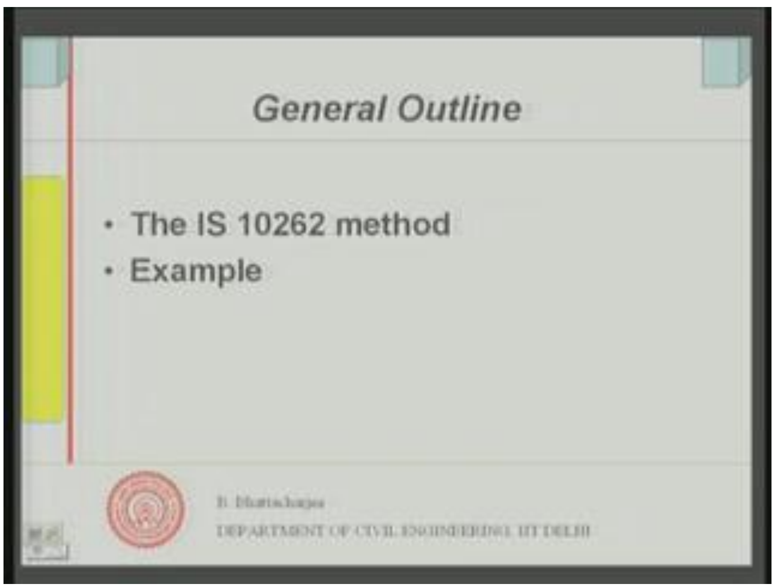
Building Materials and Construction
By Dr. B. Bhattacharjee
Department of Civil Engineering
Indian Institute of Technology, Delhi

Module - 9
Lecture - 2
Mix Design of Concrete IS Method

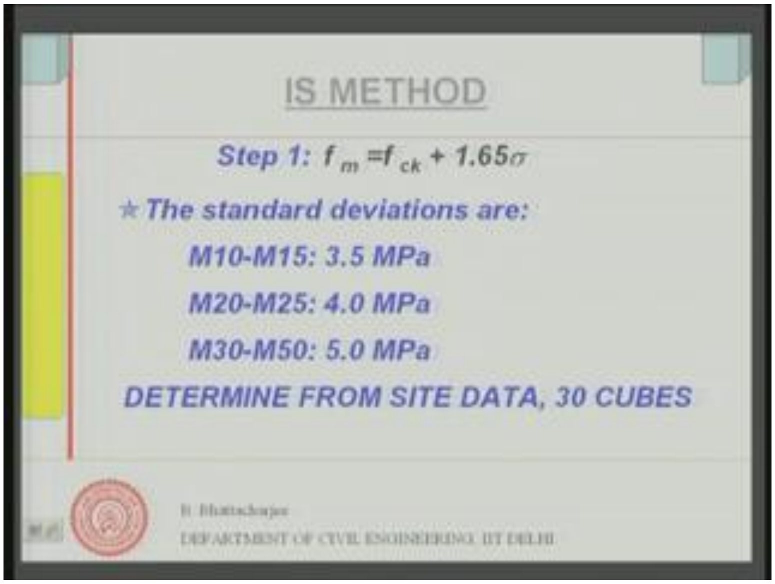
We have looked into the procedure, principle of mix design in the last lecture. Today we shall look into the Indian standard method of mix design.

(Refer Slide Time: 01:25)



As I said the mix design method is not unique, because it is based on lot empirical experiences, empirical charts and graphs that for there are number of methods. There is no unique method Indian standard method is one of them. And that would be our topic of discussion today, and also we will take up an example problem.

(Refer Slide Time: 01:58)



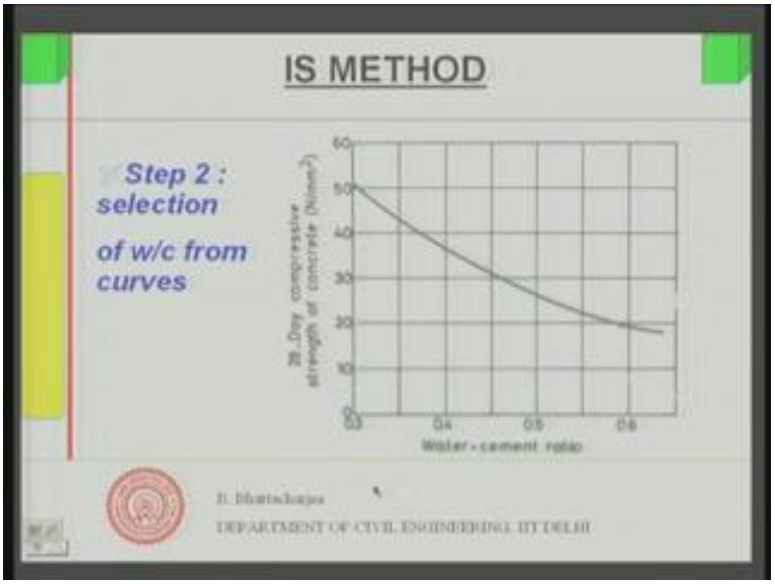
So, like all other methods as we discussed yesterday, Indian standard method also starts with determination of water cement ratio, based on the strength. Of course before that, you have to find out target means strength.

So, step 1 yesterday we discussed what is target means strength, step 1 is to find out target means strength that is fm which is fck plus 1.65; what is fck? fck is the characteristic strength and that is the grade itself. Because this is characteristic strength this characteristic strength and this is the grade itself. So, we can follow it up; now the standard deviations must be determined at site, but when you have nothing available. You are starting for the first time; you do not know the degree of quality control. Because we said yesterday that standard deviation is a function of degree of quality control you have, if you have better degree of quality control standard deviation will be less, but if you have poorer degree of quality control standard deviation will be higher.

So, whatever it is if you do not have standard deviation value available, the highest 400 and 56000 gives you a kind of guideline, its suggest that in absence of any available data on standard deviation the site, you can choose for M10 to M15 as standard deviation of

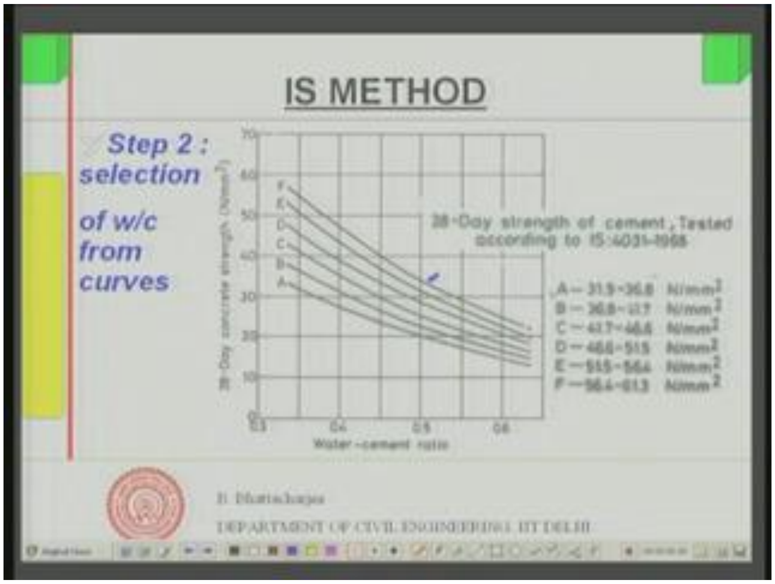
3.5 MPa for M20 to M25 rate of you know, concrete 4 MPa. And above M3 up to 50 these are all we are discussing about, normal strength concrete 5MPa.

(Refer Slide Time: 04:11)



So, this is the guideline given, but actually 1 what should do is as quickly as possible as soon as the data is available, one should determine the standard deviation from site data. The formula being given in the last lecture 1 can just obtain, but you must have at least 30 sample data, 30 you know 30 cubes, you should have 30 sample data; because 30 is sample data is important, because 30 is the one; which will ensure that, you have actually 30 data will ensure that 30 data ensures 30 data ensures that you have statistically right number of samples.So, that is why it is necessary to have 30 numbers of data; so this is what it is step 1, f is you know fck is equals to 1.6 5 sigma.

(Refer Slide Time: 05:28)



Step 2 is to determine the water to cement ratio and that is what we do like this. You have a curve available from which, you can determine water to cement ratio, and there are 2 sets of curves available. Let us look at these 2 curves. First curve would be something like this first curve would look like something like this. Water cement ratio versus 28 days compressive strength of cement concrete. So, is a single curve and this represents a single curve for all the concretes you know, all that standard for; all concretes made with all kind of Indian cements. Basically; based on empirical experimental data, that was generated by doing lot of tests. Early in 70s early; you know in seventies and from that water cement ratio versus strength curve was determined.

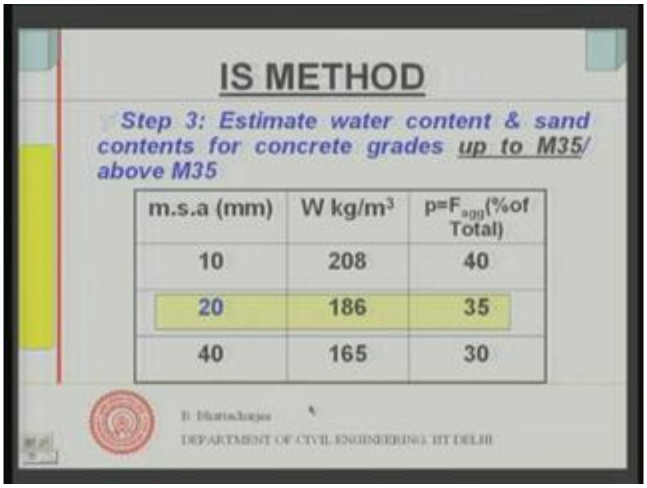
So, this is 1 curve; if you do not know what the strength of the cement is. Your general curve you can use and you can find out. What is strength of your concrete, 28 days strength of cement and using this data you can find out; strength, you know water cement ratio based on strength. We will look take up an example problem it will be clear. So, when you have cement strength available there is another set of curve given 28 days strength of cement is available. You can use this set of curve and this each curve represent cement strength.

For example: this curve A represent cement strength 28 days cement strength from 31.92 to 3 6.8 mega Pascal. Whereas this B represents curve B; which would be next curve represents cement strength of 36.8 to 41. You know, 41.7 and next 1 is, 41.7 etcetera and the last 1 is 50, 6.4 to 61.3. The is more important first curve that, we just discussed about is a curve which relates for all cements, without distinguishing between cement strength it just take all. For all types of concrete that is encountered in Indian condition; for that, they have actually a curves have been plotted between water cement ratio and 28 days compressive strength of cement.

So, when 28 days compressive strength of cement is known to you can find out, what is the water cement ratio? In this case it is dependent on cement strength, well; it is not necessary that all the mix design procedure that is there say, a different mix design procedure, they use cement strength as a basis for determination of strength 28 days strength or relationship between 28 days compressive strength. And water cement ratio our Indian code does it that way, in fact other codes do not consider, because this graphs definitely ignore the effect of aggregate etcetera, best thing is to do is find out the water cement ratio for set of strength versus water cement ratio curve for your concrete. That would be a best thing, but in absence of that the code says that you can use this curves.

So, if you know at least the cement strength or grade of cement; you can use that to find out what is the water cement ratio, because for your corresponding to your target means strength. First you find out the target means strength, which we have said that is, 1.65 sigma plus fck. So, we know target means strength from the formulae that we have given earlier. Once this is known, using the target means strength I can come back and find out what is the water cement ratio required.

(Refer Slide Time: 08:57)



So, this is the procedure adopted in step 2, step3 would be to determine water content sand content for concretes. And this is done using 2 sets of 2 tables a set of 2 tables actually, again based on empirical data generated. You know, let us recall our earlier discussion. We said the strength is mainly a function of water cement ratio.

And in the mix design procedure or principles that, we have discussed in one of the previous classes. We said that, you know water cement ratio is found out from, standard deviation and the grade of concrete, which dictates target means; strength and also from durability.

So, from durability consideration and from strength consideration we determine the water cement ratio, having determined the water cement ratio. We find out, the water content from actually from that maximum size of aggregate, then workability requirement and you know workability requirement and shape of the aggregate etcetera.

So, here also in this particular I S method what we do, first we have found out the water cement ratio from target means strength from those curves. And the second step, I mean first I have found out that target means strength. Second step I have found out the water cement ratio from the set of curves that, I just gave you. And then now, the third step we determined water content and sand content of for concrete grades, for 2 cases up to M35 if there are 2 tables.

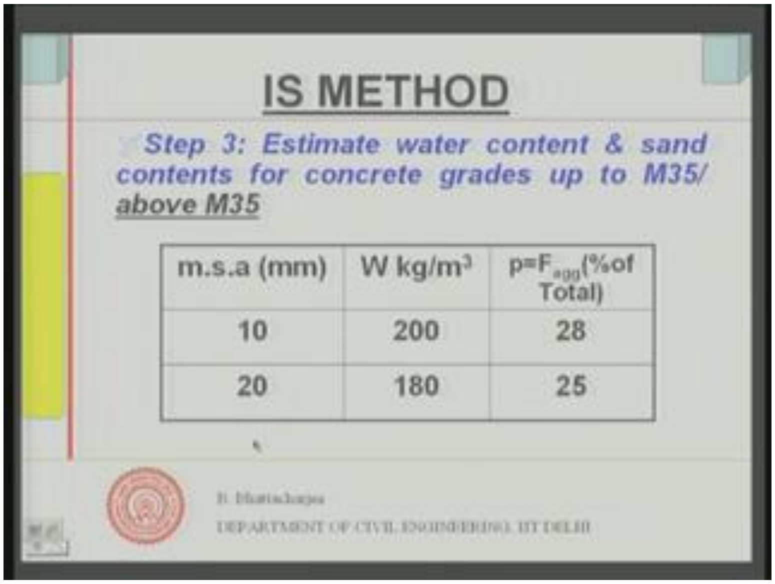
Now, let us look at the first table, first table is something like that up to; you know up to, this M35 grade of concrete. This table is valid table is valid for M35 grade of concrete and for different MSa different MSa the water content required and the percentage of fine in the total aggregate that's given. For example for 10mm MSa 208kg per meter cube of water is required, and 40 percent should be the fine aggregate in total aggregate, that means in 100 of total aggregate there should be 40 fine aggregate and if the MSa is 20 it is like this.

So it's a functional as a function of MSa we are finding out how much the water required is. and how much fine aggregate required, but then we have not taken account of we have only looked into MSa, we have not taken account of the workability not looked into the fineness of the sand, not looked into the shape of the aggregate etcetera.

Now, this table is meant for specific conditions. I shall explain this specific condition later on. I mean just for the sake of introducing it; now, this is meant for a water concrete with water cement ratio 0.6; you know with crushed coarse aggregate fine sand belonging to what is called zone 2 of Indian standard IS 383, because I mentioned that, sands are classified in zone1, zone 2, zone3, zone4 depending upon their grading.

So, it corresponds to zone 2 sand and corresponds to water cement ratio of 0.6, a compaction factor as been used as a measure of workability here and this table corresponds to a compaction factor of 0.8 and crushed coarse crushed aggregate. For other condition and adjustment or corrections are given and this table is valid only for concrete grade up to M35, M 35. A similar table is available for concrete grade more than M35, that is grade higher than M35 and this table is like this.

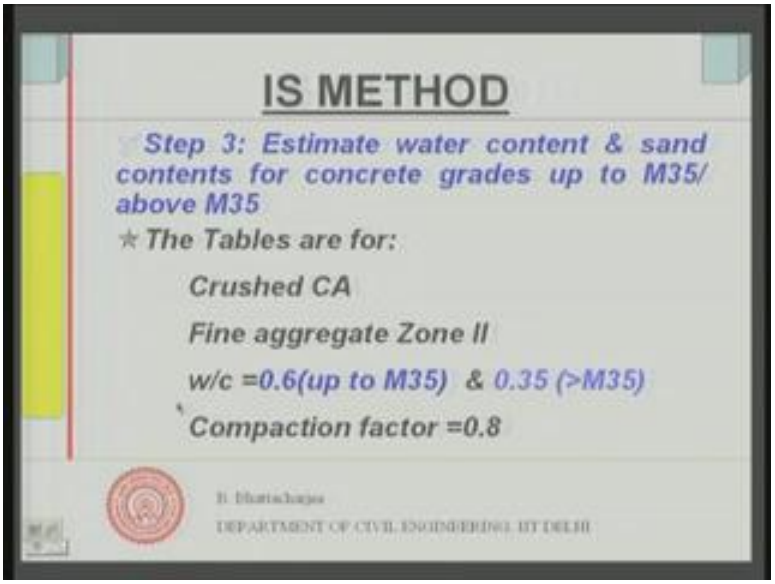
(Refer Slide Time: 12:46)



You see and you see that, MSa doesn't you know it is more than 20 millimeter doesn't exist because we have higher strength of higher grade of concrete or strength of the concrete required is more. You will have MSa will be smaller; you know you can't have 40mm MSa with grade above 3 5 grade above, 35 you can't have 40mm MSa and therefore, only up to 20mm and the basic you know starting water contents are given. And this is meant for a water cement ratio of 0.35 and the same zone to send etcetera.

So, the next step we look into a correction because water cement ratio will never be 0.35, it will be something else it will be point 6 f concrete grade below M35. So, you have to have correction factor for water cement ratio correction factor for shape of the aggregate, correction factor for workability, because these are fixed for specific workability, next table we explain the same thing.

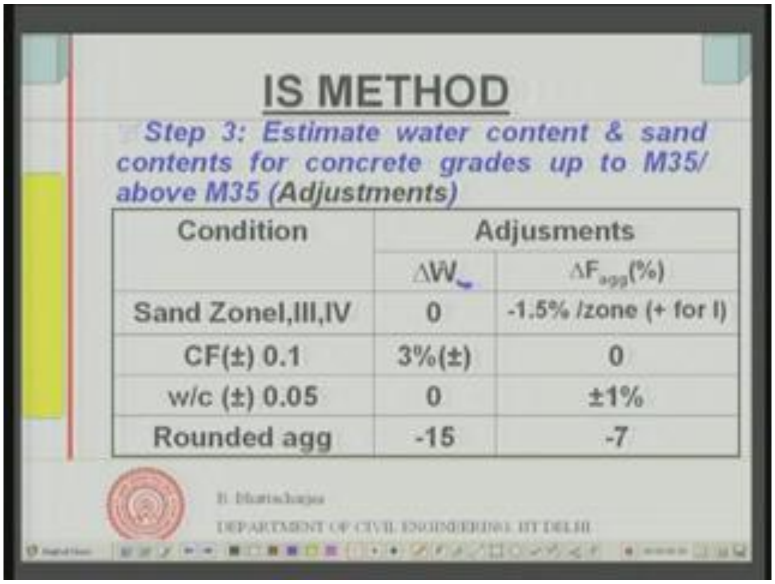
(Refer Slide Time: 14:09)



So, 2 tables are given table 4 and 5 in the code 10262 where, you have for various MSa water required and that, fine aggregate as a percentage of total aggregate is given, and then the condition for which, they are given are like this. You know, these conditions are these tables are meant for crushed coarse aggregate, these are meant for crushed coarse aggregate. They are meant for fine aggregate zone 2, they are meant for water cement ratio 0.6; for first table that, is first table up to M35 grade table and for 0.35 for grades more than, M35 higher than M35.

So, this tables are meant for fixed water cement ratio fine aggregate and coarse aggregate Anyway what you do is you first find out. Assuming that, your aggregates crushed aggregate is coarse aggregate is crushed fine belongs to zone 2 and water cement ratio is 0.6 or 0.35; according to the table that you are using and compaction factor of 0.8. For any other values of this you need adjustment or corrections and these adjustments are given in the next table.

(Refer Slide Time: 15:08)



You see these adjustments are given in the next table. For example adjustments are given in change in water content. Now, water content is affected by first of all workability. So, if you have a compaction factor change then there will be a change in work content. For higher compaction factor you need more water that's what, we have seen because compaction factor is nothing but, it is a measure of the workability. You know this code uses compaction factor some other codes of course you use a slam, pen, test etcetera, but this our Indian standard code uses compaction factor and the standard tables those which are given starting tables, they are meant for a compaction factor of 0.8. If you have higher compaction factor, then you must add water, if you have lower compaction factor then you must subtract water.

So, water content delta W expressed in percentage addition in water or reduction in water you know, addition in water or reduction in water, for each change in compaction fraction point 1 you need 3 percent change in water content. So, 0.8 supposing my compaction factor is 0.9, then I got to increase the water content by 3 percent. if it is point 7, then I got to reduce the water content by 3 percent, whatever is the value you reduce by 3 percent. And of course, compaction factor doesn't have anything to do with the, you know sand content in the total aggregate total aggregate content, this total requirement; basically, the you know sand content would depend upon the packing characteristics of the aggregate system and packing characteristics of the aggregate system.

So, the basic that you have found out for zone twos and if you change your compaction factor, its assumed that it is not change at all, but shape of the aggregate is important that would change straight away that is this delta W by 15kg per meter cube, it will change this by 15 kg per meter cube. So, whatever is the water content you have found out; you reduce it by 15kg; you know adjustment you do in delta W? So, these are not really that's why it is not called correction factors adjustment, because this is in percentage this straight forward in kg per meter cube. Let us see how the sand would change.

Now, sand zone 1 2 3; you know 2, for 2 this tables are meant for sand zone 2; now, if you have zone 1, zone 3 or zone 4 , if it is 1 then add the percentages by 1.5 percent. Now, zone 1 is coarser zone1 is coarse; so which means that you will like the maximum size in the sand is, now you know more you have, more coarse material and then finer material. So, what you can do is you can the amount of sand that, you would be use can be reduced should be increased and if you have, finer sand then you can reduce down the amount of sand. You can reduce down if it is finer sand, because finer sand means for the same water content it would possibly more water. So, finer sand they have reduced down in order to since water content. I am not changing with respect to this. It is finer sand it would reduce down.

You know, you should reduce down the sand so that your remain- same workability remain same it is also related to water cement ratio, when you have higher water cement ratio you increase your water cement ratio. You have got to increase the sand content; you have got to increase the sand content by 1 percent; for each increase of 0.05 percent in the water cement ratio. So, when you have higher water cement ratio your sand content in the total aggregate, system will increase; because we have kept the water content same.

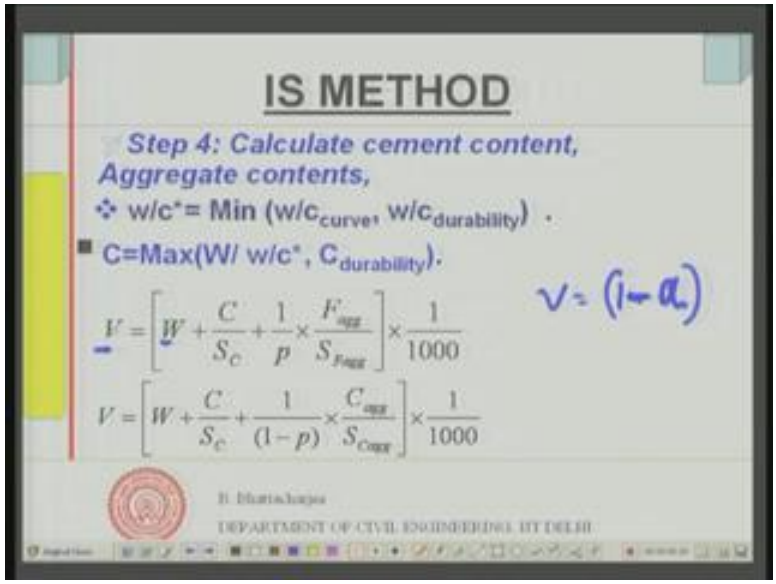
Now, if I have higher water cement ratio for a given water content which means, my cement will be higher the paste is higher. So, if I increase the water cement ratio by 1 percent, if I increase, I mean by 0.05 percent, I increase my fine aggregate content also by that, 1 percent; so that you know the paste can fill in into the space that, is available in the fine sand. Now, of course water cement ratio has got no effect to the water.

So, this is the correction factor but this is by and large whether you understand from the theory or not because there are so many factors, there involved in the whole system. There are too many complicated interrelated factor, but these are based on empirical data generated and from that, it has been found and when, you have rounded aggregate you are packing. So, you need much less sand and sand can be reduced by simply 7 percent straight away. So, these are the adjustment that is suggested from for water content and sand content in the mix.

Now, having done that now what we have done so far; we have first find out the water target means strength and corresponding what is the water cement ratio. So that is usually the step with all almost all type of mixes and first you find out, what is your mean strength and correspondingly. What are water cement ratios you decide and this water cement ratio must satisfy the durability requirement. So, whichever water cement ratio is lower you choose that water cement ratio. The next step is of course to try to find out the water content. In this case also the sand content; so you find out the water content and sand content not directly here you find out in 2 steps.

First you find out the water content for 0.6, water cement ratio 0.8 compaction factors for zone 2 sand and for crush coarse aggregate. If your grade of concrete is M35 for higher grades higher than, M 35, M40 M 50 etcetera. What we do we find out the water content and sand content for the condition that we have zone 2 sand. We have water cement ratio equals to 0.35 compaction factor 0.8 and we are we have crushed coarse aggregate and for various MSS to be first the water content, then we are doing this correction or adjustment in the water content according to this table as just I have explained that would by doing this I have now found out water content, I have found out the cement content and I have found out the percentage of sand in the total.

(Refer Slide Time: 21:58)



So, then next what I can do; since I know the water cement ratio and I know the water content, I should be able to find out water cement ratio first of all you know, first of all I must find out, what is the correct water cement ratio. And this is found out, as the minimum of water cement ratio from the curves that, I have mentioned and the water cement ratio for durability and then cement content, then I find out because I know the total water content.

Now, this is known water content is known to me. Now, water content is known to me this W is known to me, water cement ratio I have decided 1 from the curve and from the durability whichever is lower. So, that is I return minimum; since water cement ratio star is known to me. Then W divided by water cement ratio that would give me the cement content that will give the cement. So, that is the cement I am require from considerations other than, durability. And, then I look into the cement content from the consideration of durability, whichever is higher I take that cement content, because durability gives you minimum cement content and this is the cement content, I require from workability. So, the maximum you know of the 2; I take and that is the cement content. So, that is the; so; therefore, I have found out now cement content and water content these 2 are known to me.

Now, I find must find out what is the fine aggregate content and coarse aggregate content. And you remember I said the volume is concerned. That means total volume of water cement sand and coarse aggregate must. You know, must give me the total volume total volume of individual component must give me the total volume minus the air content if any because our concretes are mostly not air and train. So, volume of air that is present because I if you remember when, we talked about, compaction we said that, there will be some amount of which will remain and this void should be of the order of around 1 percent, 2 percent and maximum 3 percent.

So, not more than that and this void content is again specified by the code; so therefore leaving this void content aside rest of the space must be filled in by the it must be occupied by sand that, is the fine aggregate the coarse aggregate the cement and water. So, if I sum total find out the sum total of volumes of individual component; they must add up to the total volume, because it is you know, after all each must occupy the spaces that's what we talked about, when we were talking about the principle of mix design.

So, what we are doing then here we can see that what we are doing here is you see if this is my volume and this volume V can be written as 1 minus 1 minus 1 minus air volume, you know air volume of air 1 minus volume of air stands for air volume this is air volume that, must be equals to the volume of water. Now, you know if W is the mass of water 1000kg per meter cube, it occupies density of it is 1000kg per meter cube.

So, W divided by 1000 will give me; you know, W is in kg per meter cube. So, W divided by 1000 W kg divided by 1000 does the volume occupied by water in 1 meter cube of the overall concrete. And C divided by specific gravity of cement which is usually taken as 3.15. So, C is the cement, in kg divided by 3.15 that is the volume occupied by 3.15 divided by 1 by 1000, 3000divided by 150 that is the volume occupied by the cement.

So, this is this divided by 1000 occupied by the volume occupied by water this is the volume occupied by the cement and proportion of fine in total aggregates is known. So, fine aggregate total specific gravity, you know this is the volume occupied by the fine aggregate divided by the volume percentages, you know occupied by sand in total volumetric percentages that was not percentage volumetric percentage.

So, this is the volume total volume occupied by all aggregates; so volume occupied by aggregate is this volume occupied by all aggregates is this and p is the percentage volume occupied by sand in the overall volume of the total aggregate, as we have found out volume occupied by fine aggregate. So, this is the total volume of the aggregate, this is the volume of the cement. This is the volume of the water, I mean all divided by 1 by 1000; that must be equals to the volume occupied by solid total volume minus the volume of air so volume is conserved.

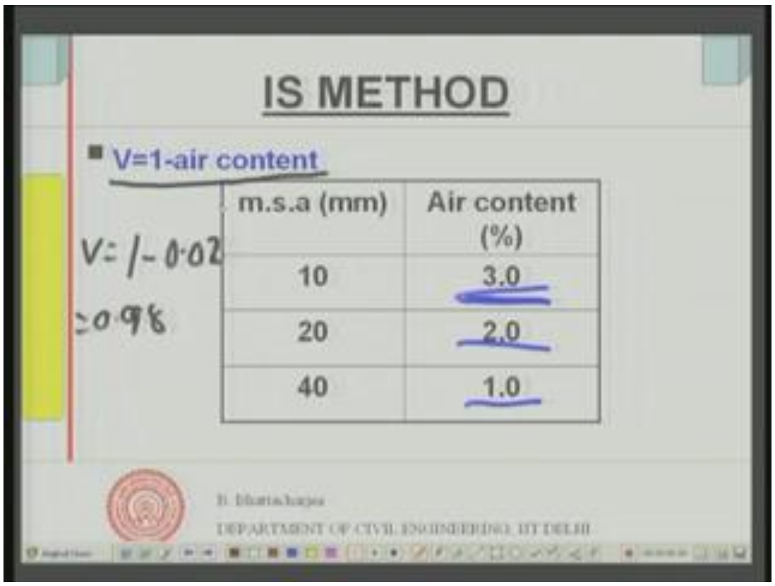
So, you know because this is solid and and the water they must occupy this volume whatever is not occupied by air. So, I have an equation of this form, now when this is known, these value specific gravities are known; this is known this can be found out. So, all this being known I can find; you know this ones. So, when everything else is known I can find out this one. These are known specific gravity of fine aggregate will be known percentage you have calculate.

Similarly; I can have an expression for coarse aggregate as well only thing I got to do is see this portion of the total volume of the aggregate, I can express in terms of the coarse aggregate volume, because coarse aggregate this is the mass of the coarse aggregate, this is the specific gravity of the coarse aggregate. So, this the volume occupied by coarse aggregate and 1 minus p that is, the percentage occupied by the fine aggregate that is the volume occupied by coarse aggregate.

So, 1 minus volume fraction occupied by coarse aggregate; so this divided by this will give me the total volume of the aggregate. So, therefore this expression again the same expression only this has been replaced and when all are known to me, I can find out this.

So, use this 2 equations I can find out the fagg, that is the mass of the fine aggregate and mass of the coarse aggregate in unit 1 meter cube of the concrete. Because I can write this V equals to 1 minus volume occupied by of by air in 1 meter cube of concrete. So, if I know that, from that I can find out this an example, calculation will make of course the things better. You know it will make understandable more understandable.

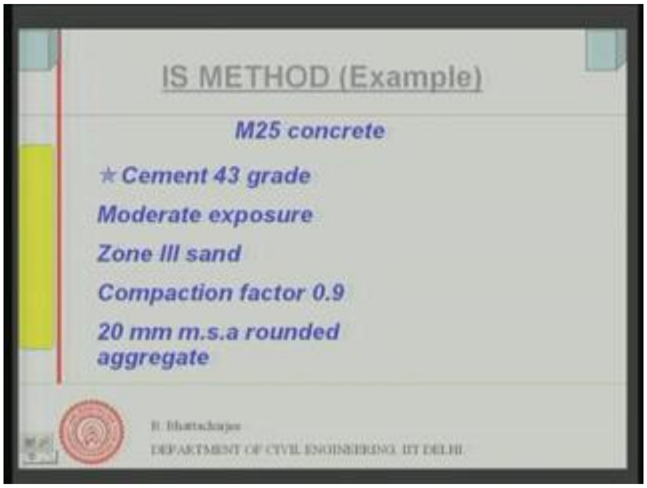
(Refer Slide Time: 29:01)



Now, volume of air as been already given in the code for example if you have MSa is 10 for 10 MSa, for MSa equals to 10. The volume of air content is given as 3 percent, because you know in the packing its finally depends upon, what is the best packing you can attain. Now, larger the aggregate size and you say you can attain much better packing it is finally 3 percent after compaction it is approximate air content assumed is 3 percent. For 20 it is assumed as 2 percent for 40 it is assumed as 1 percent and as I said, V is given by this formula; V is given by 1 minus it is air content.

So, air content percentage is known and so this will be simply, supposing it is 2 percent 1 minus 0 2 V will be equals to V is equals to for 2 percent it will be 1 minus 0.02. So, this will be 0.98, so I can find out V meter cube that is 0.98 meter cube is must be the volume of the all solids plus water all solids plus water, because air occupies 0.02 meter cube. So that is how it is to be find out; so all proportions therefore we can find out .

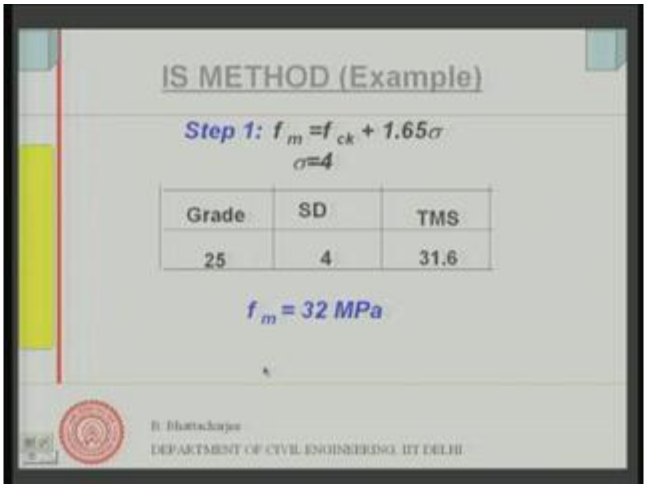
(Refer Slide Time: 30:18)



So, all proportions; therefore, we can find out. Let us take up an example problem this will make IS method clear because this is this is by and large this will be this is a popular method in the country. So; therefore, let us look at example, calculation now let us consider, M 25 grade of concrete and we use a cement 4 3 grade. Let us say and also we assume that, it is in moderate exposure. I have zone 3 sand that is available locally and that is what I am using compaction factor is 0.9 I require.

This is the compaction factor because we have discussed how we arrive at these values from, our requirement from application that is etcetera. So, my required compaction factor is 0.9 and I am going to use 20mm MSA rounded aggregate not aggregate rounded aggregate. So, this is the specification and also I know the specific gravity of the cement is known, specific gravity of the coarse aggregate and fine aggregate are known as and when, required I will be using them to show to explain through this example, calculation in the Indian style and method.

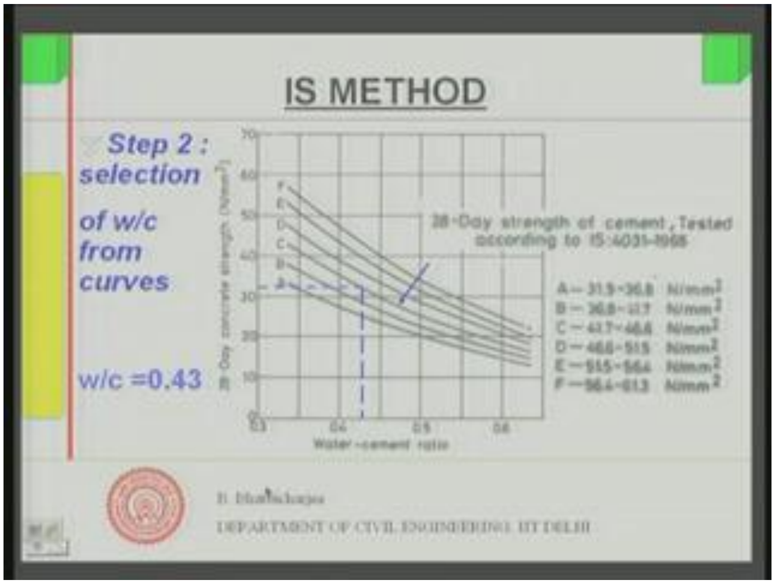
(Refer Slide Time: 31:42)



So, first step what we do; I said my grade is you know, first step is to find out target means strength. So, fm is given as fck plus 1.65 sigma and if you remember, if you recall I said that, for M25 grade of concrete 10 to 15; we use 3.5 sigma equals when nothing, is available. And from 20 to 35 possibly we use 25; we use or 25 to 30 we use for and above that we use 5 MPA. So, 4 MPA is a standard deviation given my grade is M25 that is known to me.

So, now I can find out what would be my target means; strength standard deviation is 4 grade is 2 5, then f m will be given as target means strength fm will be given as 25 plus 1.6 5 sigma and if I calculate this comes out to be 31.6. So, I can take this as approximately 32 MPa; so that is my first step; first find out target means strength, we have discussed why we find out the you know, why target means strength is higher than the characteristic strength and the formula, we have also discussed earlier. So, first step is to find out that, target means strength my target means strength is 32 MPa; my step 2 would be to find out the water cement ratio.

(Refer Slide Time: 33:04)



Step 2; would be to find out the water cement ratio and that to I find out from curves and I said my cement is 43 grade of cement and this is the set of curves which, I have discussed earlier. Because if I had, I didn't know the cement strength then of course, I would have used 1 particular single curve which is there.

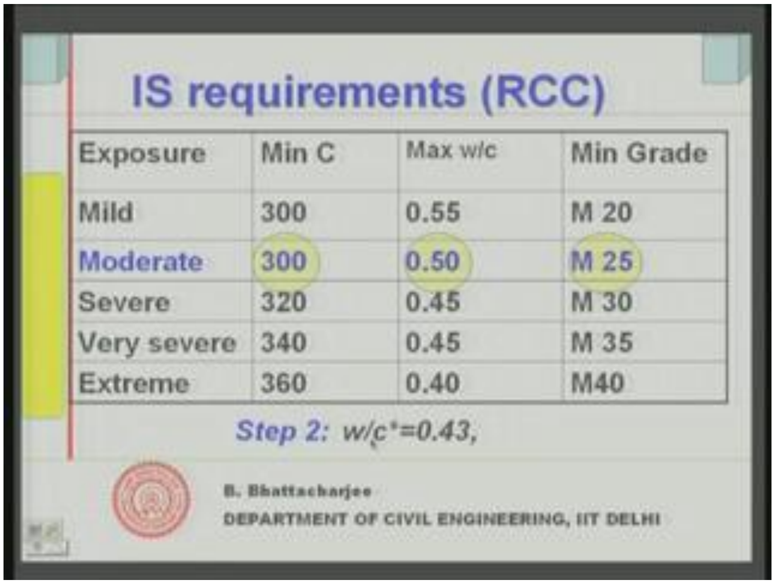
You know, and it will be very approximate well it doesn't matter, how approximate your mix design calculations are, because finally you have to do a trial mix and you have to adjust there is no other way, it is based on total as I said. So, therefore there is no other way you can get rid of trial mixes you have to do a trial mix only starting point you are getting. So, if strength of coarse cement is not known 1 could use that curve, which is a single curve and all cement or all concrete that is available in this country, but that would be very approximate. Slightly better is, that is I know about, the cement strength.

So, if you remember I said that cement 28 cement strength for me it is 41.4 8, 41.7 to 46, because I said my cement strength is 43; if you remember my cement strength, I mentioned was 43 grade and for 403 grade 43. So, 43 grade means 28 days strength of cement would be 4 3 here and this belongs to this, and therefore my curve would be C curve. So, therefore I have selected C curve, now my target means strength is 32.

So, if my target means strength is 3 2, that mean somewhere here target means strength. I should use this curve and find out the strength and that is what I do. You see I have 32; I draw a line and which cuts the C at this point, and then I just project it downward to get the water cement ratio somewhere there. I project it downward to get the water cement ratio there; so I have now determined the water cement ratio, water cement ratio and you can see this water cement ratio is about 0.43.

So, the water cement ratio is about 0.43; so this is how it determine the water cement ratio target means; strength first I find out and based on this from this curve, I find out what is a water cement ratio having found the water cement ratio this is not the final water cement ratio. I must compare this with the water cement ratio specified according to the durability requirement and whichever is lower I should select. We will do that exercise. Let us look at the next step. Next step is to look at the durability requirement.

(Refer Slide Time: 35:44)



Now, you can see that durability requirement for my case it is moderate we have stated it is moderate and this is a row which, I shall be using; you know moderate is the case and this is the row, which I shall be using actually, this row I shall be using which, as been colored actually blue for discussion. And if I use this then my cement content should be this, then my water cement ratio should be this and my grade of concrete is M 25. So, anyway we have chosen grade of concrete M25 that right in the beginning we have done. Because we said it is moderate exposure had it been any other exposure, 1 had to choose the grade of concrete accordingly. So, my case it is this so water cement ratio therefore, should be what minimum of you know minimum of this minimum of this and 43. It should be minimum of this and 43 and my you know, water cement ratio is this 0.43; because minimum of this 0.50 and 0.43 so whichever is lower I take point 43. So, 43 is my water cement ratio.

Now, this water cement ratio star that means it is finalized this is the variable this final. So, that's how I find out my water cement ratio water cement ratio. Let us see, what is the next step? Next step is to find out my water content and find out my sand content volumetric percentage of the sand content. And since I am my grade of concrete is M 25; I am using up to M 35 table. The table that was mentioned for up to M 35; I am using that and that table I am just, I have just reproduced and I am using MSA20 .

So, this is what I am using MSa20 MSa; so if I use 20 MSa my basic water content should be 186kg per meter cube starting water and volumetric percentage of fine aggregate in the total aggregate is 35 percent. I think this should be clear the first I find out from because it is below M35 grade of concrete. So, I just check what my MSA is and in this case my MSa is 20 and with 2 MSa we just find out, what is the water content starting water content and what is the percentage volume percentage of fine aggregate in the total having done that, we can now find out how much the adjustment required is.

So, the adjustment is done in this manner you know we had this table earlier if you remember. So, delta W that is change in the water content because there is a change in the zone the adjustment required for the zone, because our you know, the basic tables are meant for zone 2 sand. Now, our zone our sand is zone 3 sand zone 3 sand, and then the water cement ratio for the basic table is 0.6 our water cement ratio is different 0.43.

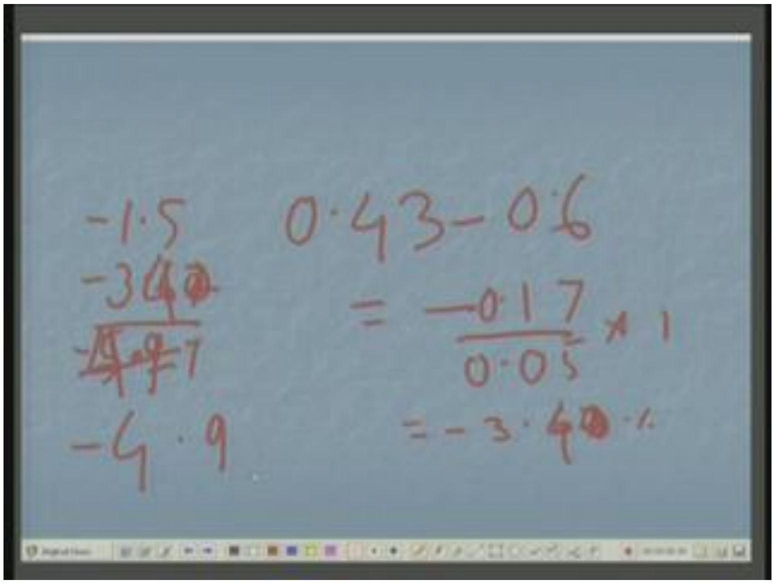
So, they will have we will have some corrections here as well, and then we have compaction factor 0.9; whereas the table had that compaction factor 0.8 and our aggregate is rounded aggregate. So, therefore we will have corrections in both delta W that is water content, as well as the volumetric proportion of the volumetric proportion of the fine.

So, let us see this as since our sand is zone three and we said that minus 1.5 percent for each zone, minus 1.5 percent for each zone. So, I will have minus 1 point 5 here, and then you see coming to compaction factor compaction factor. And this will have no effect in the water so there is now no effect here. Now, come to compaction factor I had 0.9 compaction factors. So, compaction factor will have a correction or adjustment in water content alone 0.9 minus 0.8 divided by 0.1 because for each 0.1 my correction is 3 percent. So, for 0.1; I have multiplied by0.43. So that’s by multiplied by 0.186 that would be the correction because 3 percent correction 3percent of 186. So 3 percent of 186 is 3 divided by 100 multiplied 186 into 0.1 into 0.9 minus 0.1 again, so this will be the correction due to compaction factor change.

The correction in water content correction in water content but no corrections here no corrections in delta p, then correction due to water cement ratio, there is no correction in this only correction here and how much is the correction? 1 percent plus and minus for each change of 0.0 5 percent of water cement ratio. So, my water cement ratio is point 43; so 0.4 3 minus 0.6 is the is that, you know that correspond to the basic table and then adjustment for 0. 43 I need.

So, 0.43 since there is a reduction; so 0.4 3 minus0.6, this will be a negative value multiplied by. You know, multiplied by 1 divided by 0.6 t 0.5 multiplied by 1 divided by 0.4, this would be 1 not 0 1 it is one. So, there is no percentage I can write directly, this 1 divided by 0.05 and minus 1.5 already I had. So, that would be this be the quantity;

(Refer Slide Time: 41:53)



So which would be something like 0.43 minus 0.6, which is equals to minus 717 minus point 1 7 and divided by 0.0 5 would mean divided by 0.05 for each 0.5; I have 1 percent correction. So, this would mean this will be equals to minus 3.67 percent. So, if you see if you go back to I had 1.5 minus 3.67 would make it minus this is 7. You know, 5.17. So, it will be something like 5.17; this is correct this should be correct 3.2. So, 5 no this is not 3 point this would be 3.67 this is 3.4.

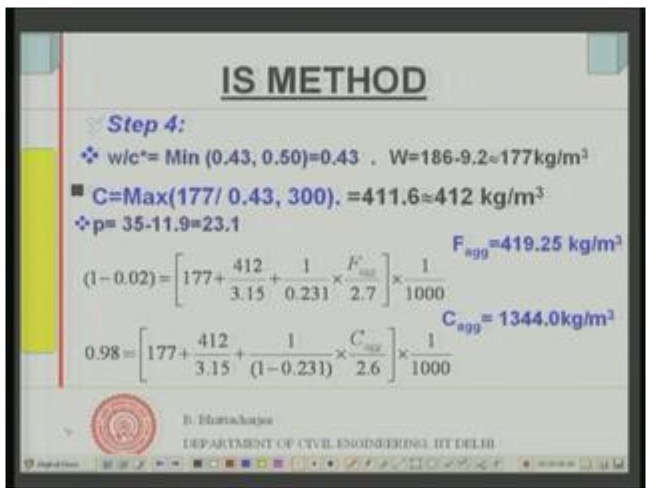
So, 3.4 it would be 9.4 9 so this would be 4 .9 is minus 4 .9, because this is 517 divided by 5 into 1 is 3.4 plus 1.5 will make it minus 4.9. So, 4.9 is the correction due to correction due to in this p delta p; you know 4.9. If you see minus 1.5 and this comes out to be 3.4. So, makes it 4.9 that's what we have seen and then additional correction will come because of the rounded aggregates.

So, it will come minus 15 minus 15 k g per meter cube here straight away and here it will come 7 percent. So, 7 and 4.9 makes it a 11.9 and here 15 and this 1 which, we have added because of the higher compaction factor you need more water. So, this gives us a net 9 .2kg per meter cube, so correction in water adjustment in water content is delta W is

9 point minus 9 point 2kg per meter cube and adjustment in the volumetric percentage of the is 11.9.

Let me write it down here again, this is you see this has got 2 components. You know, 186 multiplied by 0 .83, 186 into 0.03 this is plus and minus 15. So, that makes it 9.2 and this is minus 1.5 plus 3. 4 minus 7 minus 3.4. I mean this is minus all are minus minus 3. 4 make it and minus 7 would make it eleven minus 11.9. So that’s the adjustment that is the adjustment in the overall adjustment. That is the overall adjustment in water cement ratio. I mean water content and the volumetric percentage of the fine in total aggregate.

(Refer Slide Time: 44:57)



So, now with these corrections we can look into change in the you know, total water content we can find out and total fines we can find out. Let us see, now water cement ratio you remember that it should be minimum of the water cement ratio found out from the curve that is, this and the 1 corresponding to durability, so therefore 0.4 three. So, water we have found out to be 186 minus 9.2; now the adjustment because of the rounded aggregate and because of compaction factor change and this 9.2. If we subtract we get 171. Therefore, cement now, I we can find out cement content which will be maximum of the 171 the water content divided by 0.43 and 300 and which makes it 411.6 and is about 412 kg per meter cube.

So, that is my cement content after all adjustment and then I got to find out what should be my volume of fines coarse aggregate. What is the volume of fines and what should be my volume of coarse aggregate. Now, volume of fines if I you know you remember we said that, we find it out from this equation where this is this represents. You know, this represents this is the amount of water divided by 1000 obviously; this is the amount of cement divided by specific gravity of cement and 1000, because you know, since I am finding out in 1 meter cube.

I am taking the total volume as 1 meter cube cement water in the kg per meter cube. So, everything I am finding out the quantity in 1 meter cube. So, in 1 meter cube this will be the volume fraction of air because we said there will be 2 percent air corresponding to 2 percent air corresponding to our MSa 2 MSa 2 corresponds to 2percent air content 2 percent air content air and therefore this 2; I am subtracting from 1 meter cube.

So that must be the volume occupied by all the ingredients namely waters the cement the fine or total aggregate. This represents the total aggregate as we have seen earlier; now, the volume of cement volume of water is 177 because we know the density of water is 1000 kg per meter cube. So, if I had 177 kg of water that, would occupy in meter cube divided by 1000.17. So, I just divide it by 1000 what would be the volume occupied by cement 400 and 12kg is the amount of cement divided by3050,that is 3.15 the specific gravity, which is basically nothing but, relative density with reference to water.

So, 3.1 5 and 1000; so if this got a density of this will be 3.15 times into 1000. So, divide this by 3.15. Now, fine aggregate if fine aggregate mass is here divided by p. Now corrected p was 0. 231 how does 0.2 31 comes we can see that, would be coming like this my I had earlier 35. If you remember I had 35 minus 11.9 and this 11.9 comes, because 7 percent I can reduce, because of the rounded aggregate and I reduce 1.5 percent because of the zone of the sand which is zone 3 and also I reduce 3.4 percent because of the change in the water cement ratio.

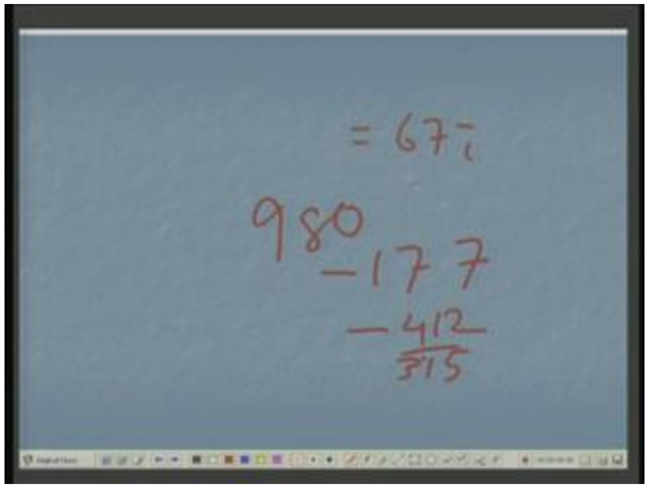
So, considering all that the total change was available minus 11.9 with the adjustment from 35 and that gives me 23.1 percent. So, my p is 23.1 percent that means the volume fraction of fines in the total aggregate. So, volume of fines is fine aggregate mass of the fine aggregate divided by the specific gravity of the fine aggregate. So that is the volume of fine aggregate, if I divide this by 0.231, I get the total aggregate volume.

So, total aggregate volume is this is the total aggregate volume total aggregate volume these are volume of the cement and these are volume of the water. So, this total of the volume must you know all of course, divided by 1000 remains must give me the volume occupied by everything other than, air in 1 meter cube and this is volume occupied by air This is 1 is the total volume minus this so this is the volume occupied by all this m; so this is the equation I use- to find out the value of fine aggregate.

Similarly I can use changed modification of this equation to find out the volume of a coarse aggregate and here the coarse aggregate comes into picture divided by 2.6 and the volume fraction of the coarse aggregate, which is 1 minus 0.231; because this is the volume fraction of fine aggregate in the mix.1 minus that will give me the volume fraction of the coarse aggregate in the aggregate mix.

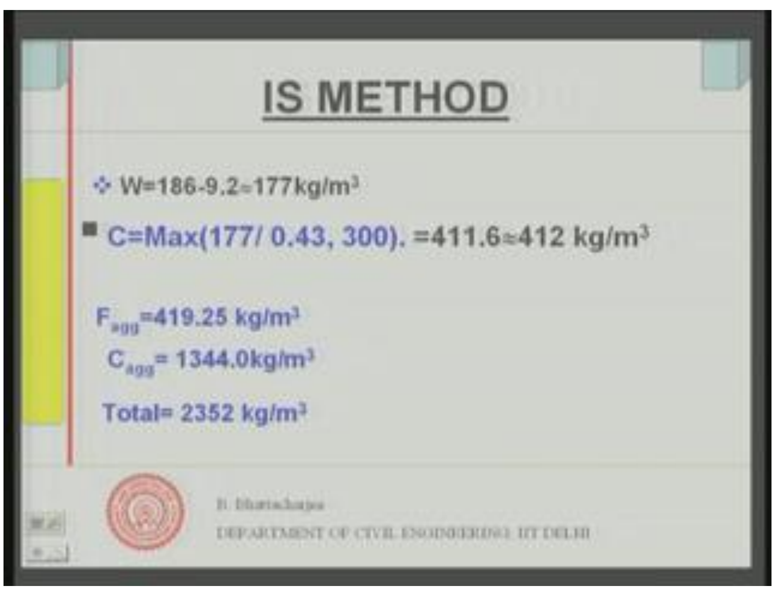
We said this is the proportion volumetric proportion in total aggregate of fine aggregate in total aggregate and this is therefore, is the volumetric proportion of coarse aggregate in total aggregate. So, using this 2 equations therefore I can find out the quantity of fine and coarse aggregate I have and I find out, the quantity of fine aggregate as this and quantity of coarse aggregate is this. You know, just making calculation what I do 0.9 8 minus this quantity which, will comes out to be about 0.6 and 72 or something you know 0.98 multiplied by 1000.

(Refer Slide Time: 50:45)



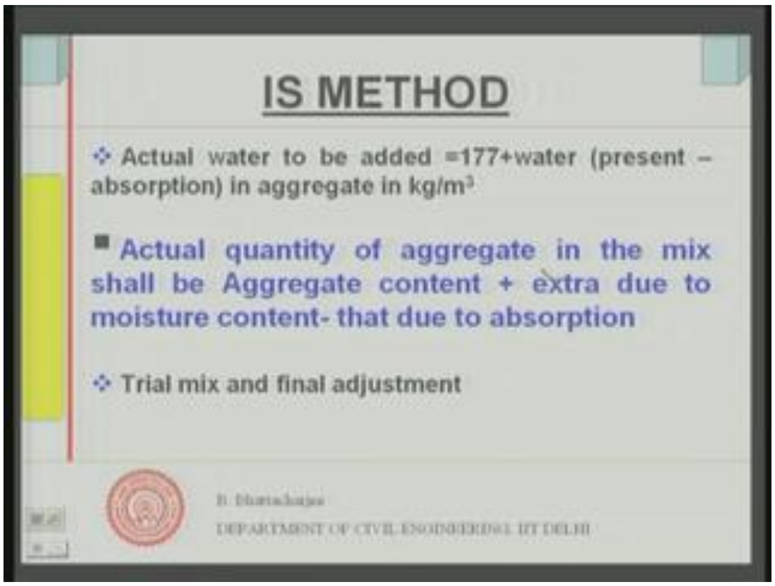
So, actually 980 if you see it will come out to be 980; it will come out to be 980 minus 177 minus you know minus 4 12 divided by 3000. You know, 3300 and 3.15 and this this is 672 point something whatever it comes out and if I calculate it, then I will get then I will get, if I calculate it I get this. You know from this 2 equations I get 400 and 19.2 5 and 13. 440; 44.0. So; now, I can look into my total mix- design or mix- proportions that I have got the mix proportions as I have got water I have got 177 kg per meter cube.

(Refer Slide Time: 51:22)



I have got cement as 400 and 12k g per meter cube aggregate as 400 and 19.25kg per meter cube coarse aggregate as 13.440kg per meter cube. The sum total therefore would come to be 2353kg per meter cube and a density of the concrete that's, the density of the concrete that would be occupied in 1meter cube of the volume. So, therefore that is what gives me the total mix design, now supposing I want to you know, supposing I want to hmm do further I have to do actually trial mixes, I have to do trial mixes and I have to have some more adjustment.

(Refer Slide Time: 52:06)

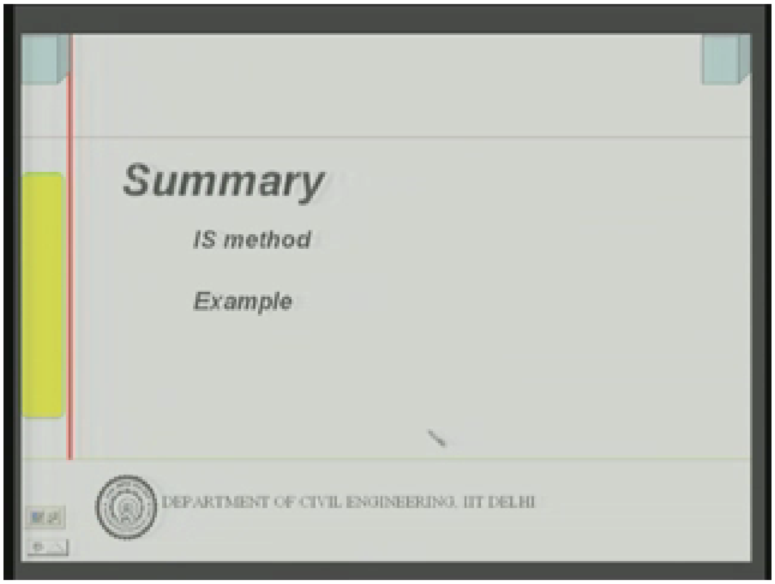


So, first thing I do is I do trial mix but while doing trial mix 2 things I need I must actual water that, I should add is that 1.77 plus the water present in the aggregate minus it absorption in aggregate in kg per meter cube. You see aggregate if it is dry, if it is dry I mean some moisture may be present whenever, I am using the aggregate, if it is of course in saturated surface dry condition. I don't have to add anything it is 177 only, but actual moisture content, could be more than that; so if it is more you know then that much ,water I should reduce down from total water or whichever way.

You know like it should be actually it should be the added there should be a correction for actual water present if water present is high, water it should be this should be minus actually water present, if it is higher than, you know water present if it is higher than water present. If it is higher than, saturated surface like condition that I must if it is less than, saturated surface like condition that should be that much water I should add extra because that will go, by in absorption. So, therefore; that adjustment I will have to make so that is done, by you know adding the extra amount of first I find out how much is the moisture content minus the absorption.

So, that much if it is plus then that should be subtracted otherwise if it is minus that should be actually that should be, you know that should be if it is this should be subtracted actually not added to be subtracted. So, this is what I do, and then actual aggregate also actual quantity of aggregate in the mix should be adjusted depending upon what is the moisture content and aggregate. If aggregate cont- some amount of moisture therefore, I should take a little bit of more aggregate. So, that the moisture that is present that, you know additional weight that is moisture weight is subtracted from the total aggregate weight.

(Refer Slide Time: 54:19)



So, these corrections are need extra due to moisture content aggregate content minus extra due to moisture content and that, due to absorption that corrections are necessary. So, then do a trial mix and do final adjustment, then do a trial mix and then do a final adjustment. Now, this therefore moisture content at site as to be done, you do a trial adjust trial mix find out whether you are getting the property or not.

If you are not getting the strength then if you are not getting the strength then you have to reduce down the water cement ratio, and if you are getting the work. You are not getting the workability; you will have to increase the water cement water content keeping the water cement ratio same. In case the first case you must keep your water content; so that trial mix trail adjustments are required and that’s how we do the mix design.

Thank you.