system also. Structural system let us say a reinforced concrete element, structural element column b or whatever it is.

Now, it has got levers which would be normally steel, and then of course the cement concrete. So, the embodied energy of the cement, the sand, you know coarse aggregate, fine aggregate, anything else you are using in it and mixture so on, they all go into the embodied energy of the concrete. And, embodied energy of the steel is also there so, embodied energy of the element will have it will encompass all. It will encompass all actually, embodied energy of the system an element will encompass everything.

Like for example a functional wall, right supposing I have got blocks machinery, I have block machineries, so even with this block machineries I will have each of the block will have different jointing motor or whatever it is, it will have different, so we can combine them to find out what is the embodied energy. Energy efficiency of the system is definitely important. That is the element and things like that. So, we will look in to that as well. Now, simultaneously this is important, I will come back to embodied energy again back as I said, so the one issue is this energy this is important. You should look into that.

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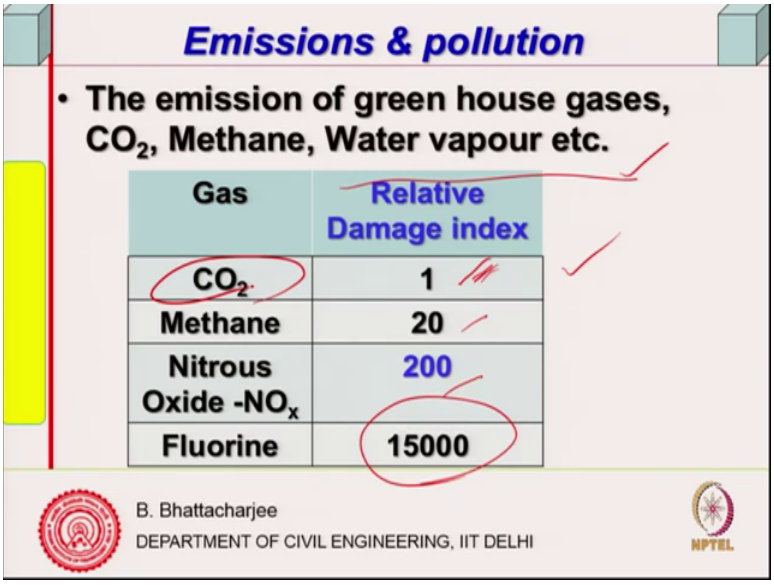

And then, this is then also important because it would generate greenhouse gases. So, if you see relative potential of this, carbon dioxide you know relative damage index as it is given is 1. Methane 20, fluorine is 15000, and so on. So, one have ideas about but the quantity that we produce is too large.

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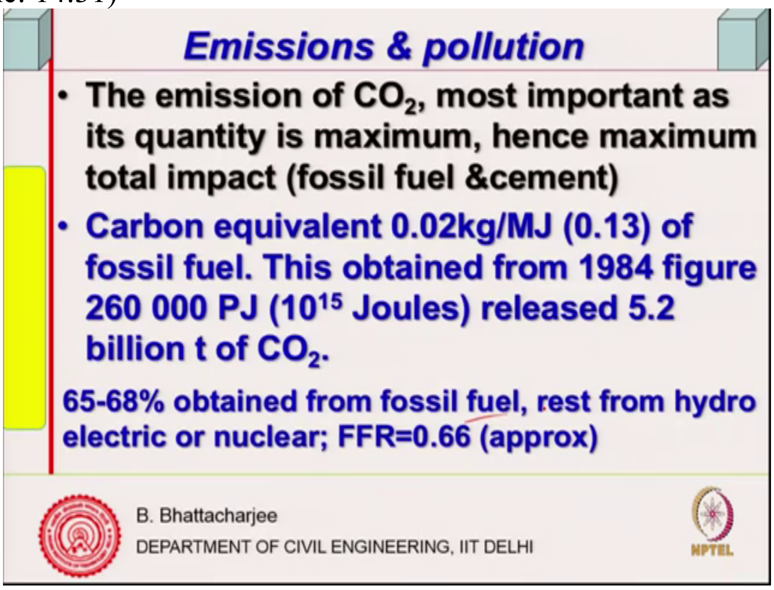

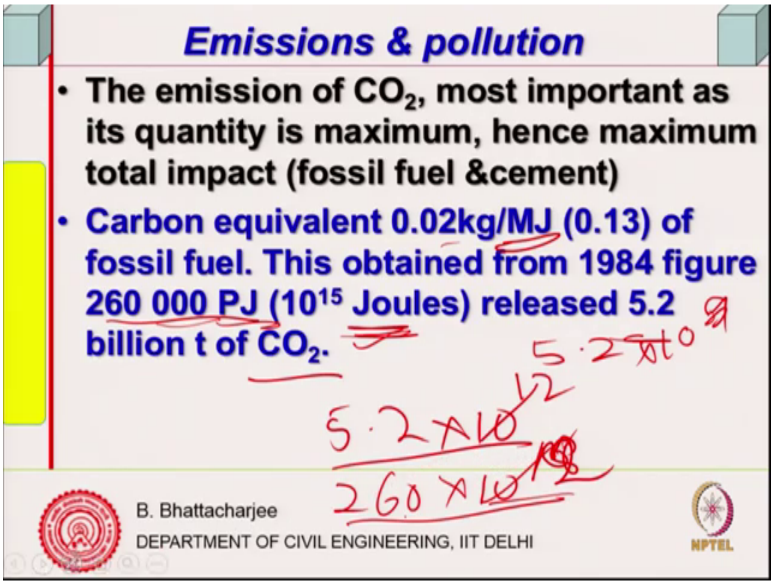

So, emission of CO2 is important as quantity is maximum. Others we produce but we produce at the smaller amount, right. So therefore total impact is much more. So, it is not only the damage index or it is you will see related to embodied energy also is a similar thing. It is not only the, their damaging capacity or capability if I may say, that is important reality. But, how much quantity we are producing? Because it will be mass or quantity weighted. So, therefore that is carbo dioxide, that is why it is so important.

Now, this is interesting, you see we define this in term of carbon equivalent and this carbon equivalent is 0.02 kg per mega joule of fossil fuel. For fossil fuel this is a carbonic equivalent. How it has been obtained? Of course fossil fuel when you will look at it, it will not be pure carbon in any case. We will see that in context of cement production also, that you use let us say petcoke or furnace oil whichever goes in cement production. But, somewhere you will have 97 percent maybe carbon, 3 percent other materials.

Wherever you extract from if it is other cases something like your thermal power plant which uses flyers might be sometime the worst case is, sometimes 40 percent might be simply clay or impurities about 60 or near about 60 percent will be. So, I could have calculated based on that how much carbon I am burning, how much calorific value is known, so how much mega joules it is. Well, this would have been very complicated because different types of fuel different part of the even coal if you take. Coals in India or coals in Australia do not have similar kind of clay content.

So, sometimes they use for you know good where you need better kind of fossil fuel oil where clay is less. In fact, in India we do import the coal as well because all coal does have lot of ash content. So, depending upon what is requirement. But, then this is equivalence was obtained in a different manner. This was obtained in a 1984 figure. What was seen is lot of data collection and statistics essentially, 260,000 petajoules of fossil fuel was used in 1984. Collected in Australia, they collected data actually and petajoules stands for 10 to the power 15 joules.

Peta is, you know you have mega, giga and then peta. So, peta is 10 to the power 15 joules and it released 5.2 billion tonnes of carbon dioxide. 5.2 billion tonnes of carbon dioxide. So, based on this of course based on this one can calculate out how much is carbon dioxide of fossil fuel. For example you know this that many that much energy so, 1 megajoule would be 10 to the power 15. So, this should be you know this petajoules produces 5.2 billion tonnes. How much 1 megajoule produces? Because 5.2 billion divided, how much is billion? 1,000 million so, 10 to the power 9, am I right?

10 to the power 9 so, 5 into 10 to power 9 tonnes is produced from and into 10 to the power 3 if I want to get in kg. So, 10 to the power 12 so, 5 into 5.2 into 10 to the power 12 kg of carbon was released from 260 into 10 to the power 18, right. And if I convert it into megajoules then it will be 10 to the power 12 megajoules, 10 to the power 12 megajoules. Just divide this, 5.2 divided by 2.260 it will come roughly around 0.2 kg of is not it? Am I right? 5.2 billion. So 10 to the power 12, 260,000 petajoules 10 to the power 15. But, then I am talking in terms of per megajoules right so, that is what it would generate. So this is the released 5.2 tonnes of carbon dioxide et cetera.

So, one can actually, so this is calculated on those kind of basis. Of course, most of depends upon how much quantity you get from fossil fuel. So, it will depend upon the country-wise. Earlier we were actually using 66 percent of our energy was coming from fossil fuel. So, now of course they say that they have increased the solar energy and thing like that and therefore it is improved somewhat.

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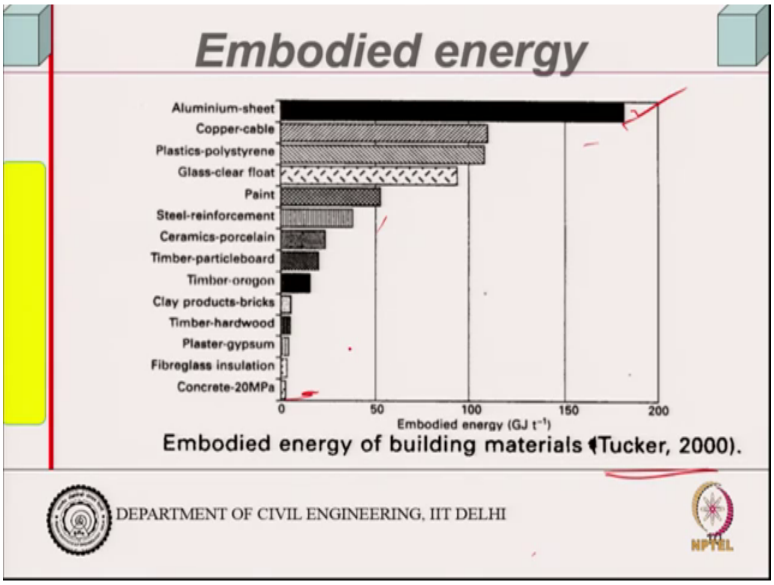

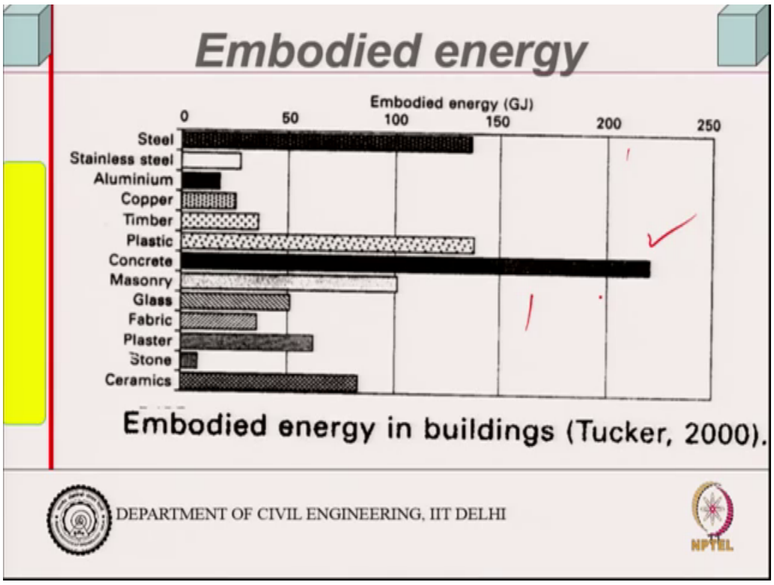

So, let us come to embodied energy back. If you see this is from (tracker) Tucker 2000 collected of this. This actually is you have to collect the data, essentially it is more kind of that thing. So, they find out that this of course you can know from the production system. So, aluminium sheet has got the highest in term of gigajoules per tonne. Maximum embodied energy, that is due to production process itself and etc. You can see that paints and concrete much less, much much less in case of concrete. Because, you know this aluminium or anything first of all you have to extract the metal.

And metal extraction process and then it would cost you a lot. And then after extraction of the metal if it is say in case of steel it is rolled steel product or, if depends upon how you produce them. So, there this is the highest, plastic et cetera and so on. This is how it is but the thing is that if you look at building typical building you will find that this is much higher in term of concrete. Embodied energy in gigajoules concrete uses much more in a typical building compared to any other material. That is because use of on an average basis.

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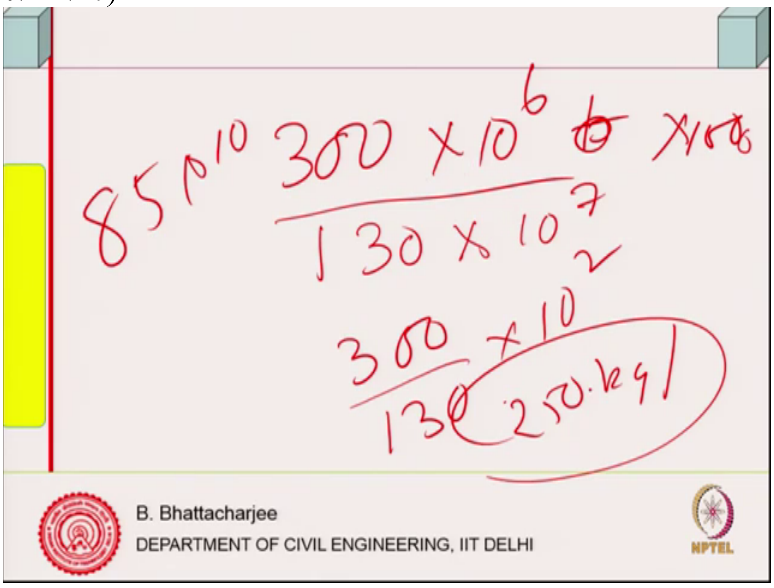

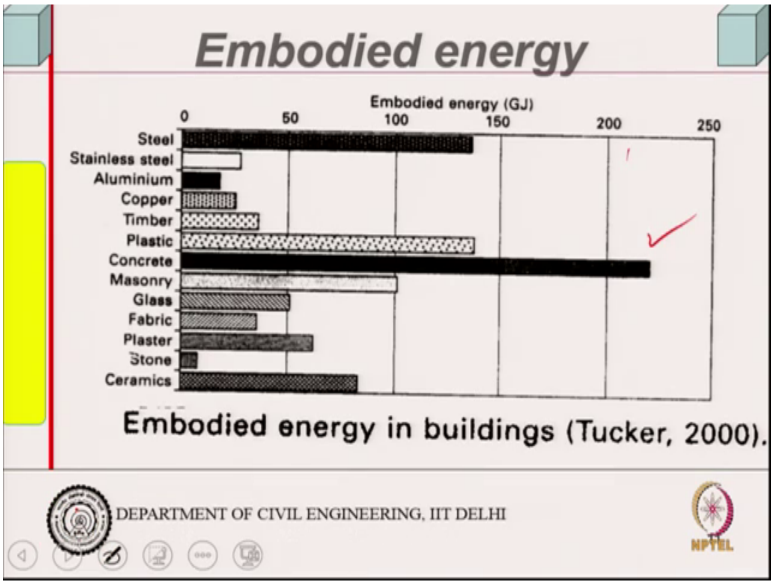

Use of concrete in buildings is a material which is used next to water by human being. For example, if I look at just quickly if I look at the capacity, the cement production capacity of India is something like 300 million tonnes per annum. And you have a population of how much it would be in terms of billion? 135 or 140? Let us say a round figure 130 or 140 we take, it does not matter. It will not matter.

Let us say 130 and that would if I want to convert into millions, 10 million is equals to 1 crore. 10 million is 1 crore so, 130 this was this 300 million tonnes, so I have just put in tonnes. And, I want to put it in number of persons, 130 crores means 10 to the power 7, right.

So, let me put it into 1000, then it will be kg. Right, 1000, then kg, so how much it is coming to? 300, 10 to the power 6 plus 10 to the power 9; 130 into 10 to the power 2. So, this is roughly around how much? 2.5 so, 250 kg per person per annum.

So, that is the quantity of cement you are using. Quantity of cement we use in India. We are not, per capita is relatively low. If you compare that with let us say stabilized situations, like United States where it would be around 85 million tonnes, 85, 90 million tonnes not more than that and their population is 30 crores. So population is about one-third of ours, more than that, one-fourth of ours. So, per capita still our consumption is not very high.

Chinese, actually produces something like 2.4 billion or about 3 billion tonnes of cement. So, they are also stabilizing somewhere around there. Now what I am trying to point out, the quantity that used in cement in the world is next to water, next to water. So, that is why if you look at a typical building it is very high for cement concrete. So, therefore the both in term of your embodied energy or as we shall see for carbon emission, this is one of the major concern; this is one of the major concern.

Well, if you even replace it by something else you cannot replace it by let us say steel. Fully you cannot replace with the steel. First of all steel is required for other activity also and, if you replace it by steel equivalent dimensions supposing you do that, structural ones you can replace. But, when it comes to other usage of the cement concrete system many of places you cannot replace. For example, making steel dam is almost you know rare on the earth, maybe there is one or two small dams because you need robustness, you need massivity. You need massivity, so it should not slide or overturn. So, machinery or concrete can serve this purpose. Steel, polymer composites and plastics they cannot serve this purpose. Therefore, the versatility of concrete is very much there.

And, if by chance you are able to consume, reduce the consumption you will actually end up having more. Because their embodied energy is much higher, their embodied energy is much higher. Still has got much higher embodied energy, ok.

So, by share use of quantity use of quantity share, you know use of quantity, concrete is one of the major contributor to the major embodied energy in building. We will try to see, it is more of accounting rather than calculation of even if you want to see it is rather of accounting. So, data has to be there, now such data of course Indian scenario little bit is available, I will give you that.

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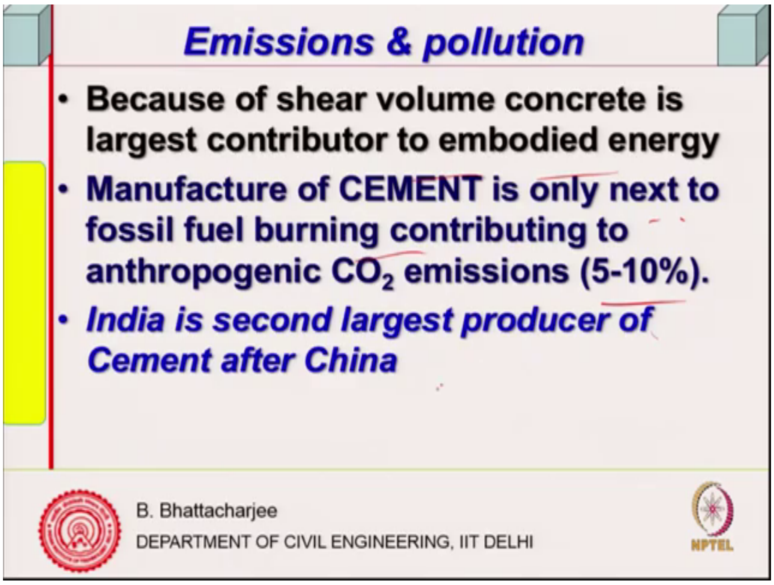

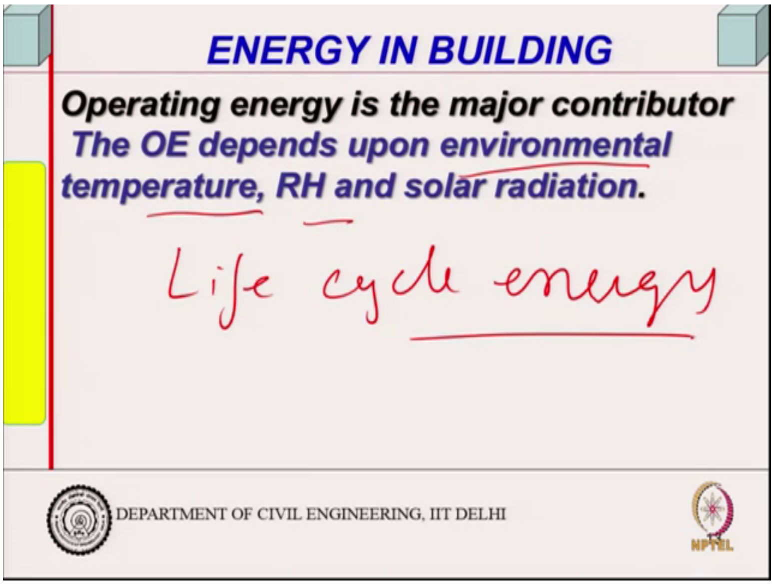

So, we are talking of the carbon dioxide issue, you know I was just mentioning about before, in between I said carbon dioxide issue I was talking about. Now, share volume concrete is the largest contributor of embodied energy, that is the one thing and carbon dioxide issue again, cement is next to fossil fuel burning contributing anthropogenic carbon dioxide 5 to 10 percent, that we have seen earlier also. So, ok this is the second largest producer. the other issue is of course operating energy. When we are talking of building, this course is related to building.

We are not looking into all infrastructure, all the passing you know some of them are useful to other kind of infrastructure. But, when we are looking at the building then operating energy is also a contributor of the, energy is also a major contributor. This depends upon environmental temperature because last class I was mentioning to you that we should look into life cycle issues. Life cycle issue you know life cycle energy including embodied energy contribution during life cycle.

Because if you do maintenance and repair, there is some grey energy which will come into. So, also we should look into overall life cycle performance in any context. Although we design, if I look at from engineering economics point of view when you are designing, our current design has mostly been based on initial minimization of the material, initial minimization of the material. But, if you are repairing it or doing some changes somewhere, after certain period of time then your cost of that maintenance or replacement of elements let us say that has to be taken into account.

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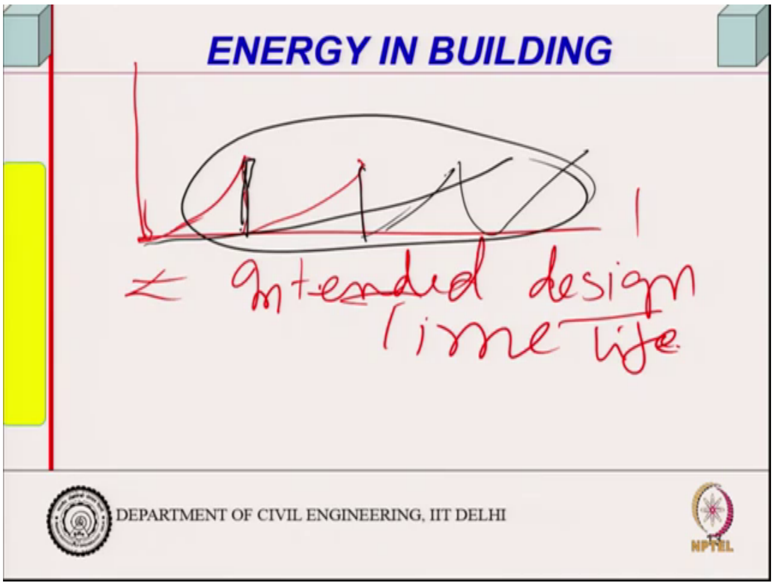

For, example I will just go little bit away from this. Supposing I at look at the you know time, we have something called intended design life, intended design life. I think sometime last class I was giving you. So, essentially the life these are inanimate, building is an inanimate system, it does not have a sharp lime of demarcation of life and death. So, it depends upon how you define, the context, how you define is a context. So there if our intention of the design time that life of the building should be 100 years.

So, what I do? I design it for that kind of load which will come but uncertain load, especially the earthquake or wind. We take that load which we can come only once in that period of life. We take it in terms of what you call return period. You know you can take the wind, extreme wind that can come once only in 50 years. If it is 50 percentage, 50 years is a return period that is intended design life. So, generally even in maintenance planning, building maintenance planning we take about 50 to 60 years.

So, that is intended design life. Now during this intended design life initially you have done, spend some money maybe but then system some of the system would depending upon what you have taken the system, system or these system are not, these are manmade, they are not natural and if it is natural then that will remain as it is. But, all manmade systems have a tendency to go back to their natural state because, you have given them produced them with expense of energy. So, they would like to dissipate that energy, their chemical potential is higher as we call it chemical potential is higher. So, they would tend to go back to their state.

So some elements or some parts will deteriorate maybe in this manner. Yeah, and deteriorate, then you have do repair so you bring them back, you bring them back; you bring them back to the original state. And, again there will be deterioration, same cycle and bring them back, bring them back here, so this continues. And more number of times you do more grey energy is involved embodied energy is involved. You know, more material is involved, so everything is going there. So, therefore if you can do something better like this, this is better, obviously maintenance is free during the intended design life.

But, anyway it is not easy to do, we will see that. So, that is what I was saying, this is one part, embodied energy maintenance and similar sort of thing, replacement and maintenance this would be what call grey energy. Because, we do not know exactly the quantum and it is not easy to at the moment it is not easy to qualify them. So, operating energy is the next major contributor we will see that and just one minute maybe you know if you have any questions I will take some questions and then again we start with the operating energy.