Sustainable Materials and Green Buildings
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Lecture 15 - Strength of Concrete and use of Admixtures

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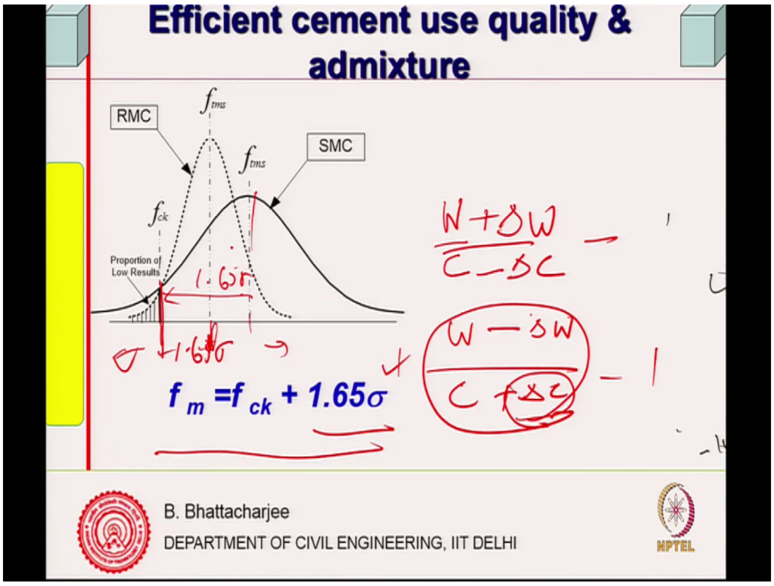

So last class when we finished we were looking at efficient cement use through quality and admixtures and if you recollect this is what I was talking about, you know if you have if you improve your quality then standard deviation will be less because it depends upon how accurately you are mixing proportions, correct proportions you know.

So essentially it will depend upon proportions of particularly with water to cement ratio and I was just talking about this divided by C minus delta C, strength would be lowest when something of water cement ratio is controlled, that water cement ratio is you know the water cement ratio is least value and this will have lower water cement ratio, so the strength variation would depend also it would depend upon proportions of all other ingredients. So but however your structural design is based on this value, characteristic strength which is 95 percentile strength, that means strength that would be exceeded 95 percent of the time.

So we know that this mean strength for which I can measure the mean easily, to measure this or get an idea about this I have to do a large number of testing, that is what we do not do. So what we do is we measure you know we design our mix with respect to mean strength which is given as f ck plus 1.65 into standard deviation. So in this case standard deviation is higher, therefore this value would be 1.65 sigma is higher, so higher sigma means higher mean strength which means that your this has to be lower and in that case you have to have more cement, less water. So cement consumption increases if your quality control is poor right, so through quality control if you know quality has got a role in cement consumption.

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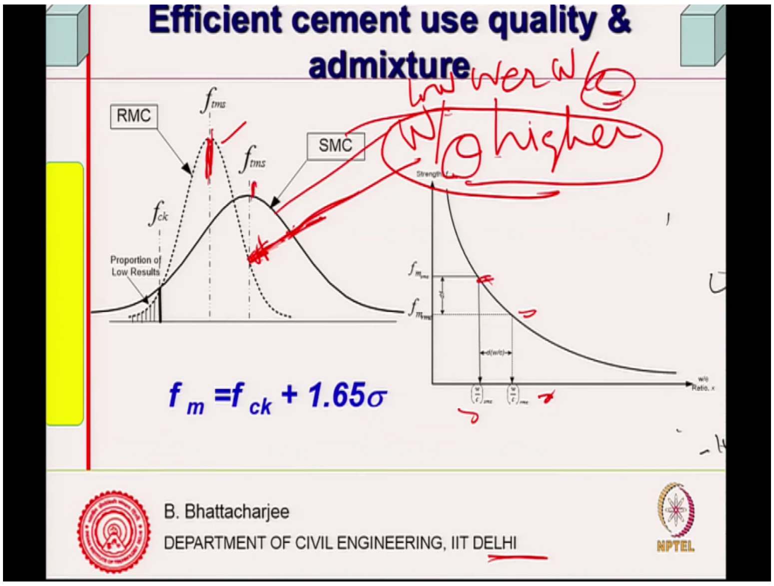

So this is one way as we have seen that higher water cement ratio strength is lower, lower water cement ratio strength is higher. So for this concrete you will require higher water cement ratio, higher water cement ratio for this concrete, sorry lower water cement ratio. Water cement ratio higher for this, this is lower W by C. So this is other way round, this is this I will require lower water you know the water to cement ratio should be yeah lower, water to cement ratio should be higher in this particular case because strength is less.

Low water cement ratio means higher strength right, so this one the strength is less so therefore I can go for higher water to cement ratio. In other words cement can be less. In this one I will have lower water cement ratio because the strength has to be higher, therefore I have to consume more cement for given quantity of paste. So that is what it is.

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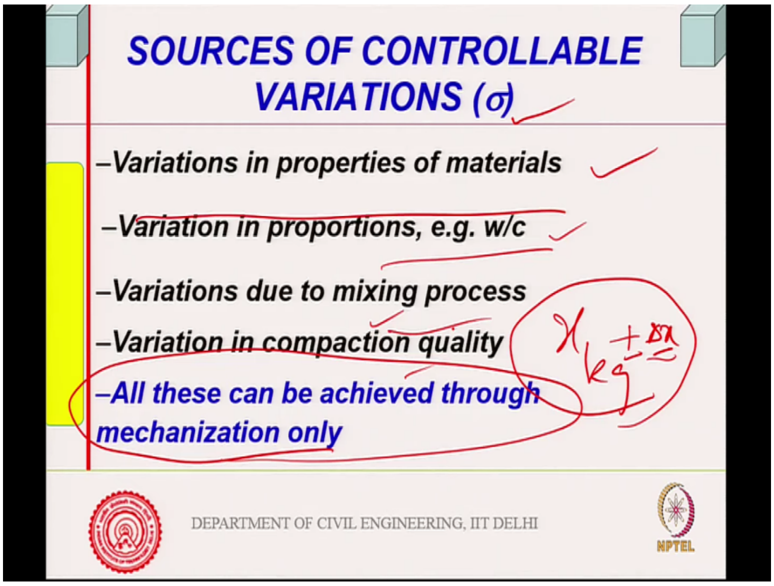

So you see the quality has got a role, quality has got a role and we have been just mentioning why this standard deviation, it depends upon variations in properties of materials. So if you have tested all your ingredients, spend some money on doing all ingredients testing for example aggregates everything, water particularly and so on then variation from material to material will be less. Specifications, it follows all materials follow the specification as desired, so variation will be less you know. And if you do not test them then they can be anywhere.

Now proportion that is what I said, so tolerances in measurement and you know control in measurement should be better so that if you are saying that I will give X kg quantity X kg I should give X plus minus as small as possible delta X that would be if the control is better. So you have a least count of this measuring system should be lower or other in other words the extreme you know better one should be computer controlled system. Mixing process also introduces variation in strength because if you mix it properly you will get less variation in the strength.

Variation in compaction quality variation in compaction quality and so many other you know many other processes many other small small things which are there but all this can be improved through mechanization and industrialization of the production process. So that is what also will make concrete sustainable because it will reduce the cement consumption, it will reduce the all resources consumption, actually that would be you know optimally used everything will be optimally used.

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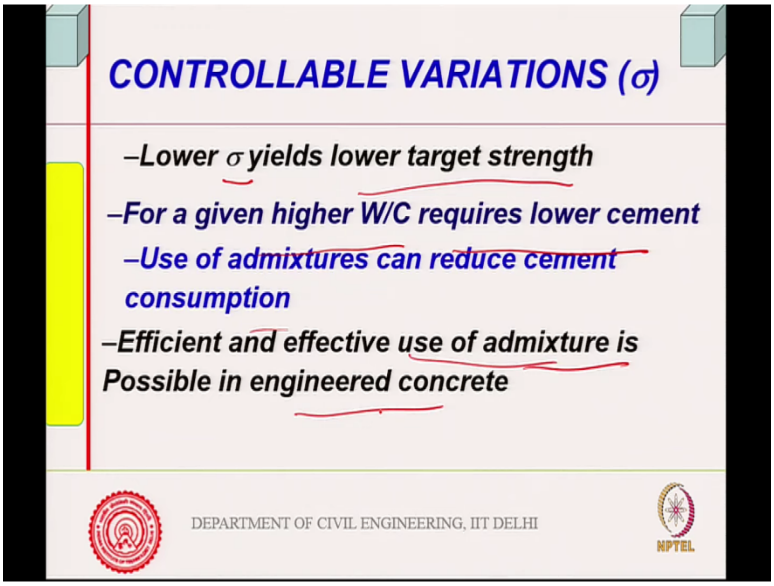

So lower standard deviation means lower target strength for given higher water cement ratio requires lower cement, that is what I was saying. Then use of admixture can reduce cement consumption, super plasticizers you know plasticizer super plasticizer, hyper plasticizers they can reduce and so therefore you can efficient and effective use of admixture is possible in engineered concrete. If it is manually mixed, you do not know how much quantity you are mixing.

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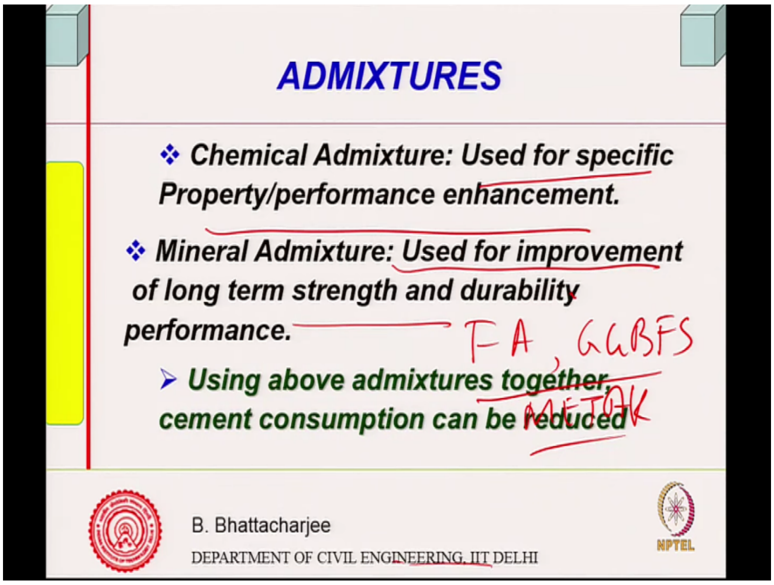

So it has to be engineered concrete and this is particularly admixtures are used for specific performance improvement. Mineral admixtures as I said like fly ash they can be as additive admixture in the concrete or in the cement part itself fly ash, ground granulated blast furnace slag and Meta kaolin, several other things you can add actually. So many other things you can add as a mineral admixture. So you can using all this together you can reduce down the cement consumption, this we have looked into but this you did not look into quickly. We will look into this.

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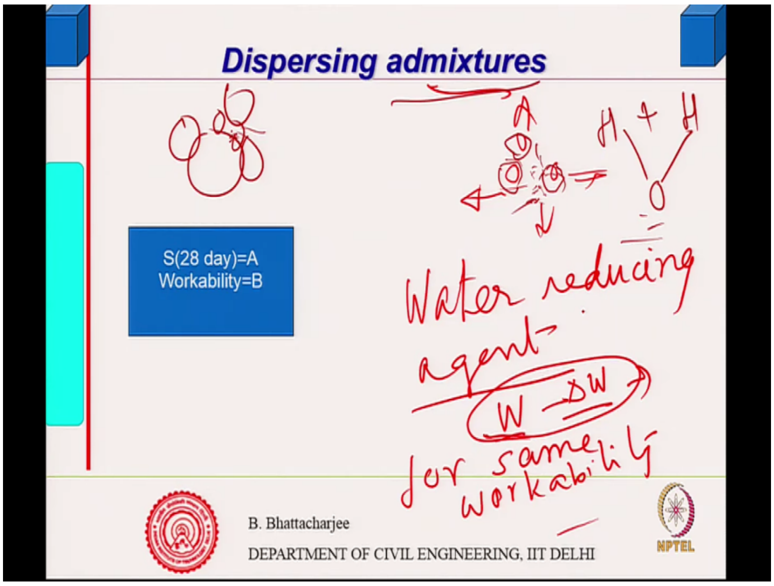

So for example you know this is what this diagram explains, this dispersing admixtures or what we call water reducing agent water reducing agent, what do they do? They reduce down for the same flow properties plastic properties they reduce down the water. So if you wanted you needed W minus W earlier, now you will need W minus delta W for same what we call workability or you know it is essentially flow properties. Compact is ease of compaction so I can cut down onto the water. Why I need water and minimum water content? That is because I need sufficient you know flow properties to compact it easily.

So if I use this dispersing admixtures which actually pushes the particles cement particles or such particles away from each other, they push cement or such particle away from each other causes dispersion and also we know that they also we know that they form a sheath of sheath of charges in some cases. In some cases therefore effective sizes increases and therefore when they form sheath of charges here, water molecule here tends to orient themselves according to the charges because water is a dipole you know as we know water is a dipole.

So this is the positive charge, this is the center of the negative charge so they do not coincide and therefore this is a dipole. So this can orient itself because if it is a calcium rich system and this admixtures which are you know negatively charged there they have been, they are radical which are negatively charged which gets attached to the cement particle or cementitious particle and converts you know creates a negative sheath of charge around, there water can get oriented because positive charge of the water, positive you know water will be oriented, so they are attached to the cement particle in an ordered manner.

This also causes release of some amount of water, particle gets separated so in a clogged up system you will require more water. If it is clogged up system you will require more water and still you would not get plasticity so you will require higher amount of water because water to cause this separation and penetrate in between the interstitials you need more water. You know in a clogged particular system lesser the surface area for the same water you need more water to separate them out or push them out but if this is done using admixtures then obviously you will require lesser water.

So one thing is that particle themselves get separated out because of their similar charges or size effect what you call steric effect you know in chemistry so or electrostatic charge effects. So they get separated themselves, so water now gets easily attached to the surface and they are oriented in a systematic manner rather than random manner therefore quantity of water gets reduced for the same flow properties. So if that is the case and use and this quantity needed is very small you know quantity needed is very small not more than 2 percent of the cement, so therefore the cost benefit is very much there.

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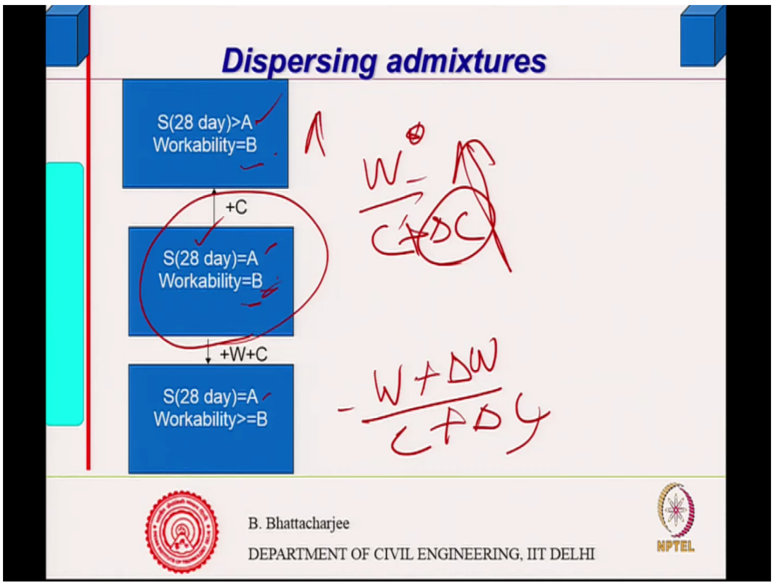

Now you can cut down onto the cement with this, for example if I have a concrete with 28 days strength A and some measure of the flow property or workability as we call it B and I want to increase this strength and keeping the workability same normally without admixtures. What would I do? I will add some because this will happen when W by C is lower than this, so now W dash and C dash this is lower than this, this is to be lower because B is same so I can keep the W same but C I will have to add.

So I will add some cement so that water cement ratio reduces and I get higher strength higher strength, so that is what I am writing add some cement. If I want to increase the workability and keep the strength same I have to add water, so I will add water in this case, I will add water. But if I add water and keep the cement same, strength will reduce. So what I do? I add some cement also. So both the cases you are adding additional cement, so this is what it will say W plus C and I am adding some W and adding plus cement as well, so this is how I can increase or reduce my strength.

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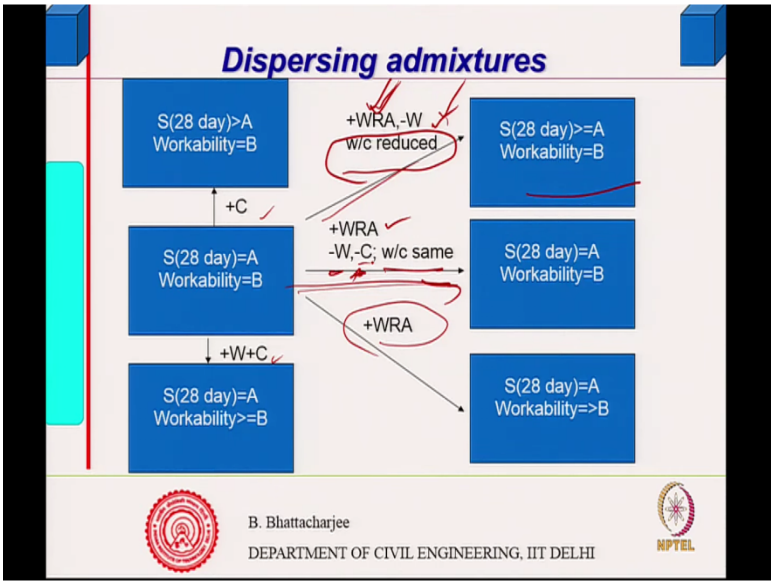

But supposing I am using admixtures like water reducing agent WRA then using this you know this WRA I have added I will reduce the water and then I can reduce the automatically keep the cement same. I need not increase the cement I can keep the cement same or I can design the system of course, I might even reduce the cement or you know accordingly I can do so what is just add WRA water will reduce W by C reduce therefore I get higher strength.

So you see and if this is to be maintained same then I add WRA, I can reduce water I can reduce C keeping the water cement ratio same, I will get same strength, same strength and same flow properties. You see so therefore reducing cement I am reducing cement, in this case I do not have to add cement here and if I want to add workability simply increase WRA and the cement issue is not there. Here I was indicating cement both the cases I do not have to.

So normally if I am not, you know this is not I am not playing around but simply I can do this and this ensures that I reduce the cement if I am using, dispersing admixtures or plasticizing admixtures. So therefore again this allows me to reduce so reduce the amount of cement and amount of water also, so therefore this is you know dispersing admixtures obviously adds to sustainability.

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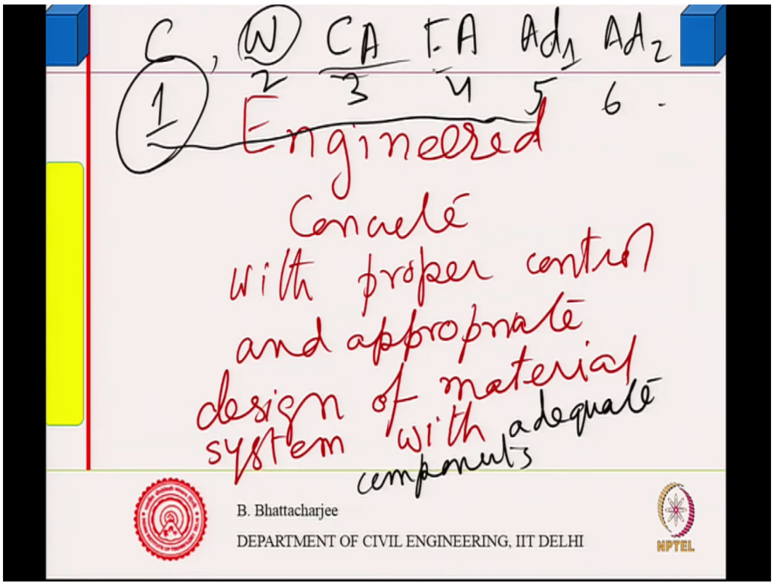

In other words I say that engineered concrete with proper control and appropriate design of material system with you know possibly not one you know normal concrete is essentially normal concrete is essentially cement that is one component, water the second component, say coarse aggregate third component, fine aggregate fourth component.

I can have number of admixtures, admixtures one which could be mineral admixture, fifth admixture, two which could be chemical admixtures, six or may be more with more than or you know adequate components, adequate components. Not just four component concrete which was conventional earlier or just 5, 6, I can have different types of admixtures added to it, they will always add to sustainability because you will reduce down C and you will reduce down others also. Proper design of coarse and fine aggregate system, their shapes production process et cetera they also add to all this. So this this is you know this will make concrete sustainable, this can make concrete sustainable.

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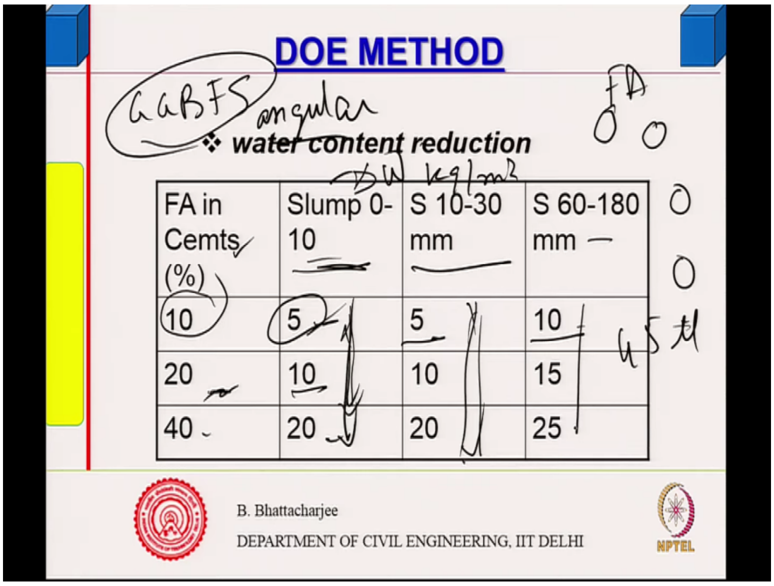

Now this is this shows that if you reduce down in case of fly ash there is something specific because you can reduce down the, if you use fly ash which is spherical in nature one of the mineral admixtures unlike ground granulated blast furnace slag if you remember which I said is angular. Now this is spherical in nature fly ash, therefore addition of fly ash in as 10 percent of the cement for example if you add, if your slump which is the measure of workability between 0 to 10, you can reduce down the water content by 5 kg per meter cube of concrete, 5 kg per meter cube of concrete.

So this in kg per meter cube of concrete. If it is 10 to 30; 5, 60 to 180; 10. And if you are using 20 percent fly ash so you can increase the fly ash content, do not go beyond 40 obviously because we have seen stoichiometrically it is not useful and otherwise also they will have you know excess fines in the system.

So as you increase the percentage of fly ash used in the system you can cut down on water. So fly ash also acts like plasticizer somewhat you know it is not exactly but it improves the water reduction can be achieved by using fly ash not necessarily with this in its ordinary condition because this is angular, just because of this spherical shape which packs better and also the sizes are important. So there which will pack the cement system because they go you know some particles will go inside the cement system.

So if you have sufficient particles below 45 micron that seems to affect, have this effect more. So you can see that you can, you know this is the delta W minus delta W, the amount of water reduction water content reduction is possible with use of fly ash. So you see this if you use a

6 component concrete let us say, you are using some amount of OPC some amount of fly ash and super plasticizer or hyper plasticizers which are dispersing admixtures, water reducing agents, then you can cut down onto the cement consumption together with water consumption as well. So this is this is advantageous specific to fly ash.

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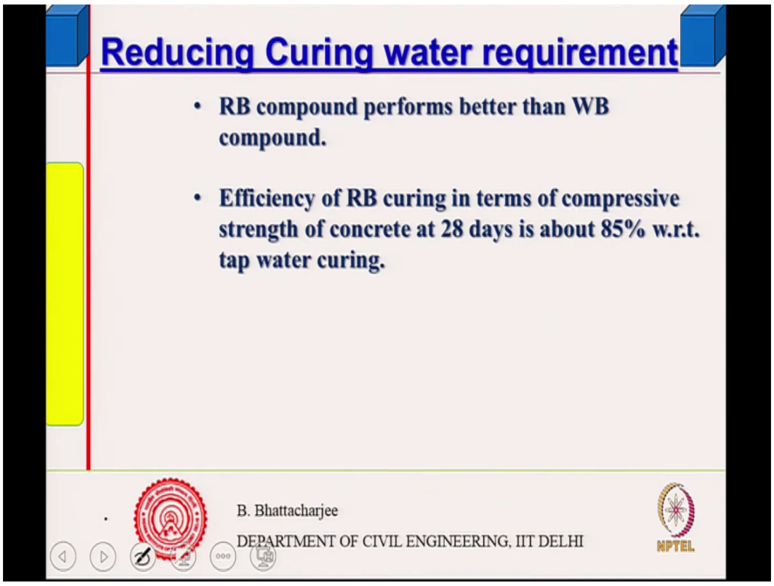

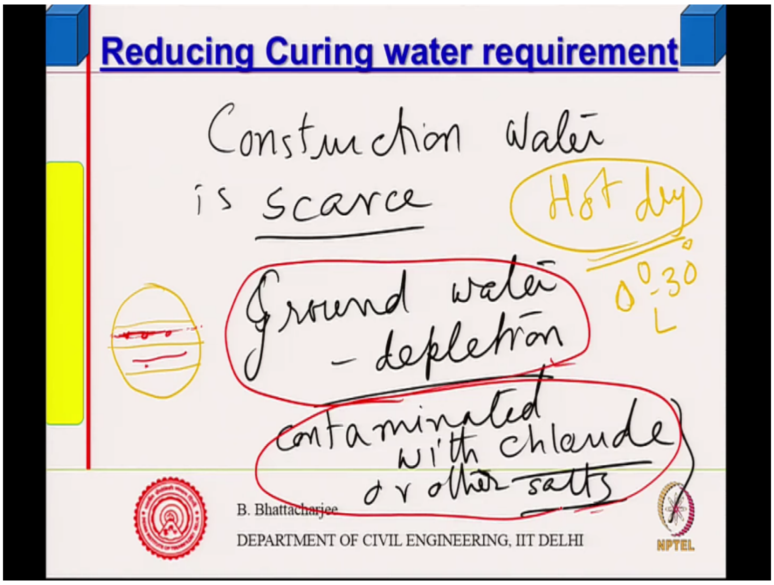

The next one is reducing the curing water requirement because water is also a resource and as you might be knowing, as I said some parts of the country in India or it would be rest of the world also, the construction water is scarce. People have been using groundwater and there is a depletion of the whole thing. So there is groundwater depletion and besides that groundwater is quite often contaminated with chloride or other salts which are dangerous for construction which are dangerous for construction concrete construction I mean.

So therefore you know one is the water, reduction in the water sources there is a reduction you know particularly in areas or dry desert climate depending upon the climate where tropical climates. For example, one of the tropical climate is hot dry climate which is in the 15 degree to you know generally it will 0 to 30 degree latitude. In some place you will have hot dry desert, so interestingly if you look at globe, this is your equator, this is the tropical areas, you will find that all the deserts lie almost in the same latitude same latitude.

All the deserts almost lie in the same latitude, for example you will find you know in similar latitude you will find somewhere the Thar Desert, the Arabian, Baluchistan then African Sahara desert all belong to land area. If you look at it they belong to the same line, similarly you go there somewhere you will find Kalahari in Africa, Latin American deserts, Australian deserts they fall into the same line, so there you find similar climate. So in these ones water availability, rainfall is less and water either I mean unless you are storing yourself it gets stored into the groundwater.

So if you want water for consumptions of populations, groundwater depletion is likely to occur and this has got the other problem also. Also in the Indian scenario if you look at let us say NCR region, many places one has to show where is the source of your construction water, so otherwise the construction is now not being permitted legally. You cannot use sea water directly because this is chloride treated so you have plenty of water on the surface earth, but you cannot use some of them because if it is chloride ridden then it is dangerous, so directly you cannot use.

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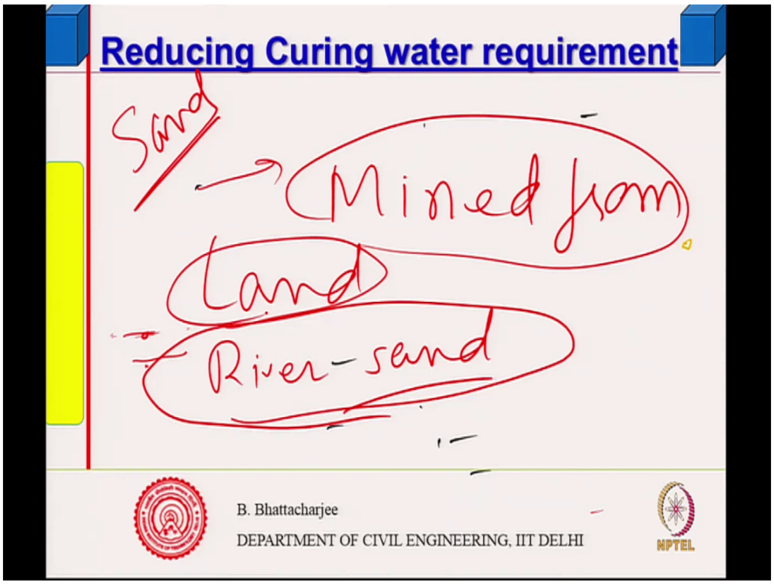

So this construction water is you know is also a problem. Generally water, the sand these are, these resources are becoming scarce. For example in NCR earlier what they were doing? NCR, earlier what they were doing? Earlier they were all as far as this is concerned, so we will see that later on sometime later on related to the aggregates we will see, right now we will look at water. But just let me mention about this right now. See this was actually mined from land, many other places they use river sand, now when you use the river sand you are creating maybe separate path for the you know water, there will be water logging at a localized place and river course. You are disturbing the rivers course altogether, so many places this is banned and this is mined from land and not only that it has actually disturbed the groundwater situation, at least two lakes were around which are not there now because the aquifer has been disturbed.

There is one lake, Surajkund around Delhi and it is just not there now, 30 years back one would have done some boating there, today it is all dry. There is another lake also nearby there just bordering in the NCR region Haryana Bathkal Lake, no water. That is because the aquifer has been disturbed by construction activity and the water has gone away and the aquifer does not exist now, it does not get recouped or recharged and so on. So this is also a problem we will come to that sometime later, now let us look at water more closely now.

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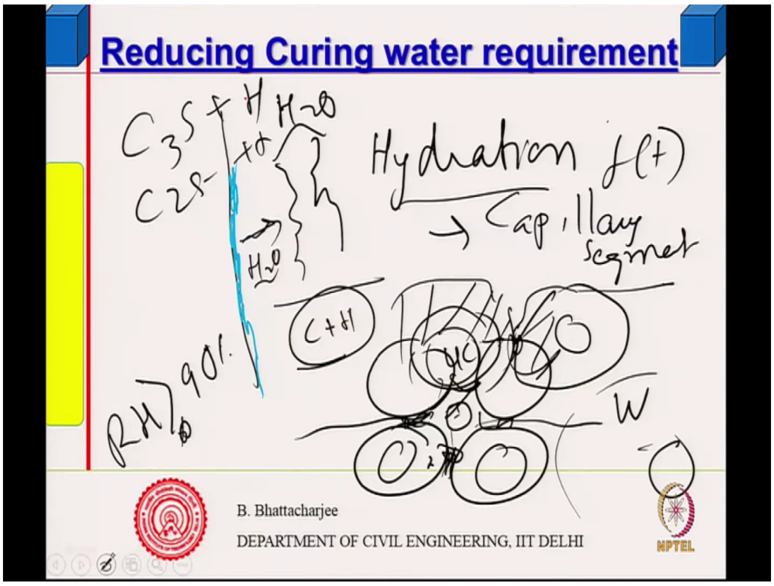

So you know if you look at curing water, curing water is also not less, first is the construction water another is a curing requirement. So there are curing compounds, now what you do with the curing compounds, first is the curing then we look into the construction water as well. You can you know if this is your concrete surface if this is your concrete surface you simply apply this curing compound on top, you apply simply curing compound on top you know you just apply them, brush application or spray application. Now why do I need curing? Essentially to continue with the process of hydration reaction you know hydration must continue which is not instantaneous, it is a function of time.

So it must continue number one, ensure capillary segmentation because as the hydration progresses hydrated cement occupy the spaces surrounding it, this is unhydrated cement unhydrated cement this is a hydration product and hydration product from another cement when this also touches it the capillaries are segmented. Earlier you know earlier this is one cement this is another cement, if there is a if the hydration product still are separated from one another, one particle hydration product of cement particle is away from the hydration product of the another cement particle then there would be interconnected pore system will existing because particles should be like this particle should be like this. These are your larger pores but this will be interconnected through these spaces.

But when the hydration product touch each other when the hydration product touch each other, capillaries are what we call segmented so I need minimum number of curing days for segmentation of the capillary, minimum number of days of curing for say segmentation of the capillary. So hydration should continue for segmentation of the capillary that is number one and this segmentation of the capillary depends upon the days for segmentation of capillary depends upon water cement ratio, higher the water cement ratio it will require more days of curing because the space around the cement particle is larger now, more water less cement. So here is more space so it has to be filled in. So this capillary segmentation is important.

Capillary segmentation, this is one issue and why do I need second thing? If it dries off there can be shrinkages occurring at the surface cracks might come. So shrinkage cracks and capillary segmentation otherwise durability will be the problem and strength development. All put together I need curing to be done, now curing to be done means I must supplement the water which evaporates out from the surface, right. So if it is a horizontal surface vertical evaporation will occur water will go away, H2O will go away, even here H2O will move away from this one, evaporation. Besides some H2O reacts with cement, so H2O reacts with cement and therefore there is what we call self-desiccation.

So self-desiccation occurs and some water evaporates out, I must replenish this water otherwise this reaction do not occur, these reactions do not occur. So cement reactions do not occur unless I have sufficient water in the system, relative humidity must be more than 90 percent you know 90 percent, RH should be 90 percent then only within the pores only reaction progresses. Therefore, I must keep them in some manner moist and I need water for that I need water for that, so need for curing quickly you know is required for hydration process to continue such that at least capillary segmentation should be there, capillary should get segmented and also the strength development would occur only when everything every particle touches each other then also required to avoid shrinkage, drying shrinkage, cracks at the top so that it does not become dry.

So you know such kind of dimensional instability such as shrinkage, shrinkage cracks coming in such things should not be there. For this all I need curing, curing is also required to supplement the self-desiccation water, the water which goes in chemical reaction.

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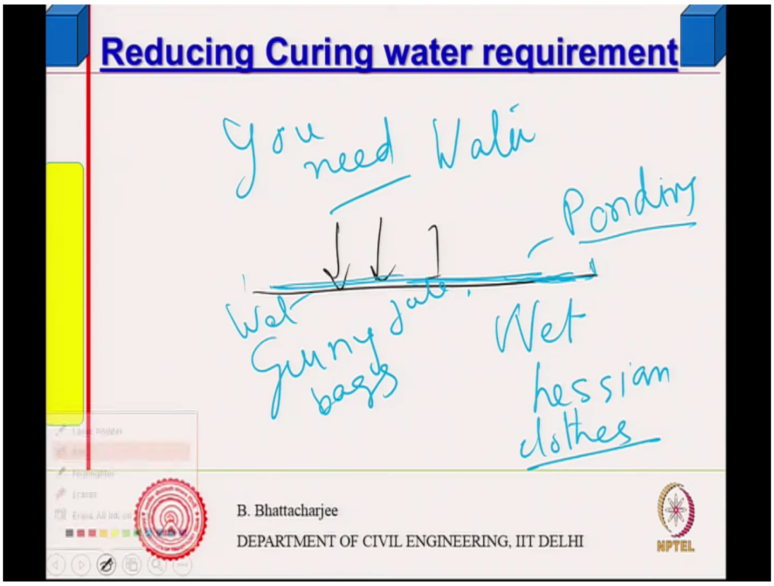

So if I what is the best way of curing? I will not go too much into the curing aspect right now because best way of curing is put water, you know so one way is you know horizontal surface, one way to put water onto the horizontal surface is pond it, ponding.

Ponding will not allow evaporation from the concrete; I am not talking of not small elements small elements you can submerge into water that is the best theory. But flat surfaces like slab deck of a bridge or something of that kind, that you can actually do ponding or you can even put ponding you know like just spray water all the time, let the water be there or you can do is wet hessian clothes, hessian clothes some thick clothes or gunny bags, wet gunny bags not plastic jute bags, jute bags or similar kind of thing which can hold onto the water for longer period of time, put them on top.

This is what but all these cases you need water, you need water for this. Supposing I want to cut it down, now this will do what, this will replenish the water both cut down the evaporation loss and replenish the water that has gone in chemical reaction, self-desiccation as we call it.

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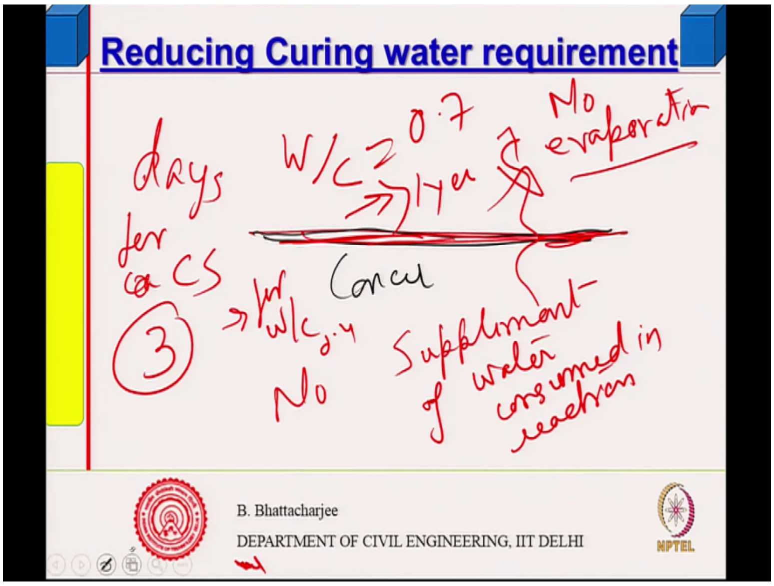

Now instead if I do not want to use water what I can do is I can put a membrane you know membrane curing as we call it, membrane curing or curing compound. So I have a membrane, this is my concrete and I have a membrane here that means brush application, put a layer. This is my concrete and brush application I put a layer, I put a layer on top of it such that no water can evaporate, no water can evaporate, no evaporation.

So evaporation loss will be reduced no evaporation, no evaporation, so evaporation loss will be stopped. But evaporation loss will be stopped but this will not supplement the, it will not supplement the self-desiccation. So supplement, so no supplement of water consumed in reaction. So it cannot be as good as the ponding or submerged curing but here I do not need water. So what all you can do is, you can design the system possibly with a slightly lower water cement ratio because we have seen that days of segmentation, capillary days, days for capillary segmentation or capillary segmentation, let me put it like this, depends upon water cement ration.

For 0.4 water cement ratio, for 0.4 water cement ratio this requires about three days, for W by C equals to 0.4. For W by C equals to 0.7 for W by C equals to 0.7 this could be more than a year, more than a year and still may not segment. So it is a function of water cement ratio, so if you are not able to do moist curing by ponding might reduce the water cement ratio slightly. So slight increase in the cement content would be there but water you would be saving or use plasticizer or things like that, judiciously engineering designs has to be done, but this can be done and this ensures that whatever you have done this will work. So this is what we call as membrane curing, membrane curing right or you know curing compound.

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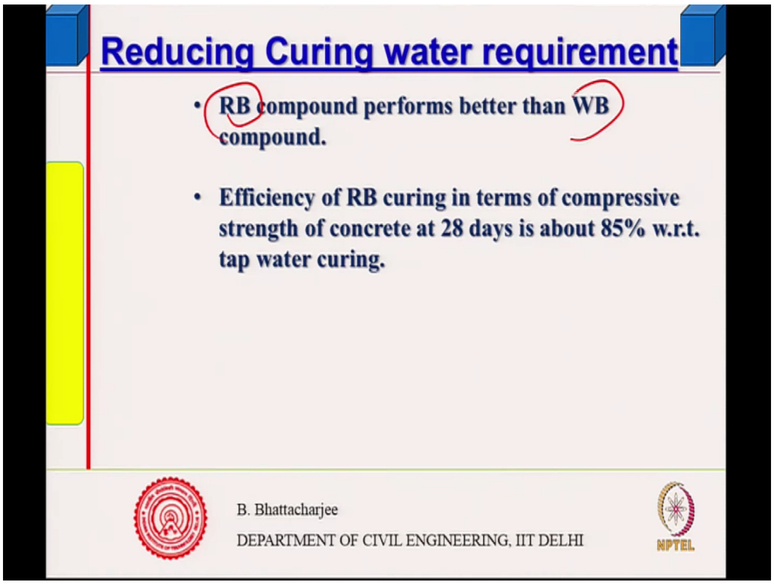

So this is, there are varieties of type we will just look at them, so if you have some question I will answer, then we will come to this. The resin based and wax based, these are the two types of compounds we will see that actually and then instead you can use treated wastewater, so we will see into all of this right now. Any questions if you have I can answer.