Sustainable Materials and Green Buildings
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Lecture 14 –
Types of Composite Cements

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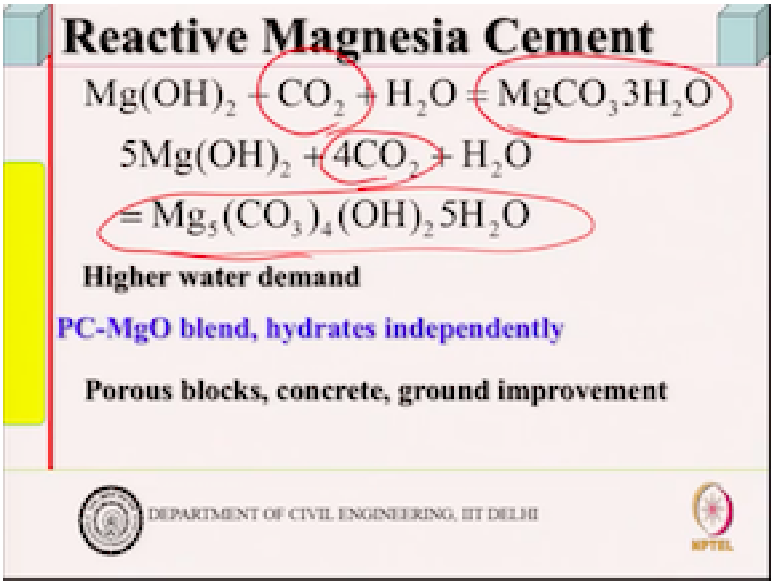

So the other of course, this is, we continue the magnesia cement, these are the products, these are the product it comes from the atmosphere this comes from the atmosphere. So therefore it is captured whatever carbon dioxide actually would have been released whatever would have been released it has captured some of it so that we just the advantage again these are still in research stage I will say commercial production it to come but then porous block etc has been done.

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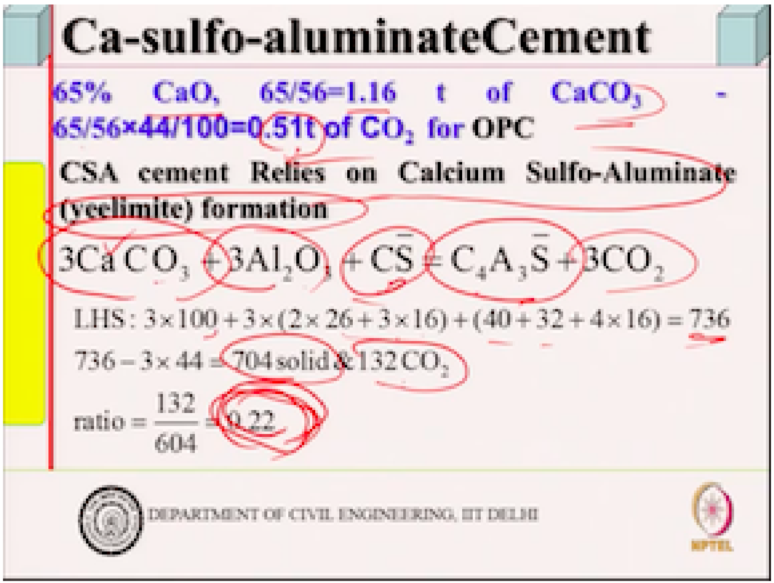

Then there are calcium Sulphur aluminate system, for example in ordinary Portland cement, you have got this this, and you need 1.16 ton of carbon dioxide. So 51 percent OPC calcium Sulphur aluminate even relies on calcium Sulphur aluminate formation. Here we might one of those. So the reaction is something like this you take carbo aluminate actually calcium carbonate, aluminum and calcium. This is calcium sulfate. They form this sort of sulfur aluminate system and of course the releases some carbon dioxide also now ratio of carbon dioxide is relatively less left hand side if you calculate out calcium carbonate is 100 3 aluminum L2O3 is 2 into 26 into 3 into 16 and this is calcium sulfate 40-32 etc, etc from 736.

So, 736 units will produce 704 solids and 132 carbon dioxide because carbon dioxide is 16 plus 12, 44 into 3, that will give you so the ratio is 0.22 while in case of cement it was 0.51 ordinary Portland cement clinker it was 0.51, here you see it was 665 etc, etc we calculate and we found out it was 151, 1 ton of cement would produce 151 ton of carbon dioxide or unit mass of ordinary Portland cement clinker will produce 0.51 units mass of carbon dioxide only from the clinkerisation reaction not the energy used fuel used is separate, that takes it to 0.74 to 1.25 or whatever it was we calculate out.

So here you see this ratio reduces down 1 ton of this calcium sulfur aluminate cement will produce 0.22 tons of carbon dioxide. So we have been able to reduce his from 1.5 to 0.22. So these are being attempted again, these are being attempted.

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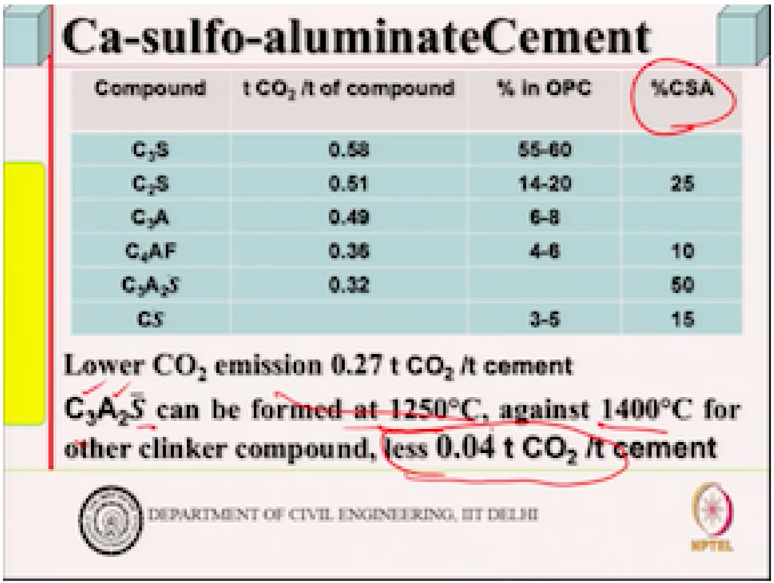

So if you see from each compound C3S production tons of carbon dioxide per ton of C3S is 0.58 stoichiometry same way you can calculate out this is 55 to 60 percent in OPC. Then C2S it produces 0.51 and 14 to 20 percent in OPC somewhere and if you see calcium Sulphur aluminate cement C3S is not there some C2S is also produced so because states about 25 percent and CS produces, where you have CS so calcium Sulphur aluminate system.

The carbon dioxide pattern is here and in OPC this is the percentage of CTS is a percentage of C2S, C3S is there to some C2S there in calcium Sulphur aluminate also, so obviously this 0.25 multiplied by 0.51 will be the amount of carbon dioxide potential of this particular one compared to this this well if I want to calculate out and calculate let us say 0.55 into 0.58 for OPC plus 0.55 I have taken so let me take this as 0.2 side slightly benefit 0.51 plus 0.49 etc etc.

I can multiply this and find out what is that carbon dioxide pattern coming and if you calculate out with this one, you will have 0.25 into 0.51, 10.35, 50.32 and 15 so this this does not produce any carbon dioxide did some do not produce any carbon dioxide. So this is 15 percent. So this 15 into zero, you will find the total carbon dioxide produces lesser much lesser, so that is the idea, that is the idea.

So lower carbon dioxide it calculate out it will 0.27 tons of carbon dioxide per ton of cement rather than 0.51 tons of carbon dioxide part ton up ordinary Portland cement clinker. So this this is simple calculations there is nothing complicated C3, this is calcium oxide. This is aluminum oxide and this is SO3. This can be formed at 1250 degree centigrade. So in calcium Sulphur aluminate system, this is formed at 1250 degree centigrade against 1400 degree centigrade in case of OPC clinker so then this also reduces down the amount of carbon dioxide emitted because energy required would be less energy required will be less.

So there are two aspects related to calcium Sulphur aluminate system, one first because, in the process of production you are generating lesser carbon dioxide instead of 51 percent now it is 27 percent. Since you are heating temperature is lower you require lesser fuel than energy and that also cuts it down so effectively it cuts down, you can edit down, So it is 51 minus 0.27 minus 0.27 plus 0.04 will be the amount.

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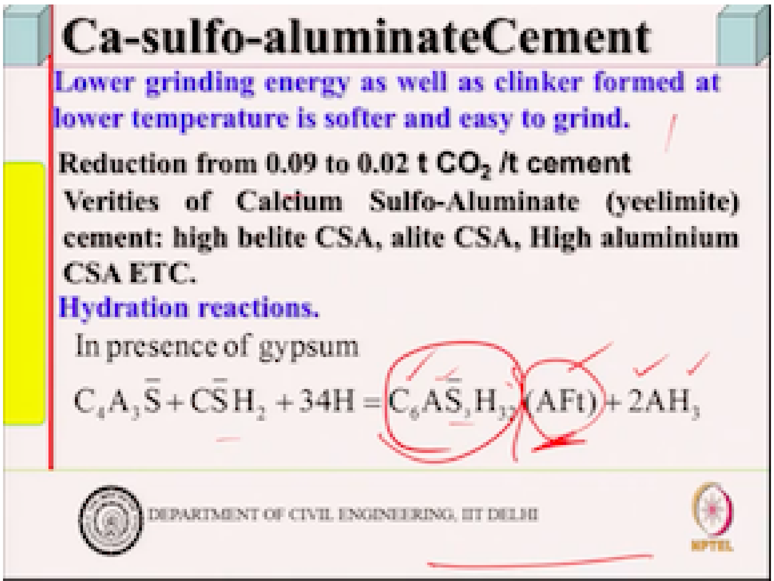

So, lower grinding energy as well because this is not as hard as this. Because is formed at lower temperature and cool. So after and easy to grind so reduction from 0.09 to because of this and varieties of calcium salts full and aluminates system etc has been tried and all of them actually, produces down the carbon.

There are two possibilities one in presence of gypsum, it gives you this kind of product and hydration reaction, in presence of gypsum. It gives you this sort of a product that is aluminum this is water, this is calcium, Sulphur aluminate hydrates, AFt phase we call it in cement hydrate, cement chemistry, this is AFt phase, there are , very phases in cement hydration nomenclature AFt is a phase this is a formula. This is this is known as AFt that's how it in bracket is AFt.

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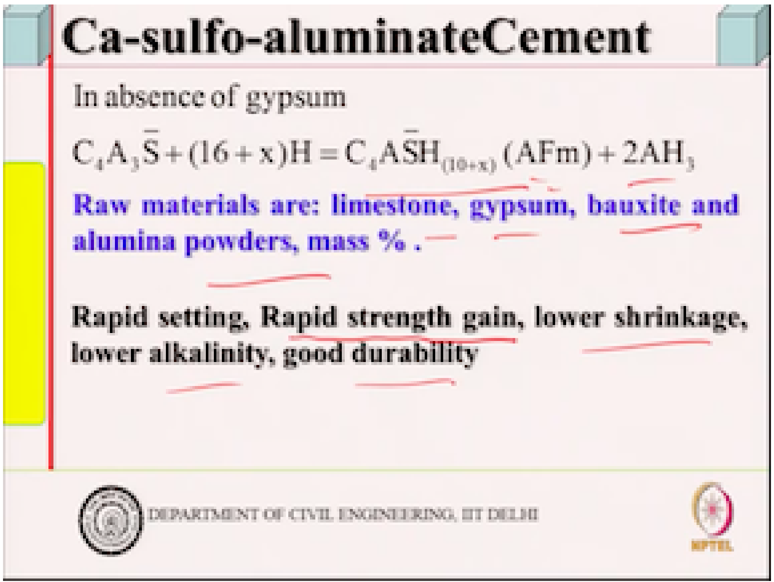

So in absence is with lesser gypsum, it would be in absence of gypsum. It will be AFM is another phase produce in cement hydrates also in the beginning. So this is this to our form actually so raw material limestone, gypsum, bauxite and alumina powder must by percentage. So that is what it is setting is rapid. Gypsum and alumina system tends to set rapid, rapidly rapid strength gain, lower shrinkage or alkalinity, well said to have good durability. So these are other kind of cements being tried, these are other kind of cements being tried to reduce our carbon emissions.

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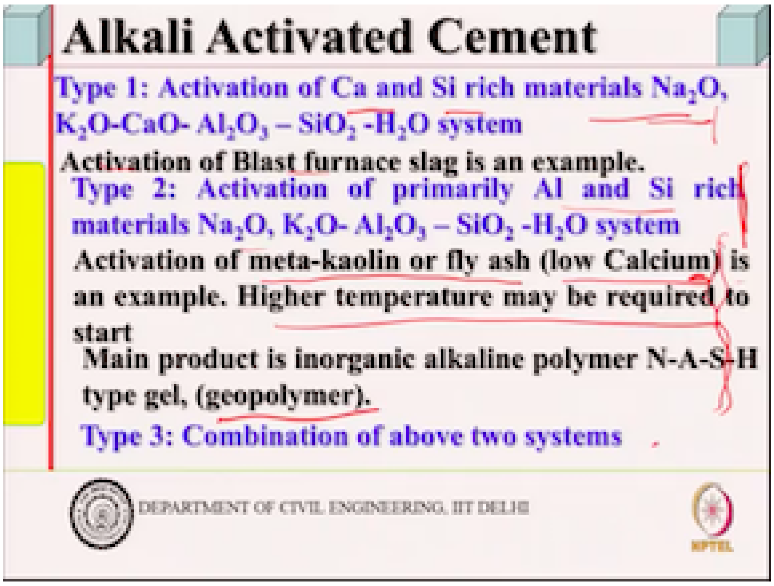

This is another variety, alkali activated cement, there are two types, type one, activation of calcium and silica rich materials with sodium oxide potassium oxide etc etc system and For example blast furnace slag, you can straight away activate it. So activated slag cement you do not use ordinary Portland cement clinker except for a very small percentage activates the slag itself using alkalis.

Then the other is activation of the type two is activation of the aluminum and silica-rich system materials which have activator sodium, sodium oxide silicates in sodium silicate potassium silicate, etc. So this is fly ash or metakaolin, which has got high silica, less calcium higher temperature may be required to start this is so this is something called, this is another name of this one is geo polymers.

So geopolymers are those system where you do not use you are not using lime at all here. This is simply silica-rich system silica, low lime, low calcium silica-rich system and this is although lime is there but it requires activation so you can have like there are something called super sulphated cement even which is about 85 percent slag, This is being relooked into so that you don't use calcium carbonate at all and geo polymer system is the other and you can have combination of the two, in fact this has been relatively more successful the combination of the two together. So, I think I have something more to you the geo polymer system a little bit later because is being attempted in it in a much bigger way particularly those places where you have got large quantity of fly ash.

Now fly ash, type F fly ash which are rich in silica alumina low calcium. So which sodium silicate sodium hydroxide potassium hydroxide etc silicate system and alkalis you can activate them and activate them and therefore that is much low carbon cement. This is other kind of one that is being tried. So what we have seen other than those 27 combinations as we seen we have seen high Belite cement, calcium Sulphur aluminate cements and just now we looked into activated alkali activated cementitious system, magnesium system. So two types we said and this next one calcium carbonate system is being attempted.

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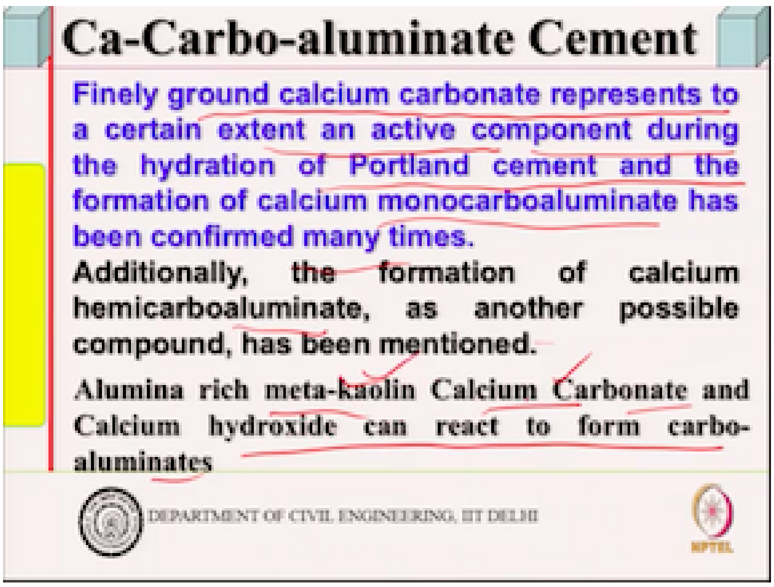

So, you have finely ground calcium carbonate presence to certain extent and active component during hydration of Portland cement. So this calcium carbonate some amount even if it is there in the cement system, it takes part in the reaction and forms carbo aluminates so formation of calcium mono carbo aluminate so this carbo aluminate is formed. So calcium heavy carbo is another possible compound so calcium carbonate also takes place in reaction forming calcium carbonate hydrate.

Alumina rich metakaolin calcium carbonate and calcium hydroxide can react to form Calcium carbonate so what you need is, metakaolin calcium carbonate bicarbonate and if you add some OPC then calcium hydroxide will also come from it after hydration so they can form calcium carbo aluminate.

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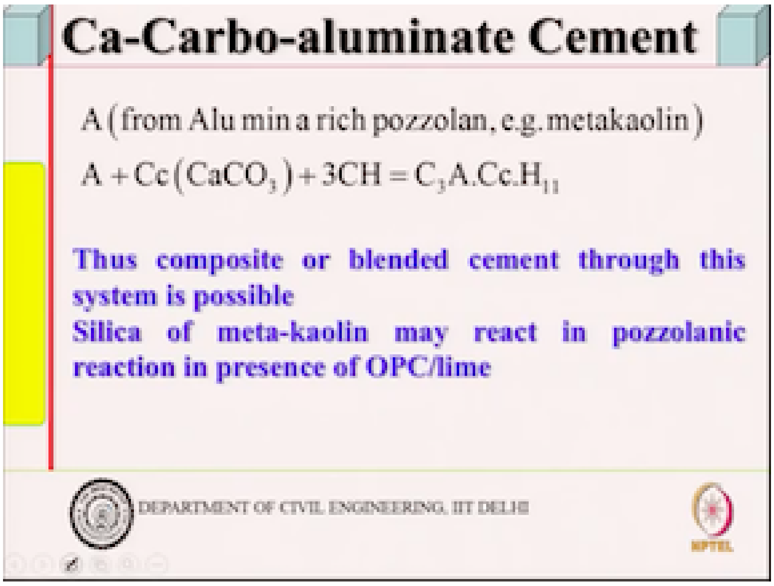

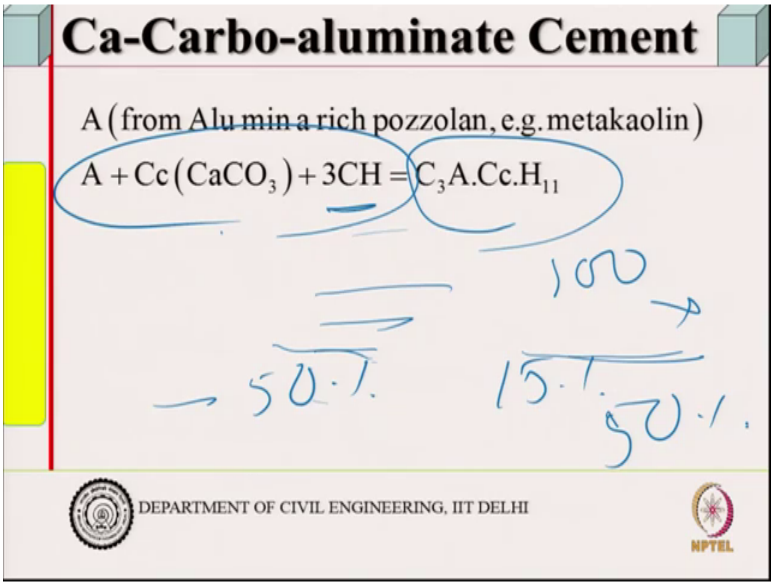

So, , this is the aluminum rich pozzolana metakaolin for example, this is this this is what it is calcium carbonate is written in this form CC. Calcium oxide is C, carbon dioxide is small c.

So, abbreviation of calcium carbonate in cement chemistry because we write everything in abbreviated form. CS bar is Calcium sulfate CS stands for calcium silicate, so alumina calcium carbonate, calcium hydroxide, calcium carbo aluminate hydrate and all of them, see the if you recollect some time I mean some other maybe I am not sure here I talked about basic idea is to have a material system which is plastic initially binder. Should be plastic initially so that I get mouldability and it actually binds or goes into the interstices of the aggregate systems.

These are my aggregate system let us say, these are my aggregate systems let us say varieties of sizes of aggregate, and this the binder system should be initially plastic filling in all the pores spaces, interstitial spaces and then it should solidify, that is how we get artificial stone or concrete type material. So all this cases they should be all these cases they should be with water, they should be plastic and they should solidify, so the reaction process that we have seen all these in organic ones in , they are they form kind of hydrates and molecular way to change, and this hydrates are solid products, hydrates are solid products, whether it is your CHS system or all the system that I was talking about, even magnesium carbonate system these all are they get converted into solid as soon as they take something, for example, that is why I was talking about lime.

So you have two types of lime, one was hydraulic lime, other was the non-hydraulic type so one would absorb carbon dioxide from the atmosphere and convert it into calcium carbonate,. So solidification is important and either they react themselves with water and solidifies form sort of tendency to form some sort of crystalline material and the other could be as absorbing something from the atmosphere carbon dioxide and then forming solid.

Of course the third variety is polymerization, for example, if you have epoxy concrete polymers, you have monomer resin and then impolymerize it to solid but then those are costly ones, we are not interested in them. Geo polymer is one of them where polymerization actually occurs, all, so that is pointing out to that going back to this so-called calcium, so this will form the solid product.

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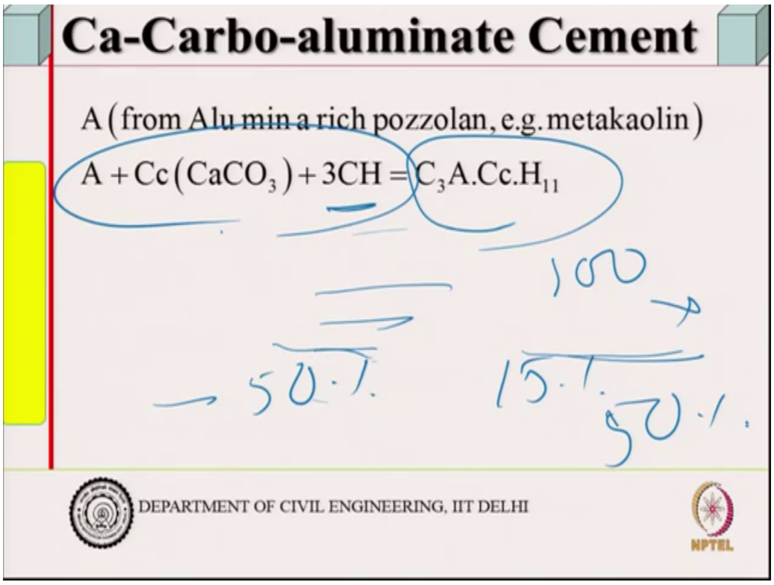

This is in plastic state and this will form solid product so you can blend cement through this system because cement will give you this and silica metakaolin may react in pozzolanic reaction, so some of these some of the additional silica if you have they can react with silica of the metakaolin react with like excess lime if it is there, so this is what it is.

Now lc3 cement actually it is Cuba and Switzerland and they started in the beginning some of my colleagues who work there as well. This is one of this kind of cement actually. So what they are trying to do they are trying to use around 50 percent clinker. Some 15 percent limestone and around 30 plus percent some gypsum would be there 30 plus percent of Metakaolin. So all this should actually react to form this kind of system. So there are several of them are being attempted and research that the moment.

So this is I will come back to geo polymer a little bit later on because that is that is trying to people there has got a relevance because if one can use this particularly country like India where we have already produced large amount of fly ash, we have producing already large quantity of fly ash, even if you stop some thermal power plants tomorrow onwards what I mean to say do not construct any new thermal power plants.

India has got large coal reserve, many countries are able to utilize their price fully in various in the cement production or various other usage in India 100 percent out of 100 percent fly ash produced only 50 percent we are using, 50 percent is unused. So, if that, if that is to be used and out of this 50 percent of this 50 percent, that is about 25 percent is used by cement concrete.

So cement concrete is the largest user of fly ash, rest all lime field etc. all put together another 25 percent will be used. So agriculture use and all that, so this is a this is where you have the chance to use it more so that is I will come back to this sometime later on, this is one of them.

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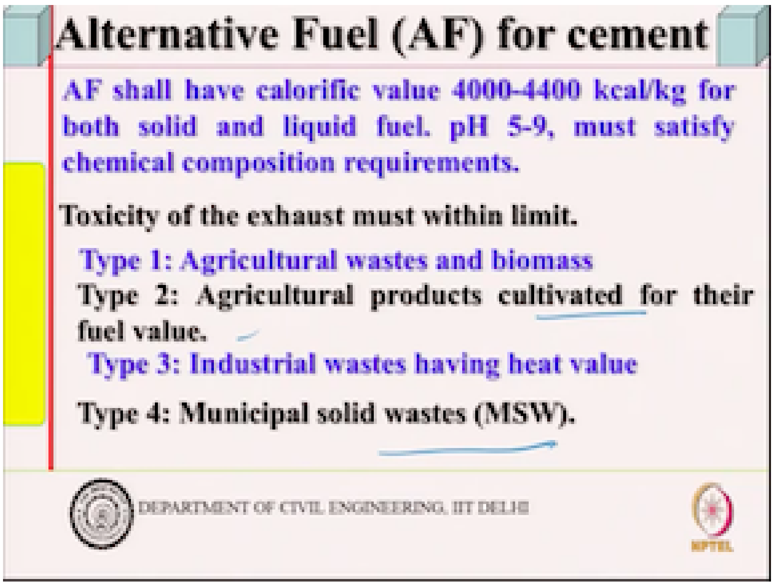

So let us look at some of the other issues related to the cement. Alternative fuels because, fuel was the one which was also contributing towards the carbon. Now alternative fuel should have a calorific value of this much. This is the first requirement. For both solid-fuel solid and liquid well and PH 5 to 9 must satisfy chemical composition. So there is a specific chemical composition requirement in terms of toxicity also because you cannot burn something, which might generate some hydro cyanide gas or something like that. Or leach out some cyanides, which could be fatal to people or anything that matters so toxicity of those ones are important.

So therefore aggregate this is the requirement must have good calorific value agricultural waste and biomass (())(19:44) for example, the one comes out from sugar cane, once they extract the juice out of it sugarcane, the remaining portion left is bio gas, which can be used agricultural waste or even like straw etc. etc, in controlled manner because this will be controlled manner.

Bio mass or varieties of farm, industrial waste having heating value sufficient heating value, which I mentioned toxicity is this must be with it. It is very important toxicity of the excess must be within limit and agricultural products for their products cultivated for their of course, they are. Some agricultural products are produced for fuel value itself, those ones you can use and municipal solid waste, municipal solid waste, so all this can be used actually if you look at calorific value of some of them.

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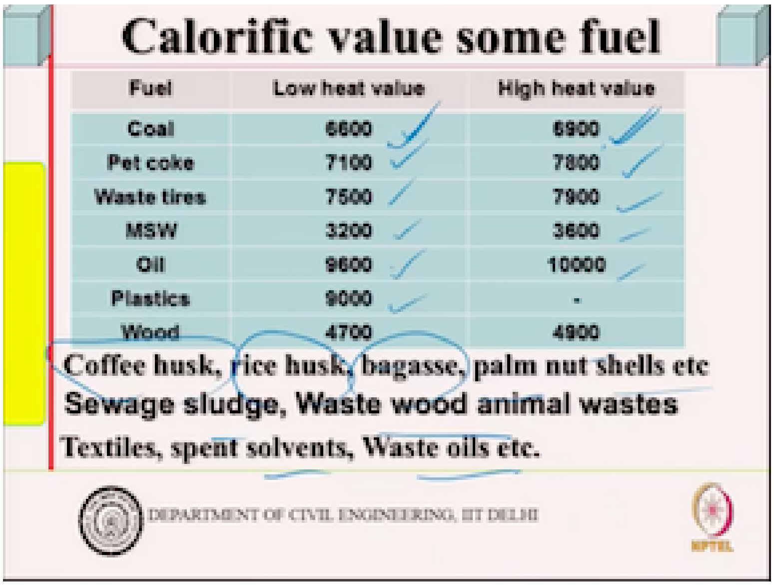

Remember we talked of high heat value and low heat value, it depends upon whether everything is brought back to the amount of heat generated after bringing back everything to their original ambient condition. That means if it was moisture vapour that should also be water, is the original state because vapour, there is some amount of heat is not available, fuel from the fuel it is water goes is vapour this latent heat will go away.

So, low heat value relates to that, high heat value relates to this, pet-coke obviously which is used in cement is much higher value, waste tires, vehicle tires their values are something of this kind, municipal waste much less some oil, they are very high, plastics and wood, this wood means waste wood, we are talking of waste wood, so therefore Similarly coffee husk, rice husk bio gas, palm nut shell, coconut shell for example, but it should be available in the proximity of the cement plant, sewage sludge, waste food, animal waste everything. So all this can be used as fuel in the cement plant.

Textiles, spent solvents, paints for example paint paint, waste paint, paint factories so many of the cement plant actually uses them today to read cut down on two things because they can show that are environment friendly which becomes kind of requirement, which is basically, requirement by law in some cases the government will not and second thing is they are cheaper.

In fact the people who are producing plastic waste the plastic factory they would like to get rid of them and they might I mean, they might even even the economics might work somebody might like to pay you a please take it away and burn it the other way around could also be true. So therefore there is a, this this is being used by most of the good cement factories, most of them are using this today and that's what it is.

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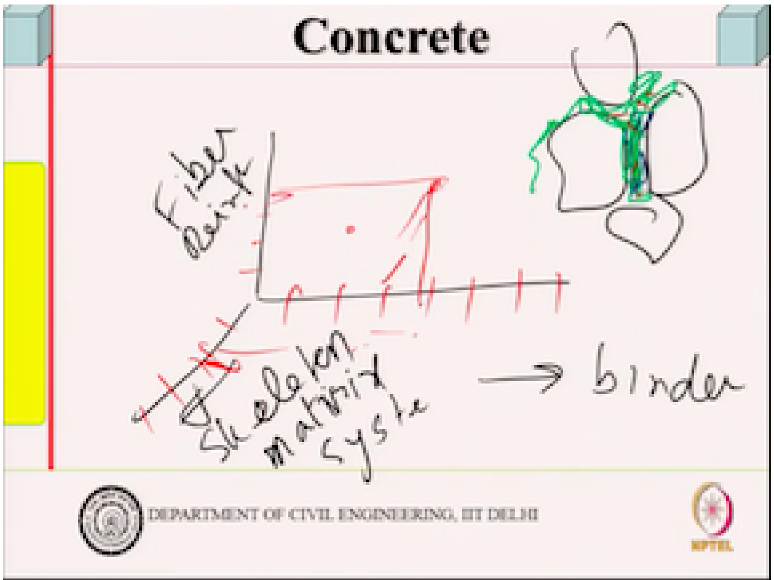

So the cement out of the cement one thing remained geo polymer concrete, I will come to that later on concrete when I talk of, so this is related to this is related to our this is related to cement system and because cement is the major contributor to carbon dioxide after fossil fuel so then that is why so much of concern and as you can there are varieties of options being looked into and this again highlights, which I might have again somewhere, some other course.

I might be shown in diagram that today the concrete cement concrete system sorry sorry, cement concrete system binder this axis is binder. This axis is the skeleton matrix material skeleton or I can say matrix material, matrix system and this could be some fiber enforcement, fiber enforcement, not the convention one.

Now this matrix means you have something like this something like this something like this something like this. The binder means binder means they will go and the binder means they will go on filling this area, this color is not the best one, may be this is better, binder means they are filling this aggregate system keep them together and if I put in some fibers, they might also go into the matrix to enhance the property.

So, you will have several binders here, not one many, matrix system will depend upon the type of cement system but this is for example, you have a high very high strength concrete dimension of the dimension is going to be small for same load carrying capacity so might save on to the material and therefore might add to sustainability since is said to be complex and fiber reinforcement of course enhance the property, so you might have something like this which will use this fiber, this matrix and somewhere this kind of having basically you can have combinations a material which will have this type three binder maybe matrix of the fourth kind and some fiber enforcement.

So it is a kind of a whole large universe of cement based material system available and it is going to be more and more like that with all varieties of cement coming in to take care of not only the performance issue other performance issue, but the sustainability performance issue as well, so it gets added up to the mechanical properties and so on.

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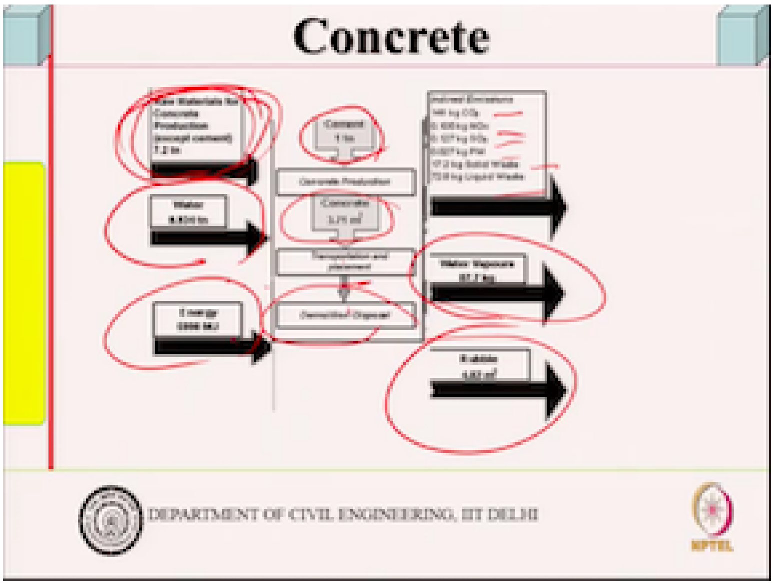

So that is what is the concrete is, lets just introduced concrete might look it in a bigger way when it comes to concrete when it comes to concrete raw materials restore, if you look at the proportion say not very strong concrete I am talking of may be something like 25 ampere or 27 ampere concrete. So one ton of cement I might add rest of the material 1 is to 2 is to 4 sort of, the rest of the material could be something of the order of 7.2 ton, something like 20, 25 25.

So then concrete production and there again, there could be some indirect emission of carbon dioxide. Nitrous oxide, Sulfur dioxide etc. etc. Some solid waste and some liquid waste, so during the production of concrete also you generate some amount of waste, you had of course water here and then produce the concrete, and then transportation, transportation and there will be some obviously when you are doing transportation in this there is some energy input. This is the one and if you demolish then also you are producing some waste and water vapors will produced so this is the kind of scenario with concrete during its life cycle because we are talking of that demolition.

We looked into the cement, now let us look into something more that is concrete. There is a final product and there also you have this kind of production of the waste and the resources that you are using.

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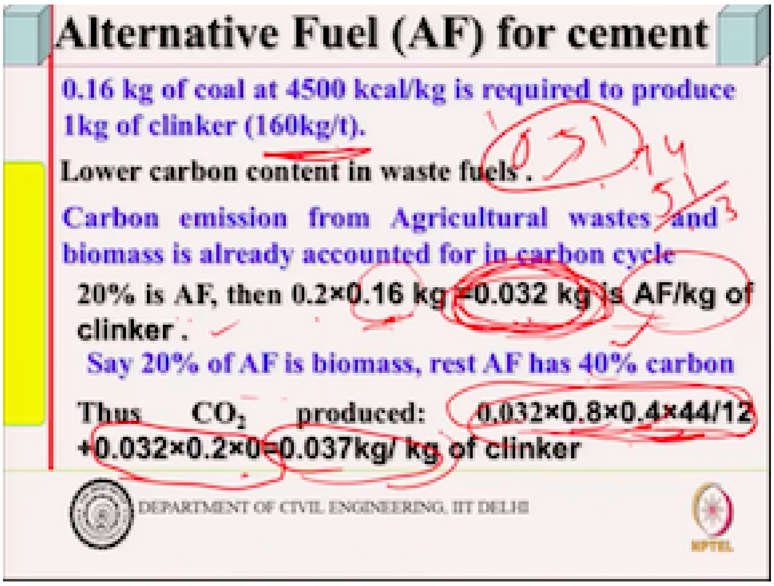

Okay, Just I think I missed this, so just this one, this is we said that in case of cement 100 to 200 kg of fuel per ton of cement, so let us take it 160 kg the calorific value is 4500, so 4500 kilo calorie, multiplied 160. So that will give you how much is a energy generated or required to produce one ton of cement, carbon emission from agricultural waste and biomass already accounted for carbon cycle so you do not continue them.

So, if you have 20 percent alternate fuel biomass rest alternate say something like 20 percent of biomass, they are biomass their carbon is already taken into account. Biomass, their carbon is already been accounted for in finally it s a accounting system as we said, so if I want to find out how much land I would require to capture the carbon dioxide generated, this is for 20 percent if this biomass 40 percent alternate fuel, rest of the 80 percent of got 40 percent carbon.

Then a simple calculation is somewhere here which fuel will have lesser carbon content, so 20 percent of alternate fuel their 0.2 into 16-ton 0.1 it will be 0.032 kg of alternative fuel, alternative alternate fuel per kg of clicker.

So if I am trying to find out in 1 kg of clinker I will require 0.16 kg of because in 1000 kg I needed 160 kg so, 1 kg I need I am look at 1 kg of clinker, will need 0.16 kg of fuel, If average I am taking 100 to 200 we are saying, Now 20 percent of this is biomass. So 20, 032 kg is of alternate fuel, so this is this this 032 kg I own go take into account and not accounted because biomass already, is already accounted in the this would have gone and made carbon if I have not done anything, would made coal later on.

Biomass say, from plant, tree you will go down in will have produce, it will have produce, it would have produced coal. So instead of processing it down below the earth I am using it now therefore I do not take it into accounting, I do not think into account, so this much I can take it out from my accounting and for the rest of the materials got 40 percent carbon, so this is this basically this, this kg total carbon dioxide produced will be given by this.

032 kg, 20 percent I am using I do not see 20 percent I'm using alternative fuel, alternative fuel, so 0.032 kg out of this 80 percent will produce carbon and 20 percent will not produce the carbon. So 80 percent has got 40 percent carbon, so 0.8 into 0.4. 0.032 kg of alternate fuel, per kg of, alternate fuel per kg of clinker because 20 percent I am using alternate fuel.

160 kg in 1 ton, so 0.16 kg of fuel in 1 kg of clinker, it is 20 percent 0.2 into 0.16 kg 0.032 kg of alternate fuel I am using in 1 kg of clinker and out of this again 20 percent is biomass. So this 20 percent I do not account for because they would have produce gone and produced coal after many years, today I am using it, so therefore I do not account it for, and 80 percent will produce, 80 percent has got 40 percent carbon.

So this 40 percent will produce this much carbon dioxide. So this is 0, this is 73 kg of kg, per kg of clinker so which is generally much less than point, remember we said that about 100 to 200kg, 0.51 was the stoichiometry carbon dioxide, and 0.74 minus 51 which was 3 and 2 some amount whatever it is, we calculated earlier now this gets reduced to a significant percent. So I think I will discuss this again in the next class, this part I will discuss in the next class and repeat this because we are going to first close and if you have a question or two I will answer.