Concrete Technology
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Lecture - 16
Mix Design of Concrete: IS Example and British (DOE) Method

Welcome to lecture three, module four. We will recall that in the last lecture we looked into the Indian standard method of mix design. We will continue to look at that with an example, now and then will start with British DOE method.

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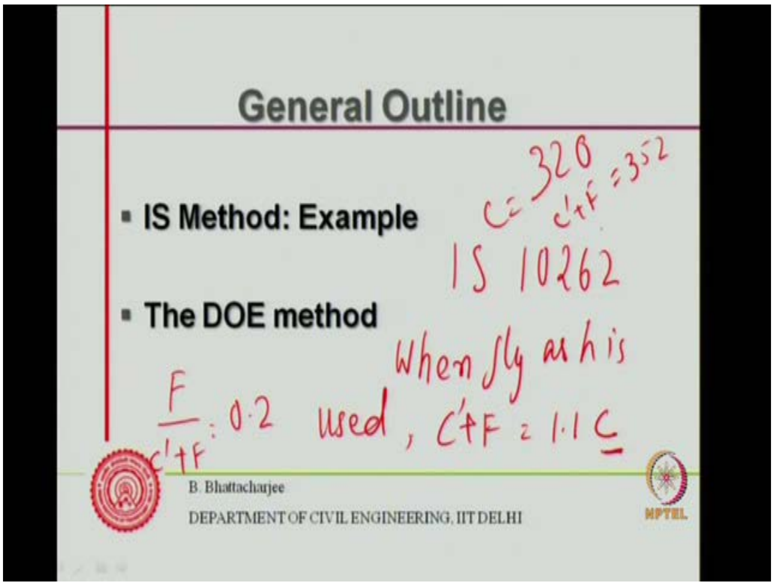

So, our general outline of this lecture is IS method example and the British practice of department of environmental of DOE method. So, just to recall the last when we discussed we said that if you are using flyash, if you are using flyash in with cement the IS method IS 10262 method, when flyash is used. It is recommended that you increase the cement plus C plus F should be C dash plus F should be 1.1 C, where C is cement content without flyash. If you are using flyash increase that cement content by 10 percent and that must be the some of the cement plus flyash content.

So, if you know F divide by C dash plus F you have decided, let us say use this as 20 percent flyash in the system. Then from these two equations you can find out the flyash and the cement content itself. Using this two equation one is that increase the total by 10 percent, so 1.1 C. You have control mix without the flyash which will have cement content of C kg per meter cube. Now, let us say is 320 was the C, then C dash plus one F will be let us say something like 352 or somewhere close to this you can approximately take that guideline. So, if you know F by C dash plus F you can find out the value of C dash and F where C dash is the new cement content and F is the flyash content that you are using in the concrete.

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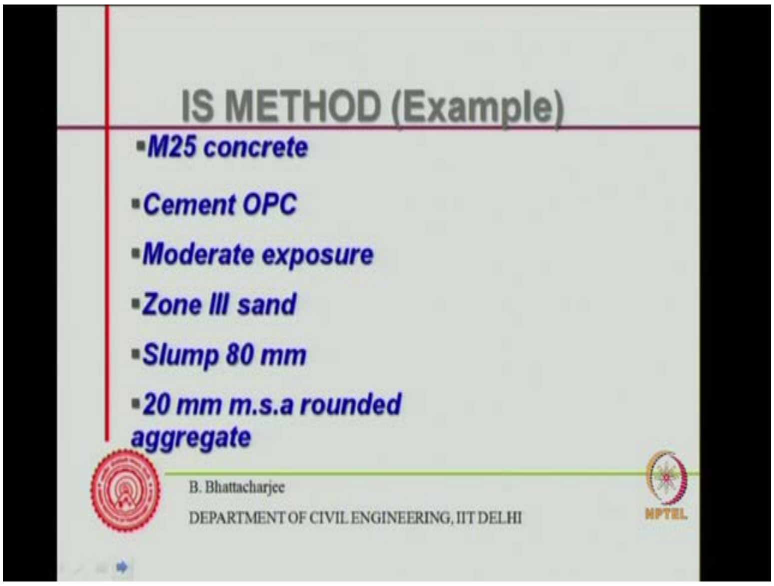

So, this is just to recall what we are last discussing. We also said that we need some correction factor for moisture content at the field and in our example we look into these issues. So, right now we look into an example using right now we look into an example using you know through IS methods. So, the example is we are assuming I mean we are choosing an M 25 grade of concrete, we are assuming M 25 grade of concrete. Cement, we are using OPC and assuming moderate exposure as far IS code is concerned, zone three sand, slump is 80 millimeter normal strength concrete and 20 millimeter m s a rounded aggregate that is what we are using.

So, IS method will be used to find this out. Now, you recall that in IS method first step is to find out the mean strength and target mean strength as we call it f m is equals to f c k plus 1.65 sigma, that was the first step if you remember in IS method. Since, you know we do not have any data available, let us say that the starting point we are taking standard deviation as 4 MPa standard deviation as given in IS 4562000 or in 10262. So, I have standard deviation as 4 sigma as 4, grade strength is 25 MPa, my target mean strength if I calculate out based on this formulae based on this formula then I get equals to 31.6. So I chose mean strength of 32MPa and design the concrete.

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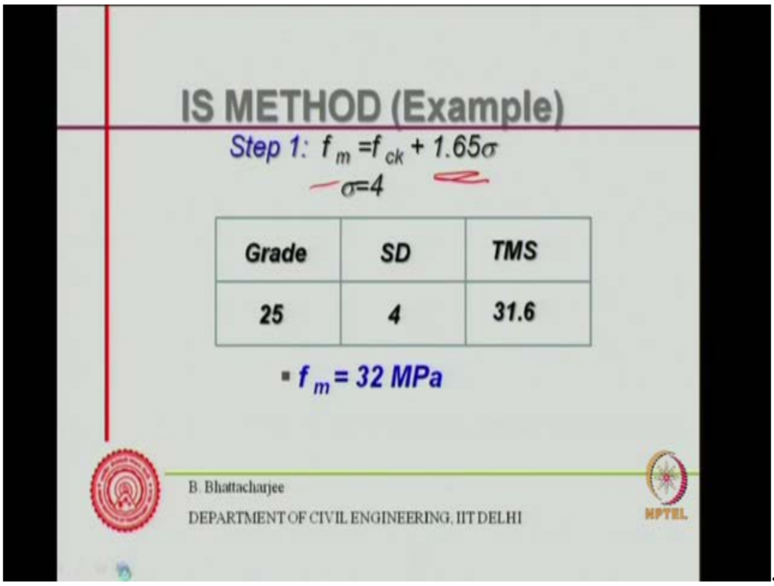

So, first step was to find out the mean strength because as we said in the last class, that I can get an estimate of the mean strength to my cube stress results very easily with samples by testing samples, but f c k I cannot get directly. Then, you need to test large number of samples which is not very easy to do. Therefore, we design the concrete mix for target mean strength and the mean strength is we have found out is 32 MPa.

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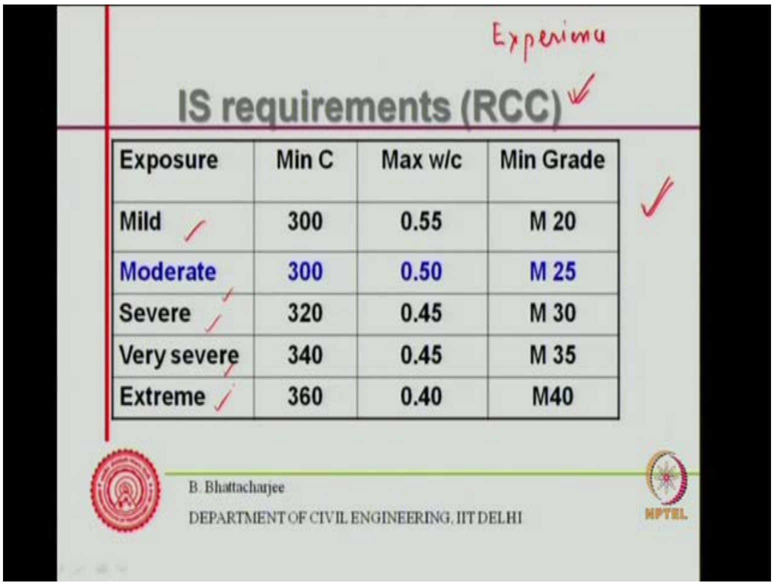

Then it says that you moves there water content from experience or if nothing is available, so either from experience past experience if it is available or from table file of IS 456 2000, you know from durability requirement. This is the table which gives the durability requirement this table is IS 456 2000 durability requirement table. This is the table and if you see the prescriptions those are given for various exposure condition mild, moderate, severe, very severe and extreme.

The Indian standard code IS 456 2000 has actually classified the exposure environment to this pipe class s, namely mild, moderate, severe, very severe and extreme. Correspondingly, the prescribed minimum cement content and maximum water cement ratio and minimum grade of concrete are given in this table. This table is reproduced from IS456 2000.

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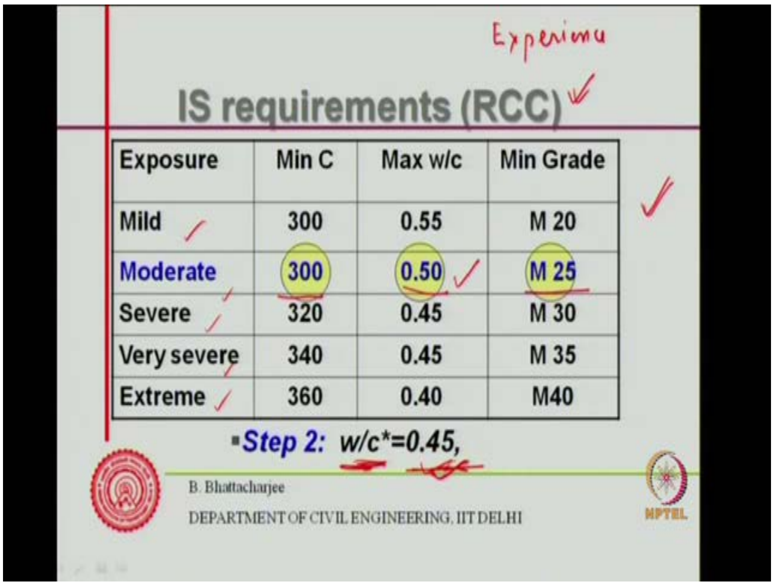

Now, I also mention in our problem earlier problem if you look at it, our exposure condition was our exposure condition was exposure condition was our exposure condition was moderate exposure. Therefore, for moderate exposure if I look at into this table for moderate exposure if I look at into this table then the one which is colored blue minimum cement content is 300, maximum water cement ratio is 0.5 and minimum grade of concrete is 25, so we are doing design for M 25.

Therefore, these are the relevant one M 25 and this is the maximum water cement ratio permissible and this is minimum cement content permissible. However, from experience

I take the water cement ratio is 0.45 deliberately just as an example. Suppose I feel that well 0.5 I am not able to get 32 MPa mean strength, I put it as 0.45. So, these are the two cases either I take this or this. Now, since my experience says I should be taking this, so water cement ratio start is 0.45.

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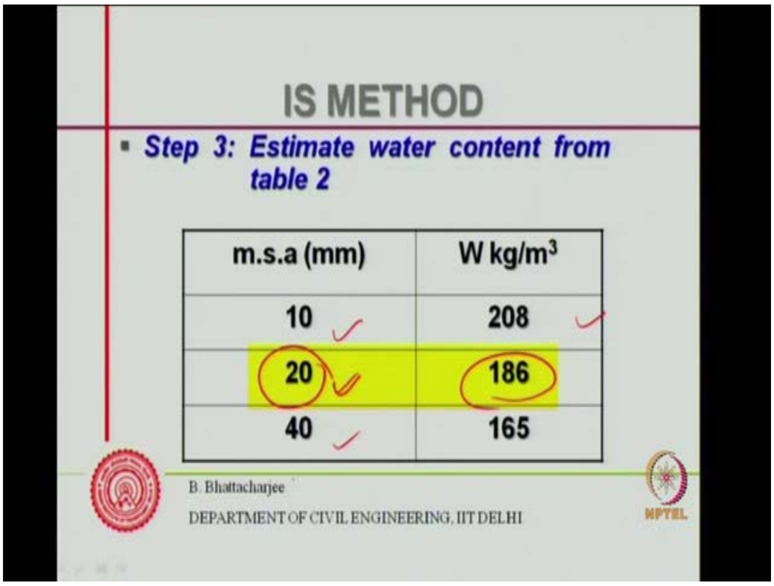

m.s.a (mm)	W kg/m^3
10	208
20	186
40	165

What I am saying is the water cement ratio we are using is 0.45, whichever is smaller, so I am using 0.45. Then next is estimate water content from table 2 of 10262, you know this table gives us the water content in kg per meter cube of concrete depending upon m s a. I am using m s a 20 mm, so this is my thing I should use water content of this. Therefore, this is the line, so 20 mm m s a prescribed, as we are seen earlier in the beginning. Therefore, my starting model content is 186. Now, this is meant for the slump of 25 to 50 and crossed, so I must apply some correction factor.

This correction factors are, this because this table as for angular course aggregate and slump of 25 to 50 for each increase in slump of 50 millimeter fraction. Therefore, I will increase the water content by 3 percent, so I increase 186 by multiplied by 1.03 by aggregate is rounded. So, I subtract because this is minus for rounded aggregate, since the packed better there packing is better. So, they consume less water in the mix for the same work ability, paste content will be less baking better therefore, minus 25.

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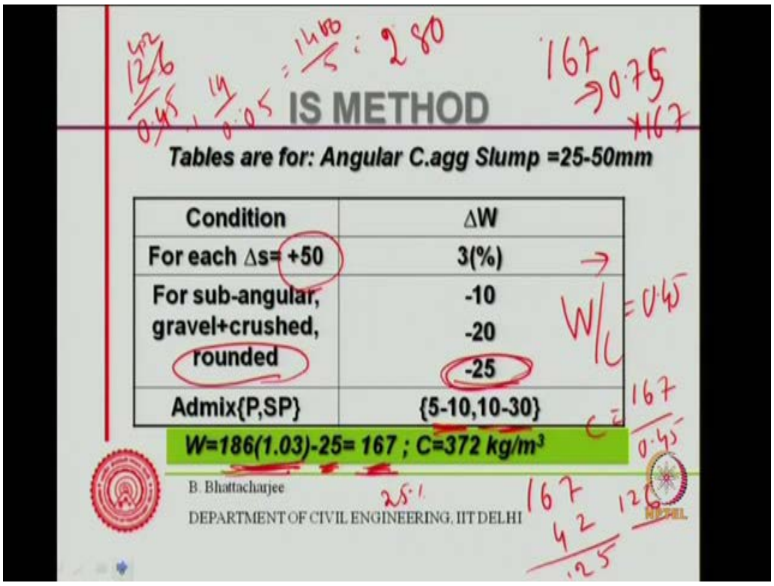

So, my water content therefore, would be 186 into 1.03 minus 0.25 minus 25, which will give me 167 with a water to cement ratio of 0.45, so cement will be 167 divided by 0.45. So, this will be my control makes if I am not using any super plasticizer or plasticizer, if I decide to use plasticizer my water content will reduce. Let us say if I decide to use super plasticizer I can reduce my water by 25 percent, which means my water would be simply you know 75 percent of this.

So, basically you will have if I use a super plasticizer at the moment in this example I have not considering super plasticizer, but if I intend to use of plasticizer I can it reduce it by 25percent by using appropriate quantity of appropriate dosage of compatible super plasticizer. So, 0.75 of this will be 167 minus 42 or 41 less you can say, so this will be 5, so what about of 125 or 126 a liter per meter cube of water I can use, the cement also. Therefore, it will become 126 divided by 0.45 which will be you know some something like if you can see this you know 3.15 or this will be 42. So, this is 14, 14 by point 14 by should be you know 42, 42 divided by 42, you know if I divide it by 9, so I get 0.05 and 14.

So, 1400 divided by 5 is 280 kg, so I put use this 280 k g of cement if I as using super plasticizer and reducing down the water content by 25 percent, because my water would become water would change from water would change from water would change from

167 to 0.75, 75 into 167. Just let us see, how this is for all controller, just let us look at it first the calculation part of it then will come back again.

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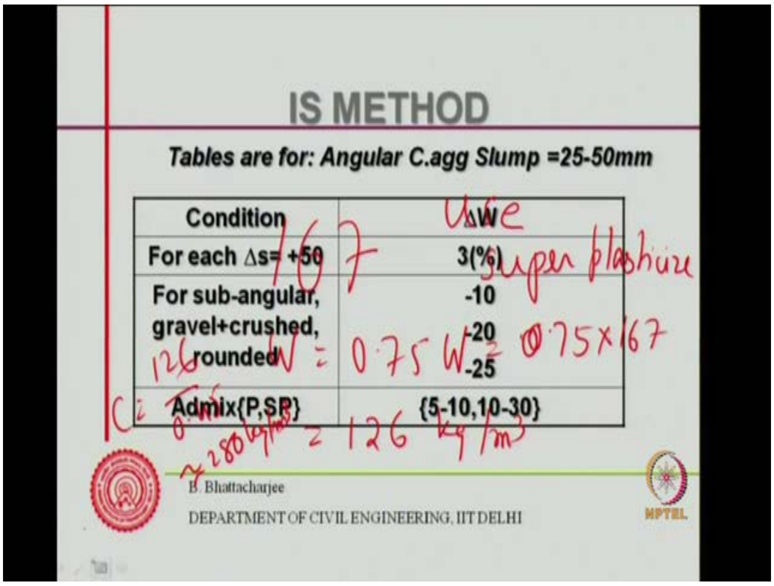

So, first of all what we are saying is that 167 was the water use super plasticizer w will become 0.75W, 0.75 into 0.70, 0.75 into 167 and that was equals to 126 let us say kg per meter cube. So, cement will be 126 divided by 0.45 which will be approximately equals to 280 kg proportion meter cube. So, you see saving as cement as well 280 water is less, cement is less.

Anyway, that is why just I wanted to show that if we use super plasticizer for same work ability you can same amount as the cement which we are seen earlier when we are talking about admixtures, so which we have seen earlier when we are talking about admixtures. Now, in this particular case of the control mix however your water is 167, cement is 372 kg per meter cube, but if use a super plasticizer, this will become 280, this will become 126 or something like that.

So, any way this is how we do the select our water content, now we got our water content and we have also got our water cement ratio, we will come to this later on. Now, from the table four, you can estimate the course aggregate volume in total volume of aggregate. We said that our sand was zone three, so this is our zone three sand, we are using a 20, therefore, this is not correct 0.485 using m s a 10, but if I am using 20 then it is 0.64.

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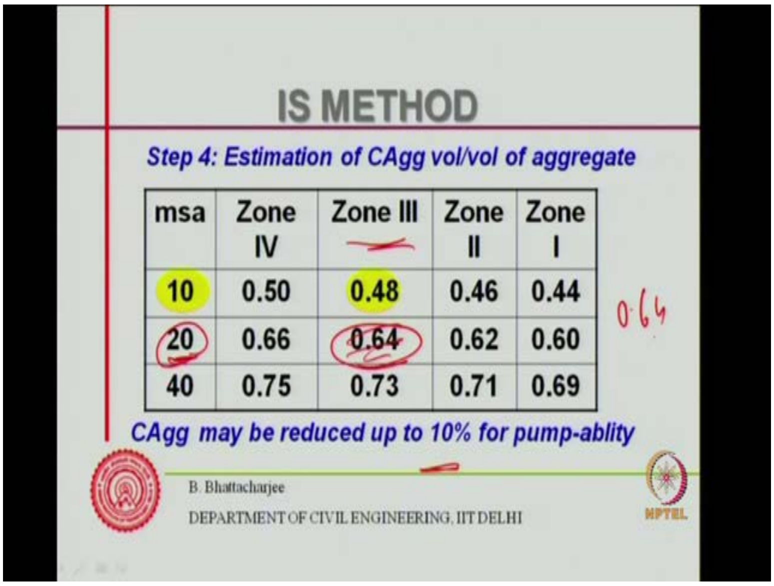

So, if am using 0.2 t, if I want it to be pumpable which is not there at the moment. Then, I can reduce it by 10 percent, but at the moment I have said It is 80 slump concrete only, so there is no question of pumpability. So, in my case therefore, this would be 6.64 with m s a 20, so m s a 10 it would been 48, m s a 20 it is 0.64, so my calculation should be done on the basis of 0.64.

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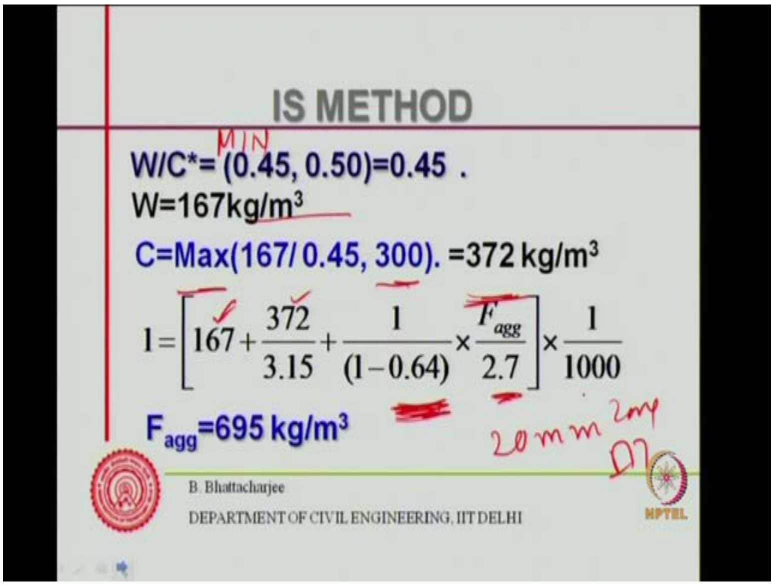

So, water cement ratio is the minimum of this two and is 0.45, minimum of this two and is 0.45, we found out water is 167 kg, cement is 167 divided by 0.45 or 300 from the durability requirement. So, maximum of this two and it is gives me 372 kg per meter cube. So, control concrete without plasticizer has got 372 kg of cement content and water cement ratio 0.45. Now, based on this 372, I can find out because we have chosen this has 0.64 right and chosen this has 0.64 because for 20 mm zone three sand, we got aggregate is in the total aggregate course aggregate is 64, so fine aggregate will be 1 minus 0.64.

So, fraction of fine aggregate will be, so the total aggregate if I want to find out divide the fine aggregate mass divided by its specific gravity and divide this by 1 minus 0.64. That must be equals to you know, so this is a volume of water this divided by 1000, this divided by 3.15 and 1000 gives me the volume of cement. This gives me the volume of total aggregate because this is the mass of fine aggregate and fine aggregate occupies a volume of 1 minus 0.64.

So, if I divide this by point 1 minus 0.64 that will be the total volume of aggregate. So, aggregate divided by specific gravity volume of fine aggregate, divided by the, you know this term gives me the total volume of the total aggregate. So, fine aggregate quantity I can find out from this and it comes out to be 695 kg per meter cube.

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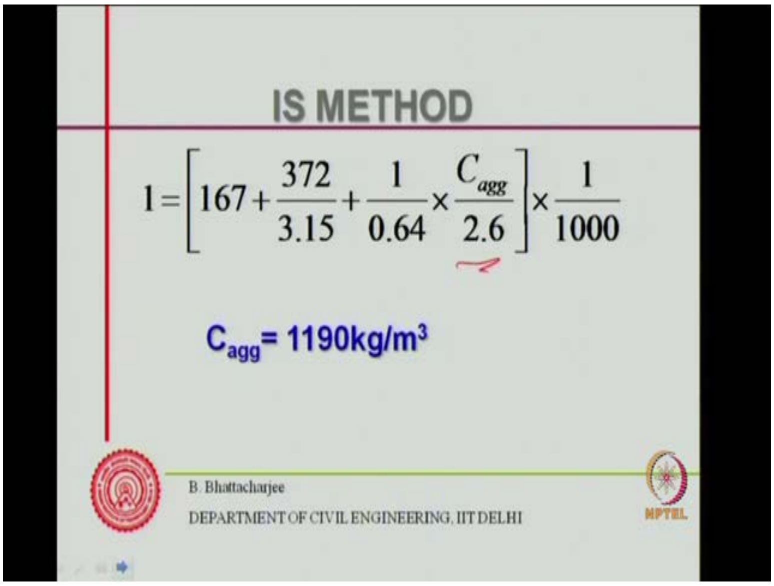

So, now course aggregate I can calculate from the same formula, only thing it will we have see course aggregate divide by 0.64 and specific gravity of course, aggregate is 2.6. So, on that basis I get course aggregate is equals to 1190.

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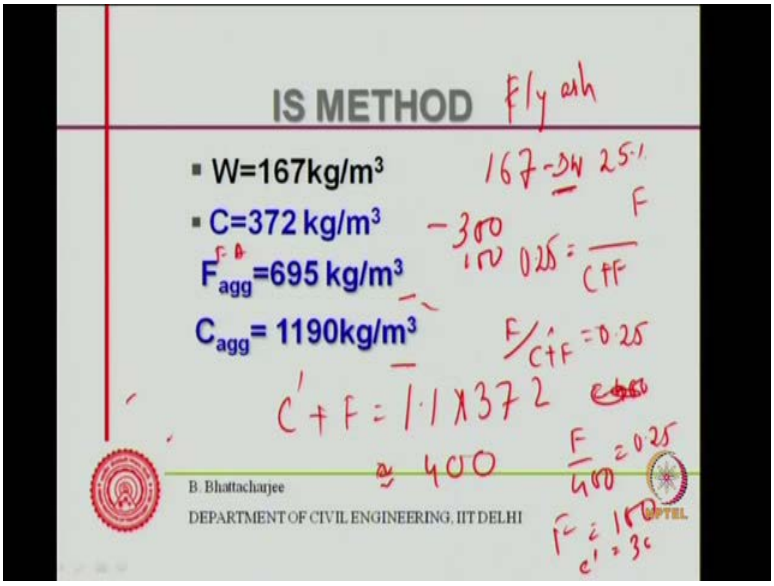

So, my control makes without super plasticizer and without flyash or anything, you know the mix without flyash or super plasticizer I may not say this is a control mix. This will be a control mix if I am using a flyash or using a super plasticizer, then I have to find out change its mix design for the super plasticizer and for the flyash as well.

You know will just do this calculation as well quickly or it is show the steps, so the water is 167, fine aggregate is 695 and course aggregate is 1190 kg per meter cube. Now, if I have using flyash super plasticizer then W will become the super plasticizer, W will become 126 this will become 280. Correspondingly, then this you can find out from this formula one is equals to 126 plus 280 divided by 3.15 plus fine F aggregate divided by 1 minus 0.64 into 2.7. So, using this formula you can find out F aggregate, fine aggregate content is unknown and course aggregate corresponding one can find out is 126 1 is equals to 126 plus 280 divided by 3.15 plus course aggregate content divided by 2.6 into 0.64 and this equation you can use to find out course aggregate content.

Therefore, you will find this value is higher greater than this. It will increase now and this will also increase and correspondingly here you can find out where you are using super plasticizer. If you are using flyash if you are using flyash if you are using flyash then let us see what will happen. If you use flyash say you decided to use 25 percent of flyash that is the F divided by C plus F equals to 0.25 this is what you decided. So, your cement new cement ash plus F will be equals to 1.1 into 372 which will means another 38, so it will become 400 approximately it will become 400.

You have decided to use let us say 25 percent, so that is you know f divided by C plus F is equals to 0.25 and let me erase this out again do it like that. So, if I decided to use F divided by C plus F is equals to 0.25 C dash plus that is equals to 0.25 which is equals to 400. So, C plus F is equals to 400, so F divided by 400 is equals to 0.25, so F will be equals to 100, the cement will be 300, and so C dash will be 300. So, new F will be if you are using flyash this can be same in fact it will reduce down plus delta W which IS code is not giving, but there would be some reduction. This will become 300 and flyash will become 100.

So, you are getting same thing in cement and correspondingly this also you can find out, but on the equation the volume equation you will now flyash divided by specific durability of pressure as well. So, fine aggregate will also reduce, this will reduce somewhat this will also reduce somewhat because volume flyash will occupy more volume cement will occupy less volume. But flyash plus cement together will occupy more volume because quantity is now 400, 10 percent increase, so 300 divided by 3.1, 3150 plus 100 divided by 2.2.

So, flyash and cement will occupy more volume than the volume that was occupied by cement earlier and now will have the therefore, lesser fine aggregate lesser course aggregate. I have shown you this calculations with flyash as per IS mix is concerned, but one can easily adopt this. The calculation I have roughly just show you the calculation not the complete calculation. Let me do it again because I must see was 372, so C dash plus F C dash is the news flyash cement content will be 372 into 1.1 approximately 400 because 38 you will add to this you will get 400, now F by C dash plus F I said is 0.25.

Therefore, F must be equals to 0.25 into 400 which makes it equals to 100. So, volume occupied by flyash would be this divide by you know this is flyash. So, cement volume will be now volume of cement you therefore, this is F is 100. So, I mean new situation becomes new situation becomes C dash is equals to 300, F is equals to 100, W is equals to 167 which might reduce a little bit. So, I will set an equation like this one is equals to 167 plus 300 divided by 3.15 plus F divided by F is 100 and specific gravity is let us say 2.2.

So, 100 divided by 2.2 by fine aggregate divided by 2.7 into 0.36 and whole of this thing should be divided by 1000 and I will find out a fine aggregate 0.10 from this. It will be less than 6 say 695 it will be less than 695 and if I put in course aggregate here divided by 0.64 I will find out course aggregate content which will also be less. Now, total aggregate will be less, now total aggregate content will be less and fine.

Therefore, you see there if you use flyash it is just not replacing it is not just not replacing of flyash by you know some of the cement by flyash you are not doing that. Actually, flyash addition will reduce down the sand requirement of fine aggregate requirement as well as the course aggregate requirement also it will reduce down. Also it will reduce down the cement requirement, even if you keep down water content same, but if the fly this is good it can reduce down. It has got sufficient fines in the system, ferocities farcical particle it can in fact reduce down the water requirement also.

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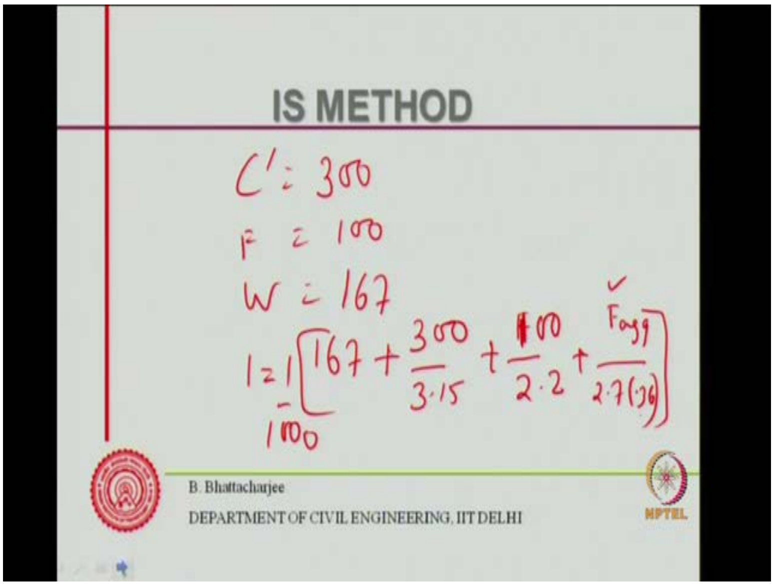

So, if you use together flyash and compatible super plasticize, you can reduce down the cement content even more. So, 300 if you use fly alone 280 if you use us super plasticizer, but it will do a much, much less. Let us say 25 percent less than the amount that you are using, so 126 liters with the flyash the water cement ratio is for you can actually reduce down still more the cement content. That is of course, anyway now I mean one can understood for whatever our discussion.

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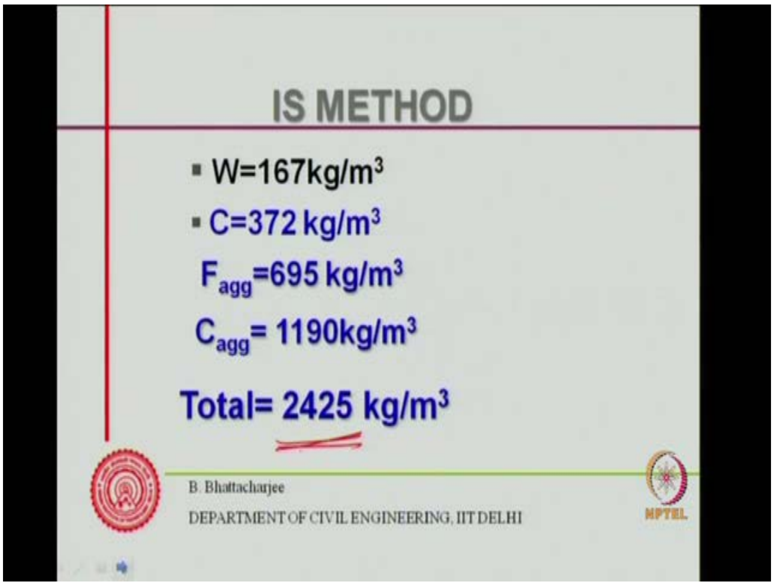

So, this is how we up to this we determined the mix design mix proportions and let us see how we do the totally is 2425 kg per meter cube. So, in 1 meter cube the yield will be 242425 kg per meter cube by sum of all this masses, but while transporting and mixing, mix after mixing while transporting, in fact some of water evaporates will get it somewhat less.

There is some loss both due to reaction auto genius you know desiccation auto desiccation and evaporation then this mass will become somewhat less. Otherwise, this should be the mass of concrete at the fresh state. If you have know site correction would be site correction that will be some site correction because water content at the site would be less water content of the aggregate would be somewhat less, I mean somewhat more. So, there has to be some correction at the site.

So, you if the measure water content is known if you remember, let us say water content water content of aggregate is W agg, SSD absorption is W ssd. So, excess water would be this is let us say for the course aggregate fine aggregate, let us say negligible water absorption and there is no water in the site as well if there you have to subtract this. So, this is W agg minus if this is greater if it is if you know like if it is greater so W agg minus W ssd is the moisture content per unit dry mass dry mass per unit, SSD mass.

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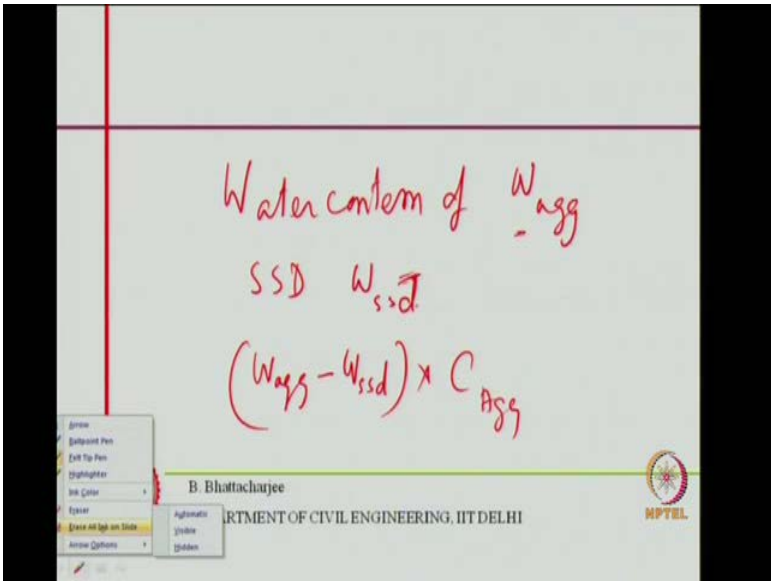

So, this is the additional water and this additional water multiplied by the C agg mass of the aggregate course aggregate mass. This mass be added to the water content, this quantity of water is additional water this must be added and corresponding you must at aggregate as well because aggregate contents additional moisture. If it is less moisture then less moisture you might add some waters likely more water should be added to the good lot of will absorbed to bring it to the SSD condition.

The aggregate quantity that you reading that should be less than the actual measured aggregate quantity because in the SSD condition mass will be higher. So, accordingly one might do this correction, so that is about less all about the mixes and method as per IS code is concerned as per IS 10262 is concerned.

So, with this now we can look into DOE method and DOE method starting point is same step one is same. Of course, then next step is I am calling this not as step one, but step one then is selection of water cement ratio from curves. Step two is then estimate water content based on slump Ve be time etcetera, m s a and shape of the aggregate from a table. So, this is what, you know this as slightly differentiable. Step three is calculate cement content which you can do because you know the water cement ratio and you know the water content, so step three you can do.

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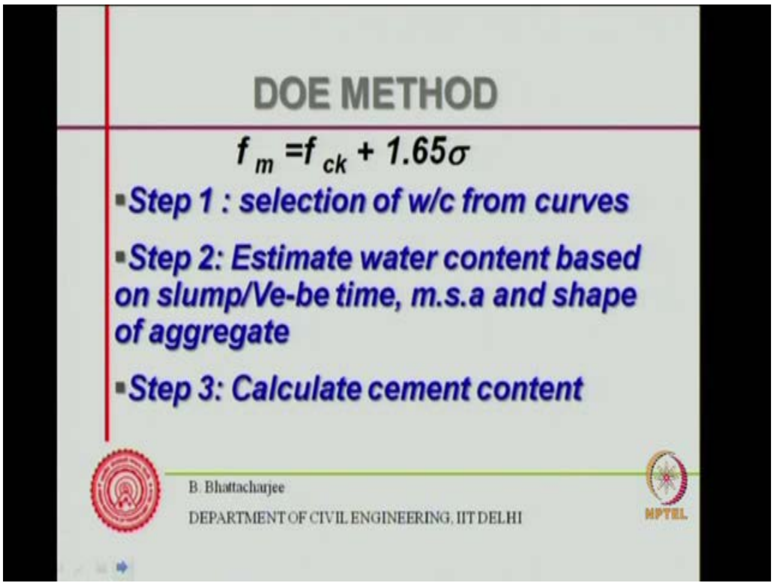

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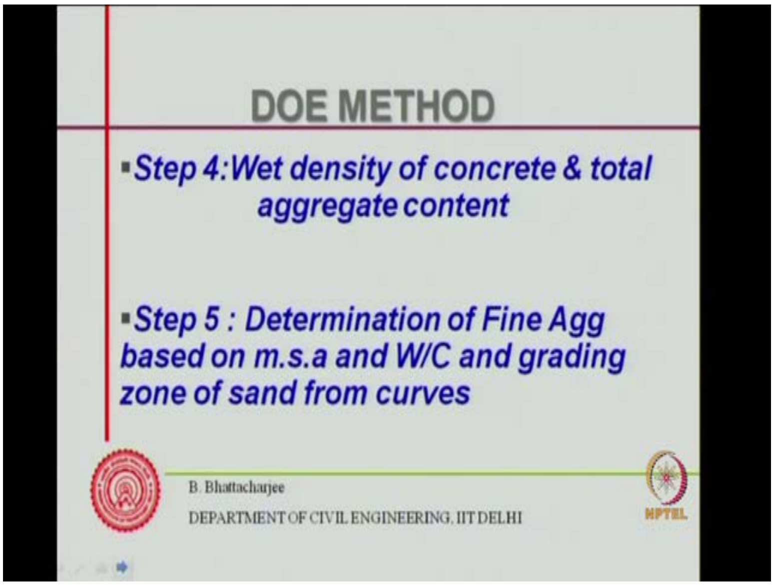

Step four would be wet density of concrete that is again from a set of curves and total aggregate content you can determine them. Step five is determination of fine aggregate based on m s a water to cement ratio and grading zone of send from a set of curves. So, let me just repeat this first is target means strength same as IS code, next you select water cement ratio from a set of curves. How we do it, we will come back to this, then you determine the water content from a table depending upon the slump for ve be there is workability factor and depending upon m s a maximum size of aggregate and whether it is a rounded or crust aggregate based on that.

So, you determined water content you have determined the cement content now next step is to determine the aggregate content that is done from a set of curves which gives wet density of concrete verses wet density of concrete verses water content. Since, you know the water content and specific gravity of the aggregate you can find out the wet density.

So, if you know the wet density is substrate the volume of cement from that or cement mass of cement from that mass of water from that you get the total mass of aggregate. Proportion of course can be obtained from again set of curves, where you give the proportions fines depending upon water cement ratio is grading zone etcetera. So, this is the step five and then site corrections are all required, so this is the step five, steps which I have mentioned. So, first target mean strength I am not discussing anymore because we have already talked about it when you are talking out IS method.

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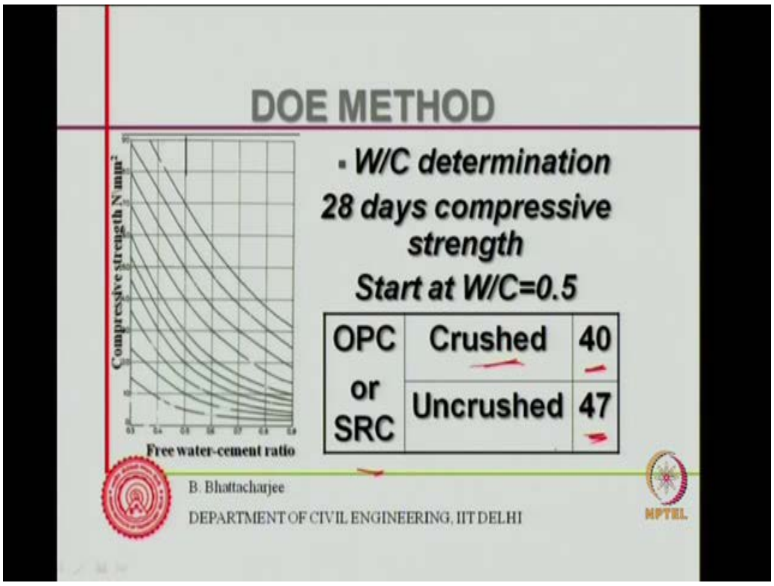

We will look into water cement ratio determination, this is the kind of curve where you plot free water cement ratio, free water cement ratio means the water that is available for free water. That is available for reaction, that is after SSD condition after absorption to SSD condition, so this is free water cement ratio against composites strength at 28 days 8 days let us say. So, this is a strength verses composite strength verses bottle cement ratio relationship 20 days composite strength you can find out, but now there is infinite number of curves here. So, you should start you should selected a curve how do you select you start at water cement ratio 0.5.

DOE methods gives you very large table, where for various types of cement and aggregate type the possible strength at 0.5 water cement ratio are given. So, for example of this c n s are c sulfate resisting cement if you have cross the aggregate you might assume that to be 40 MPa for uncrossed aggregate, it might assume the strength to 47 MPa. For same water cement ratio 47 MPa, because this is largely because crossed aggregate packing delighted issues, so it gives you 47. However, such thing will be valid for only UK condition this may not be valid in Indian scenario, see if you all other any other scenario.

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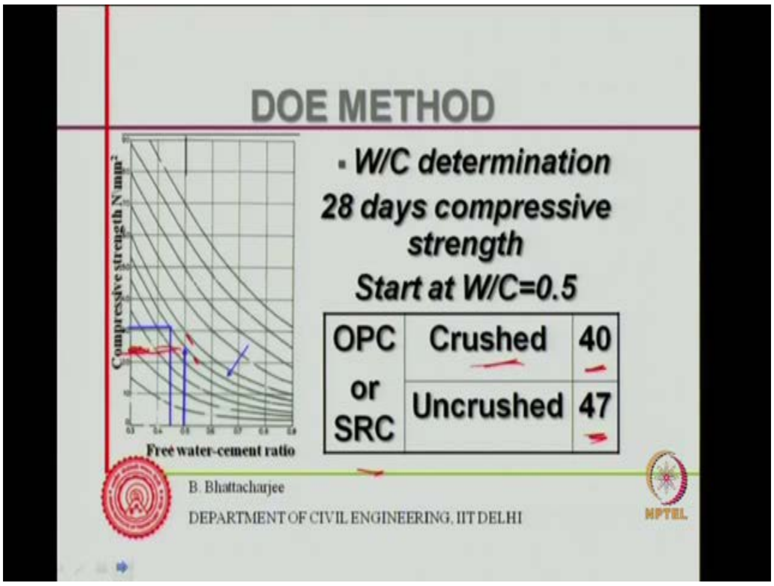

So, if you want to start you need not relying on this table same method you can use because it is also based on cube strength and same thing f c k plus 1.65 sigma so same. So, use the same concepts which we used in IS code, but you cast a transfix with 0.5 water cement ratio. With your cement with your aggregate etcetera a travel mix you cast it 0.5 water cement ratio.

So, starting point will be at 0.5 water cement ratio, now supposing you have done that and obtain the strength of let us say 20 25 also you know somewhere like this 25 strength is. So, 25 also, now with 0.5, water cement ratio we got 25. Therefore, if you can select your curve, with 0.5 water cement ratio if it is got 30 a carbonize in this, but right now you have got this therefore, your curve would be something like this, this is the curve you know this is the curve.

So, because your 25 MPa, so corresponding you can select the curve, you can always keep the lower curve if you are somewhere in between. So, make it a conservative little bit conservative, so this is how you select your curve strength verses water cement ratio curve. Now suppose you have target means strength 32 or 30 40 target means strength is 40 then the water cement ratio would be your 32 same as before. The water cement ratio would be in this curve draw a line at 32 and this will be your water cement ratio close to 0.45 it is same as the example that I have taken actually, deliberately taken that way.

So, therefore you can find out your water cement ratio in this manner. Let me repeat first you cast a travel mix first you cast a travel mix, first you cast travel mix with 0.5 water cement ratio. Determine the 28 days strength, you can accelerate test. You can do what this is to be done only once, you know for your system, but later on you may not do. For one, any grade of concrete this is done with the same results you can use it for any grade of concrete for example, M 25, M 30, M 40 you can design it for any grade of concrete.

So, you have got let us say with 0.5 water cement ratio the strength somewhere here which is about 25, but you want to get around 32 strength. So, this gets you identifying the curve, so a trial test at 0.5 water cement ratio helps you in identifying the curve which you should be using.

Otherwise, there are too many curves you do not know which curve to be used, so you find out which curve you want to use and then find out which curve you want use then go to your target means strength do you horizontal line up to that curve. So, this is my curve and up to this point and this I project downward to get the water cement ratio, so which I got around for 45.

So, water cement ratio can be determined in this manner, so the step, next step is to determine the water content. Well these curves can be also put into equation form that is what we have done actually. These are hyperbolic curves and you can fit it in this form a K 1 plus K 2 to the power W by C is something similar to Abraham’s law which says A by B to the power water W by C.

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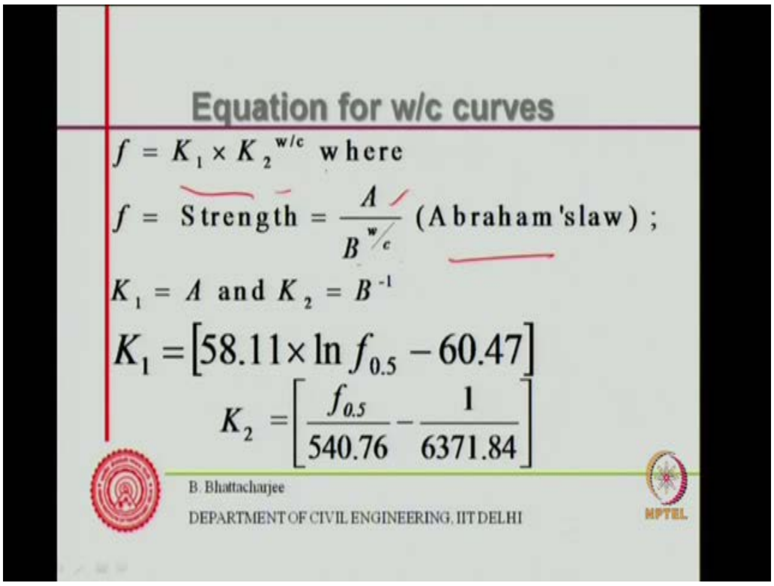

So, K 2 is nothing but B to the power minus 1 Abraham's constant you know, so this one can fit into this curve and if once fix into this curve it is been observed that K 1 can be related to log of 0.5 strength. So, each curve therefore, so many curves for each curve if you know the 0.5 strength you can find out K 1 and similarly, K 2 you can find out, this has been done on regression analyses we have done.

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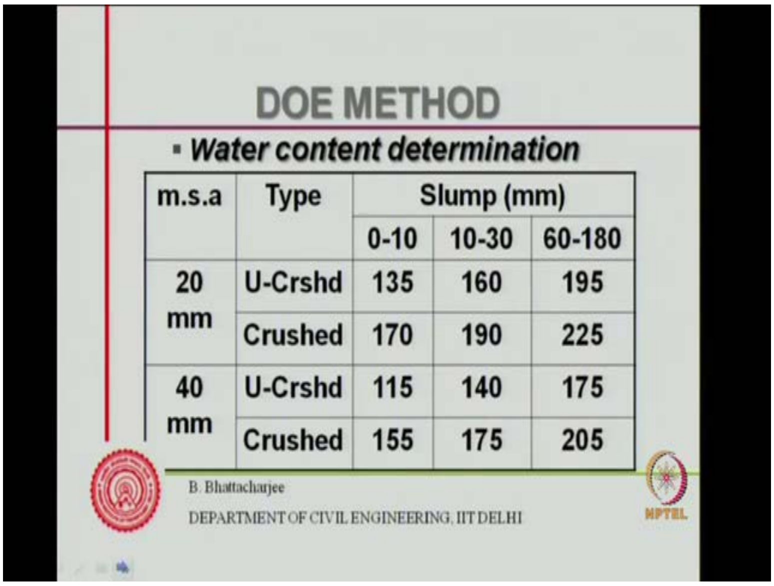

We have found out that K 1 can be related to log of 0.5 strength for f 15 and K 2 can also be related. So, if you know 0.5, strength you can actually find out K 1 and K 2 and therefore you can know for any other water cement ratio what is strength. This is being it in an equation form because instead of using the charge this becomes very useful if you are doing it in Microsoft excel or any others spread sheet.

Next step will be determined the water content next step will be determine the water content and water content determination is based on a table. I will actually take reproduce the part of the table it gives you slump also be time, I am not written the v b time part of the table I said slump.

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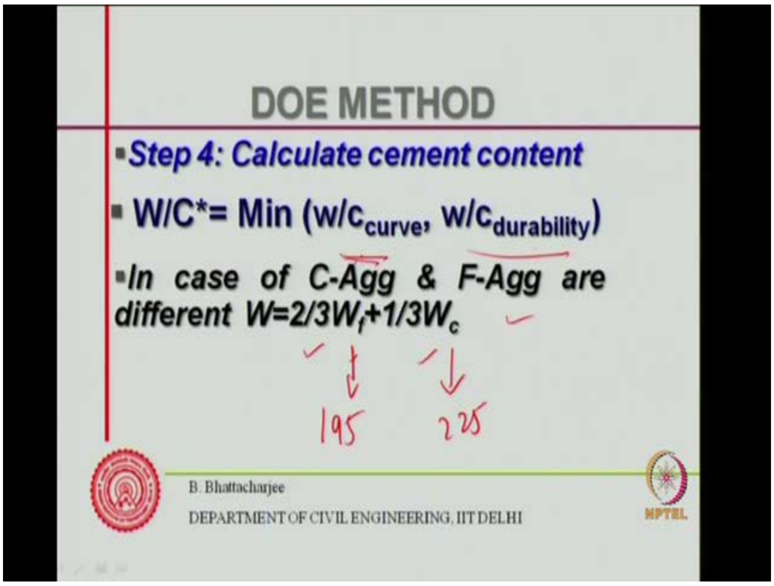

So, for various MSA 10mm, 20mm, 40mm for uncrossed and crossed aggregate it gives you the water content for various slumps for example, in our case it was 80mm slump. We have used possible 195. 80 per meter cube of water 195 kg per meter cube of water which IS code give us 167. You know if you go through the example, here would have use 195kg for uncrossed aggregate this rounded aggregate, but if it is crust then this would be more.

So, 40mm this is less and so on so forth, so one can find out the water content from this table, no correction required, and then calculate the cement content. Now, cement content will be minimum of water cement ratio from the curve.

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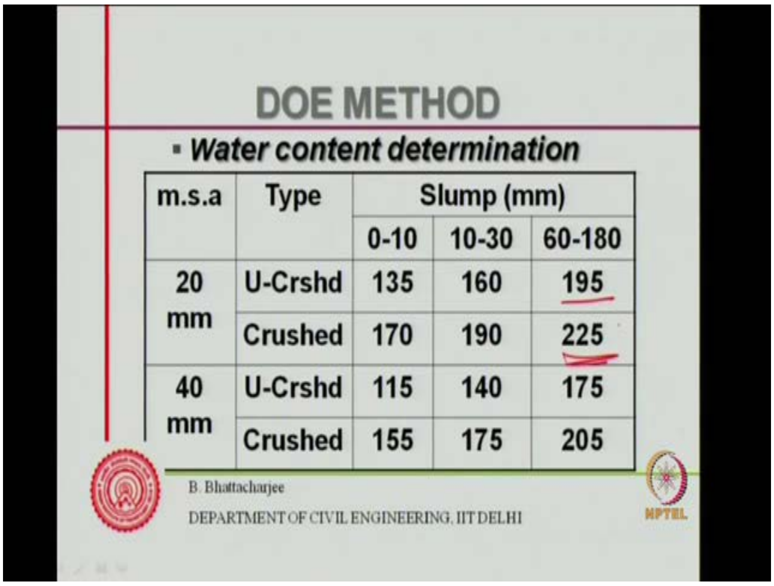

m.s.a	Type	Slump (mm)		
		0-10	10-30	60-180
20 mm	U-Crshd	135	160	195
	Crushed	170	190	225
40 mm	U-Crshd	115	140	175
	Crushed	155	175	205

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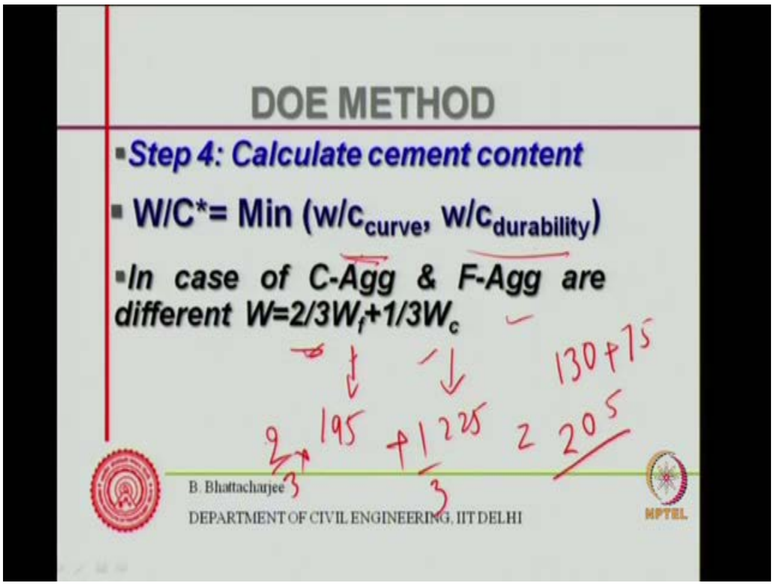

Water cement ratio, sorry water cement ratio should be minimum of water cement ratio from the curve and water cement ratio from durability. So, again if this was 0.45 this is 0.5, I choose 0.45 only, if you have course aggregate and fine aggregate one of them is crossed other is not crossed one of course aggregate is crossed and fine aggregate are not crossed let us say natural, then you take 2 3rd water for fine aggregate 1 3rd for course aggregate.

So for example, this is let us say is 195, this is 225 so just go back to this table you go to back to this table this is 195 for crossed it is 225. So if my course aggregate is crossed and fine aggregate is uncrossed then the moisture content I mean water content of the mix will be the water content of the mix will be water content of the mix will be two third of the fine aggregate.

So, two third of 195 and 1 3rd of that whole course aggregate, so that is how go wrote it and therefore, two third 2 by 2 by 3 195 plus 2 to 1 3rd to 225 which will work out to be 130 plus 75, so which will make it 5 200 and 5 kg per meter cube. So, it will be 200 and 5kg per meter cube if course is, but it will depend upon how what type of aggregates you have.

So, water cement ratio would in all case would come now actually 0.45 if you go from the figure and cement corenteually maximum of water content divided by water cement ratio which is 0.45. In this case it has 225 or 195 and C, C from durability which is 300kg, so whichever is higher you take that.

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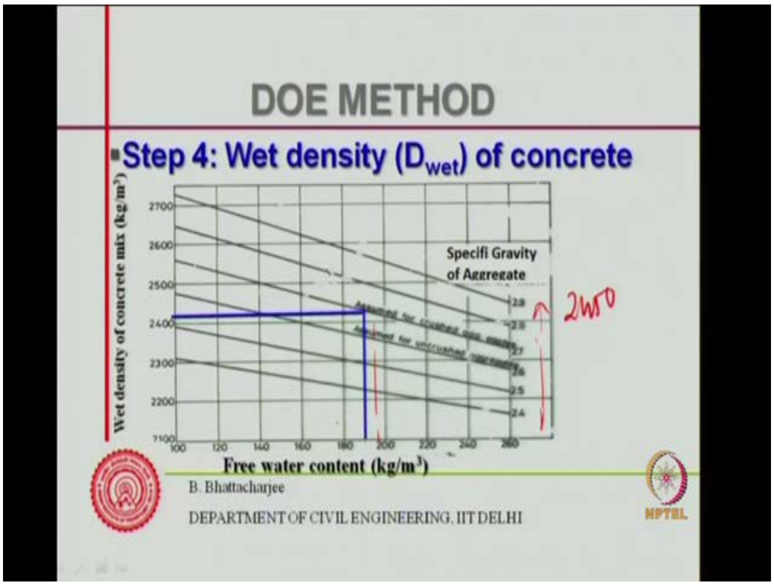

Next step would be to determine the aggregate content, now we know the cement content we know the water content we got to determine the aggregate content. This is done from a figure like this, where free water content is plotted you know the wet density of concrete is plotted again free water content. For various specific gravities of various specific gravities of aggregate for various specific gravities of aggregate, so you know specific gravity is of your combined aggregate specific gravity.

You can find out because you know the combined grading and proportional all that and you know here free water cement ratio, let us say if it is 195 it will be somewhere here and if you know the type of aggregate or aggregate specific gravity. Then, you can take this as let us say 2450 or something like this, so you can find out the wet density of concrete in k g per meter cube. You know the mass of the cement in 1 meter cube, mass of the water in the same 1 meter cube, therefore, rest of it must be the aggregate. So, this is the principal that is applied right, so for example, mine was 190 or 195 and this was my specific gravity let us say. Then, this will be my you know water content sorry work density would be somewhere around 2450.

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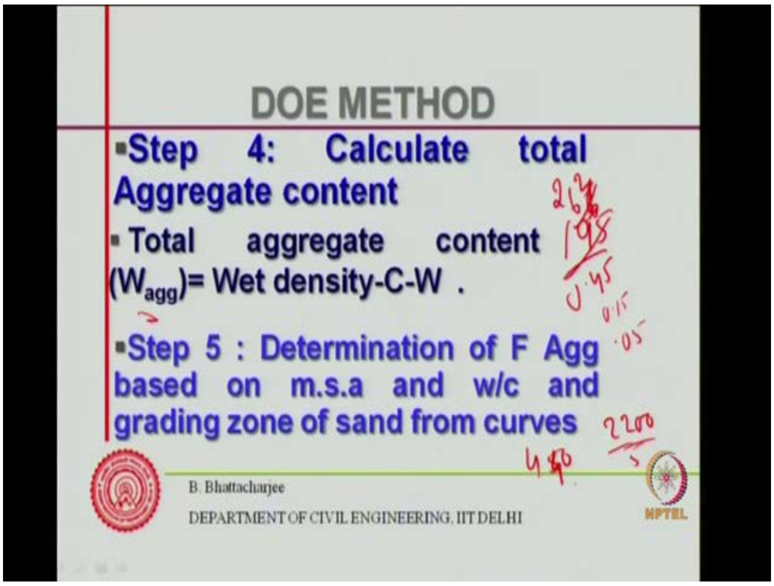

Just for an example supposing this is 190, this is 180, 190 and this is the crossed aggregate and so on so forth and you are getting 2450. Calculate the total aggregate content of the next step content would be the step port, total aggregate content is do wet density, mass of the aggregate total aggregate is equal to wet density minus c minus W, where C is the cement content, W is the water content right. So, we know cement content because we know the water cement ratio, and we know the water content you know in this particular case as telling you it would be 195 divided by 0.45 is s c and water is 195, so this would be 66 and 0.15.

So, this would be 22 divided by 0.05, so 22 divided by 0.05 is 2200 divide by 5 which will be 450, 440, so 440 will be the amount of cement you require in this particular case because 195 divided by 0.45, but if you use plasticizer you can reduce the 195 by 20, 25 percent of the cement combustion will also go down. So, that is how we find out, now just last step in this DOE method is determination of fine aggregate based on.

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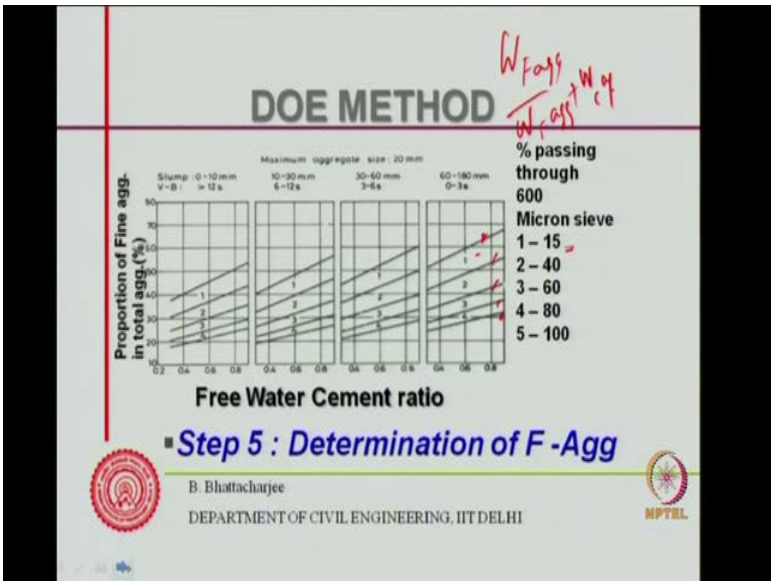

So, you have curves like this determination of fine aggregate set of curves like this, you can see there are 4 curves, this is for slump tend to 0 to 10 mm. This is for 10 to 30, 30 to 60 and 60 to 180 and this curve is for 20 millimeter aggregate, x axis is free water free water cement ratio, y axis is proportion of fine aggregate in total aggregate by the mass. So, if I know my wet density was 2450 let us say 2450 water was 195 just for the sake of understanding and cement was 440. So, the aggregate content will be some total of this to which is 5635, so 2450 minus 635 is 15185 would have been the aggregate content.

Now, out of which how much is the fine aggregate content that would depend upon the propositions of fine aggregate by mass in total aggregate. So, this is proportion by mass and this depends upon what is my slump supposing my slump is 6 to 180 and 20 mm aggregate. I am using and my water cement ratio is 0.45 or something and I have got a zone threes and somewhere our zone 3 and zone 2 sand somewhere here, therefore I know it is about 30 percent when I say by weight sort of 30 percent. Let us say 30 percent, so this will be 550, we can find out 30 percent of this, so 540 somewhere around 545 kg.

It would be the fine aggregate depending upon which zone does it belong to etcetera in fact which range it does it belong to and which range it does it belong to, which range is does it belong to and this is given here for example. The zone 1 is for percentage passing through 600 micron 15 percent, so if it is percentage passing through the 600 micron sieve that is grading of the point is such that percentage is 600 micron.

You know percentage is 600 micron, sieve is 15 percent, two is 40 percent, three is 60 percent and five is 100 percent. Now, if it is passing through the 600 micron that is quantity of real fine in the system or its grading, the zone 5 that is the range that is shown as 5 the curve number 5, this is curve 1, curve 2, curve 3, curve 4, curve 5. So, curve 5 corresponds to very fine sand where as curve 1 corresponds to the relative course and only 15 percent is below 600 micron.

Rest all them are 600 micron, therefore fine content increases as we have course material in the system because that then course aggregate will reduced fine content will increase when fine is very fine. Then, you have got maximum amount of when to use and this also depends upon the slump for a highest slump you need more fines less, of course aggregate. This is understandable because as I told you course aggregate do not contribute to more durability, it is paste and then the mortar and there flow ability contribute to the work ability.

So, therefore, this is step 5 and this is meant for 20mm, similar crops are available for 10mm and 40mm say as well. This is for 20mm as I say, so by doing this then you have found out the complete you know proportion of fine curves because you know. The proportion mass of actually w fine aggregate f a g g divided by total aggregate w f a g g plus w c a g g both sum total is in the left particle axis.

Therefore, total aggregate content you have found out by subtracting the cement content and water content from wet density, wet density you have found out from the curve. Then, once you have found out the total aggregate content of portion of the fine in the total is known if the sand is finer and you need highest slump, you will put more sand. It will also depend upon the MSA higher, the MSA you will recall as sand, because packing of the course aggregate will become better. Then, it also depends upon water cement ratio because cement contributes to the fine as well cement contribute to the fine as well.

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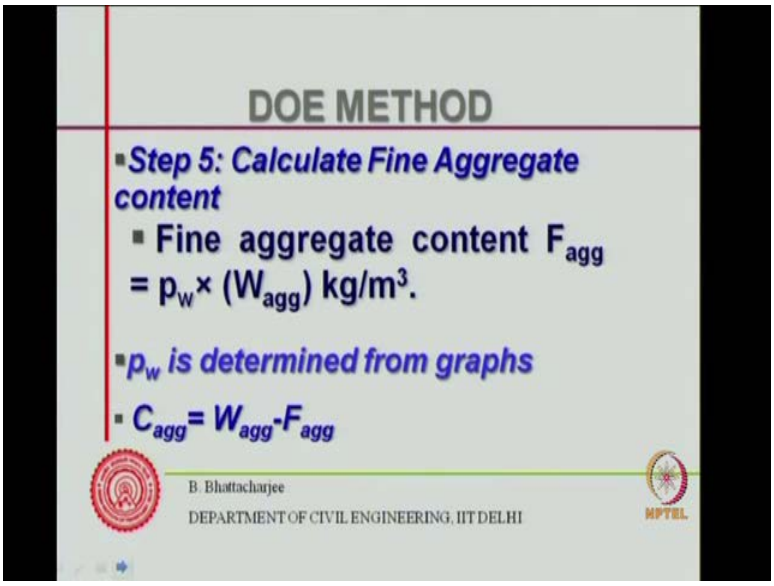

So, higher water to cement ratio means you know higher water to cement ratio means you will be using more cement as well. So, depending upon those situation fine materials it will depend upon that, so all put together this curve gives you the quantity of fines, curves are available 10mm and 40mm as well. So, you calculate the finite aggregate content as fine aggregate content is equals to p w which we have obtained from the previous curve, multiplied by W a g g where W a g g is the total aggregate content and p w is determined from the previous curve.

So, C a g g is equals to W a g g minus fine aggregate content, so you have found out the total proportion of material in the concrete without flyash and without super plasticizer. If we are using flyash, then this is the method available, if you are using super plasticizers, then reduce down the water content and rest all you are in the same manner as we have done it for IS method.

If we use from flyash, first you prepare that calculate for the control mix and then calculate the proportions for the flyash mix, so total percentage of pulverized flyash, flyash is pulverized fuel ash or may be just a fuel ash may not trap by pulverized this. So, this fixed s specify or desired, so how much flyash you would be using that has to be fix by yourself like we did even in IS system as well.

So, this is known to us and water content would be reduced, because flyash acts like a or fuel ash acts like a kind of you know it gives you better packing. Therefore, as we have discussed this we have discussed in module three when we are talking of supplementary cement ratio material, there flyash would be reduced on your water requirement because it is spherical and fine flyash does this job very well. This method actually allows for reduction in water content, so delta W is the water reduction new water content will be W dash.

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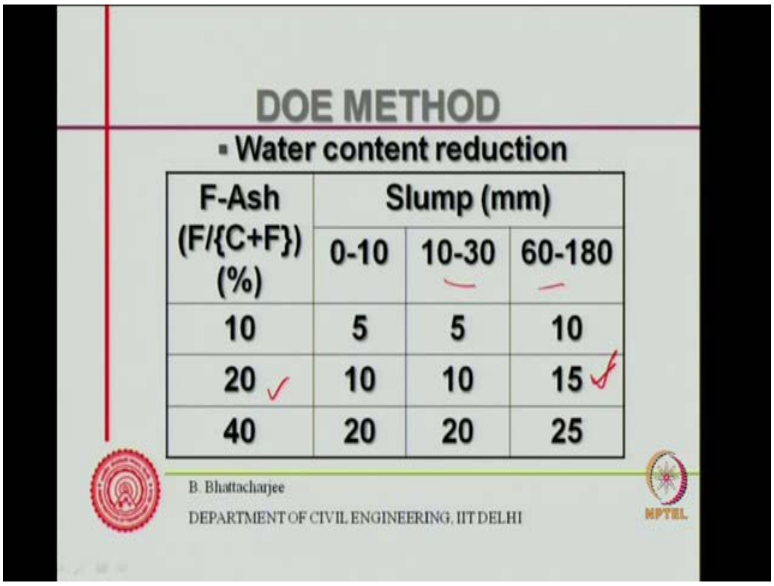

So, this water content reduction is given in a table part of the table is here actually so depending upon the flyash content percentage in the total material the and also the slump range the delta W the water content reduction, delta W you know is given here, for example, obtained 20 mm m s a you have slump of 60 to 180 and if you are using pulverized fuel ash then you can reduce the water content by 15. So if yours is 195 you can make it 180 and so on so forth. So, you can reduce it down. So you are water get reduced if you are using flyash. What happens to the cement, how we modify the cement?

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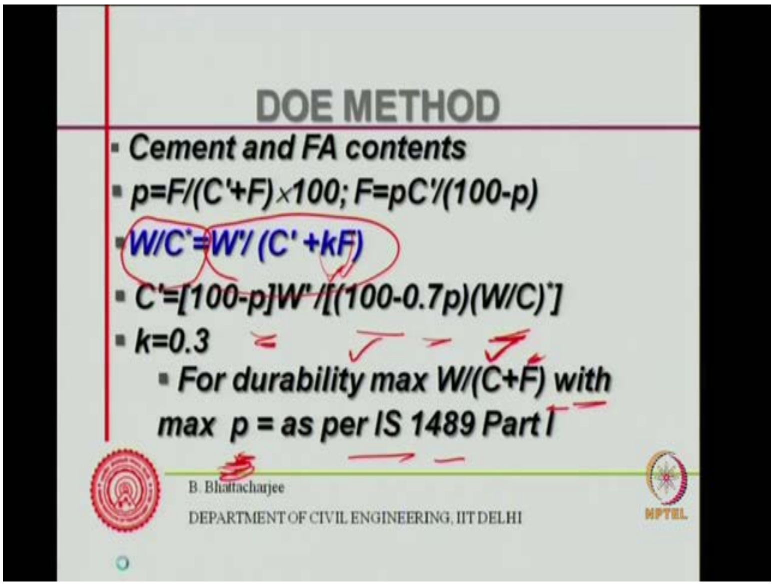

It suggests that you modify the cement content in this manner, first you find p is given by c divided by c dash plus act into 100. So, F can be written from this because F can be expressed in terms of p and f will be written as p by 100, so F divided by C dash plus F is given by p by 100. So, F is equals to C dash plus f into 100 p by 100 and you want to separate F, so you will get f equals to 1 minus p divided by 100 is equals to C dash into p by 100.

So, F can be solved out which is given in this equation; that means C dash divided by p and this can be written as 100 minus 100 divided by 100, so 100 will cancel out, you will get the expression for f in terms of p. Then, your expression of f in terms of p and W C dash star is you put you know this is for the control and you write that is equivalent to and equivalent water content where you use a factor called k factor. This gives us the amount of reduction which gives us you know a factor which is less than 1 and gives us the equivalent cement of flyash.

For example, if k is 0.3 100 k g of flyash is equivalent to 30 k g of cement 0.3 into 100, so if flyash multiplied by this is equivalent cement, so this equivalent water cement ratio. Therefore, C dash can be obtained from this equation because W by C star is known, p is known, so you combining these two equations you can get c dash from this equation which you can calculate out because this is equals to you know.

Just F is equals to P C dash by 100 and P, so replace F here and you will get this equation 100 minus p into W dash divided by 100 minus 0.7 P into W by C star where k is taken as 0.3. So, take k as 0.3 C dash equation will be this, k 3 is a conservative value, but has fast approximate says that take k as 0.3. In fact, in practical situation in India some cases it is observation that k could be as close as 0.6 0.7. Some place of course,, it could be lower. So k 0.3 k square conservative and that is why I has did not end up this kind of principal instead decided to take about 10 percent in place in the total cement issues.

So, that is how we find out for durability find out the water to cement ratio that is allowed and in that case no k is used. So, only thing is it says that maximum P the P that you can use would be as per the criteria of IS 1489 part 1 which is you know the part IS 1481 allows for maximum flyash, limits the maximum flyash.

You may use in Pozzolana system, so P should not cross this limit if you are using in this formula and this 2 4 IS method as well. So, maximum water to C plus m instead of maximum water content, this we will be discussing again when we talk about durability, so this is from durability criteria.

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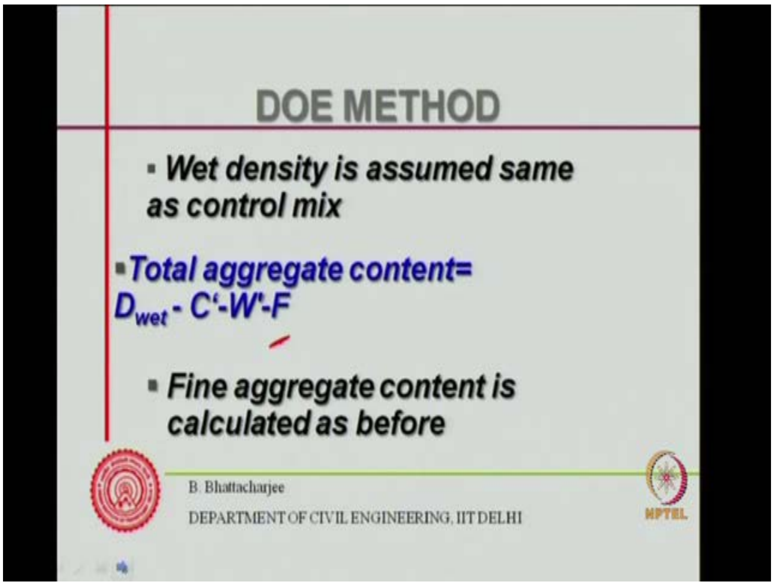

Here, C plus F wet density is assume same as control mix follow the same procedure only ash will be now reduced and finely aggregate content is calculated as before.

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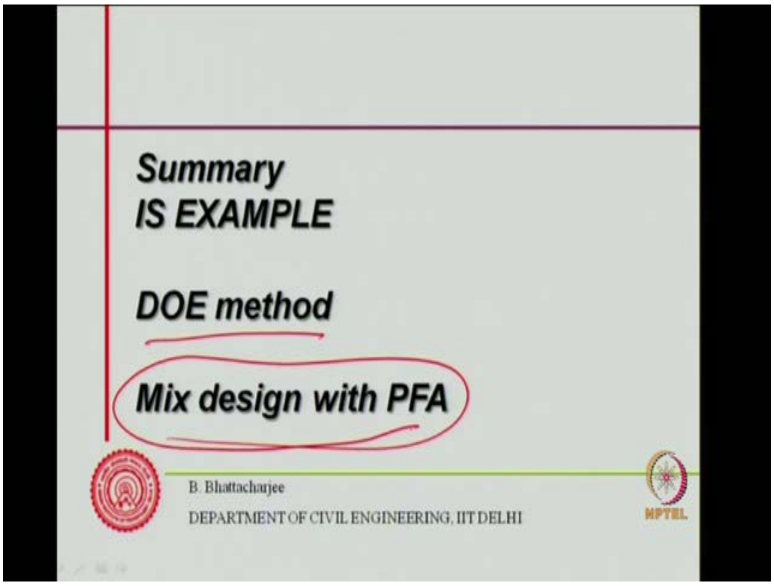

So, using DOE method, you can also obtain mix design using flyash as I told you procedure is back on same get the control mix and then you know you get the flyash content etcetera. Only thing is, it uses a k factor, now IS code does not use k factor and k suggested k is on 0.3, so to summarize we have now loosed into an example of IS code. You have looked into DOE method and in this DOE method we have also looks into mix design with PFA that is pulverized flyash or flyash etcetera. So, in this we conclude the module four lecture three.

Thank you very much.