Concrete Engineering and Technology
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Lecture - 9
Proportioning of concrete mixes (Part 3 of 3)

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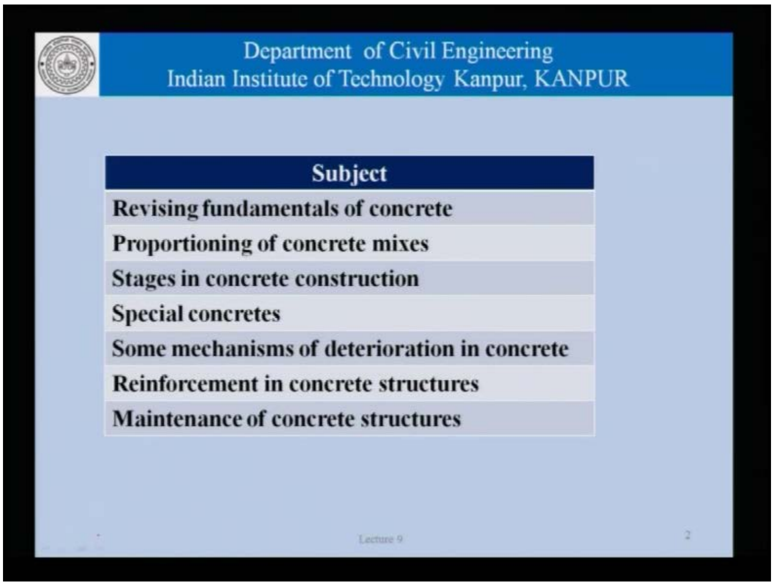

Welcome back to this series of lectures on concrete engineering and technology, where we are talking about different aspects of what concrete engineers are expected to know in the present day- beginning with the proportioning mixes, working with special concretes, understanding the deterioration in concrete structures, what kind of materials are available for reinforcing these structures, and of course finally, the maintenance of concrete structures. We were talking about proportioning of concrete mixes.

And so far, what we have done is we have gone through a numerical example and seen how a simple algorithm which is based on some experiments, properties of the constant materials, and the desired properties of concrete can be implemented, to determine the proportions of a concrete mix.

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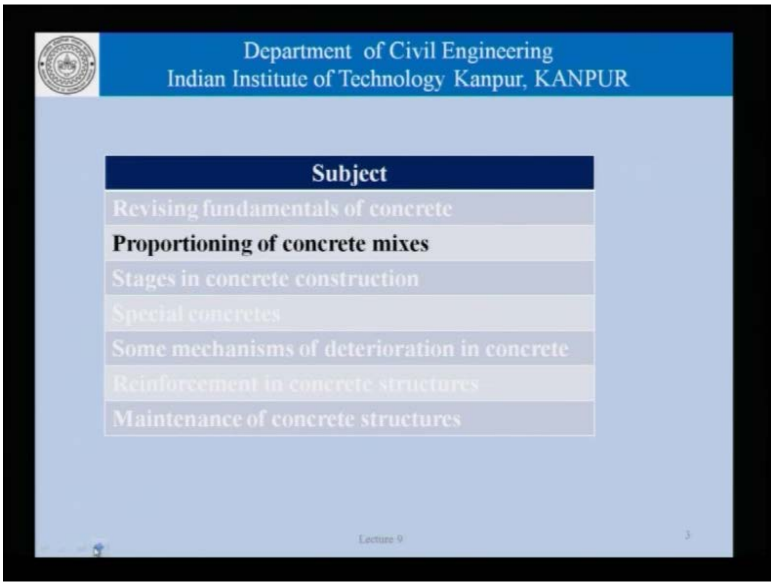

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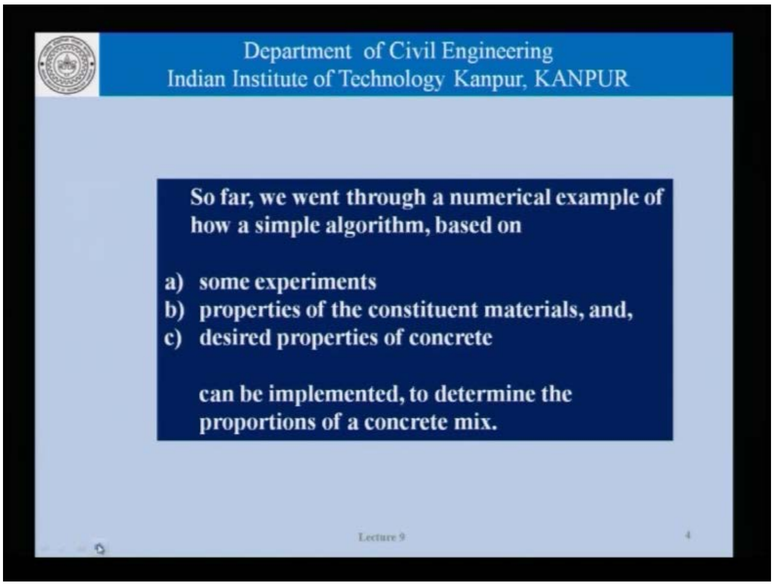

Now, the limitations or the assumptions in our example, where that we were working with the very simple concrete mix, that is only having the basic ingredients- the fine aggregate that is sand, coarse aggregate- cement and water. Of course, we assume that we will have a certain amount of air. So, the example that we used can be used for air entrained concrete as well as non air entrained concrete depending on what kind of air entraining at mixture we use or we do not use.

As far as experiments are concerned, yes, they were required because we needed the unit water content versus slump relationship, we needed the strength versus what a cement ratio relationship, we needed experiments which will tell us what will be the best or the optimum s by a, that is the sand content in the total aggregate volume or the total inert material volume, in order to proceed.

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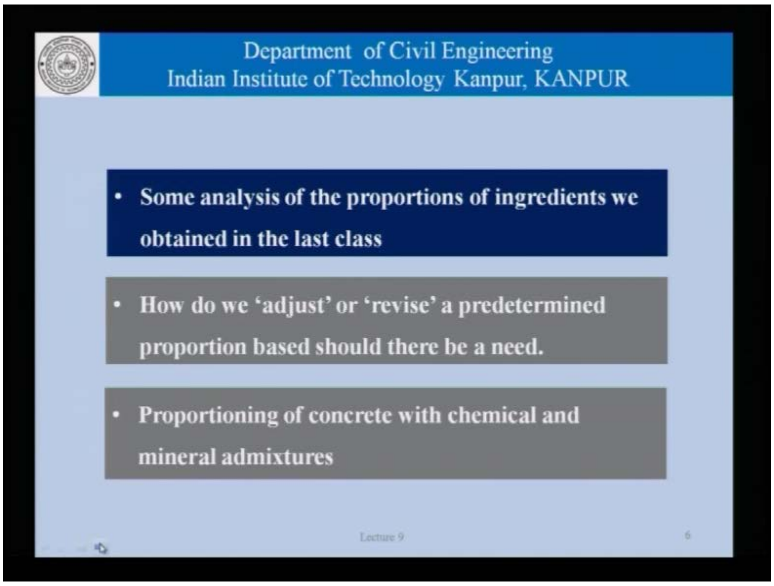

Now with this background, today we will focus on some analysis of the proportions of ingredients we obtained in the last class. We will discuss how we can adjust or revise a predetermined proportion, should there be a need. And we will try to also look at proportioning of concrete mixes with chemical and mineral admixtures. So, coming to the first part of the discussion today, which is analysis of the proportional of ingredients that we arrived at in the last class.

What did we start with? We started with an attempt to proportion an air entrained concrete. It is air entrained because air content that we have taken is not 1.2 or 1.6 or 2 percent level which is normally assumed for a non air entrained concrete but is much higher than that which means that we have at the back of our mind the fact that we will use some kind of an admixture to get this kind of air content. So, we assumed or we started with an assumption that, well, we want a concrete or an air entrained concrete which has an air of 5 percent, water content of 160 kgs, water cement ratio of 50 percent, and then s by a of 36 percent.

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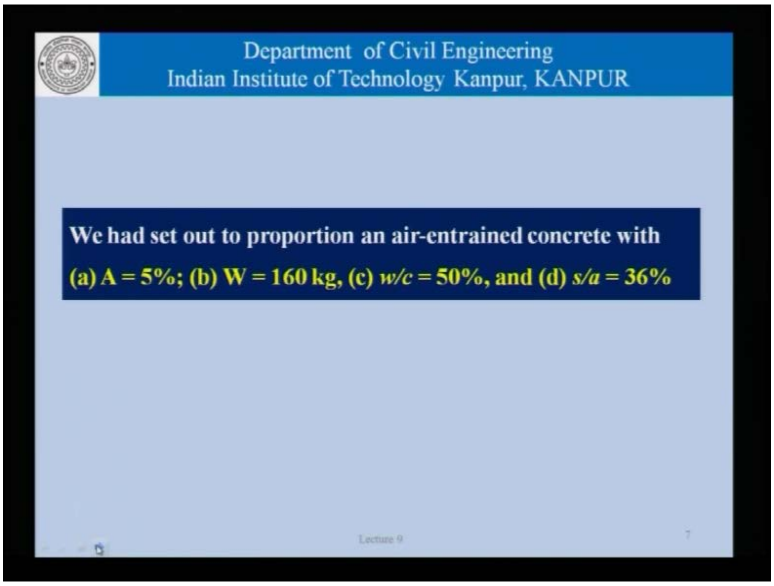

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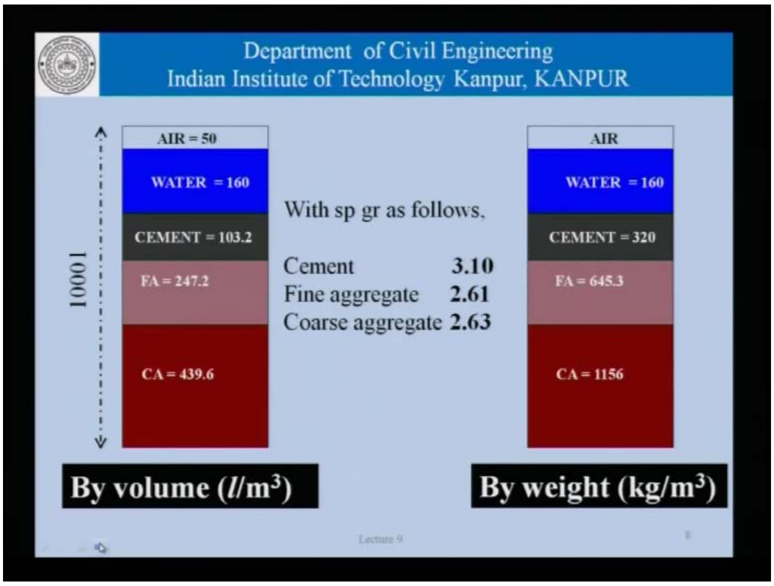

Now, when we went through that example we found this to be the volumetric distribution of the different materials- air, water, cement, fine aggregate, coarse aggregate, all these volumes been given in liters per cubic meter. We also had with us this weight distribution of the materials in terms of water, cement, fine aggregate, and coarse aggregate.

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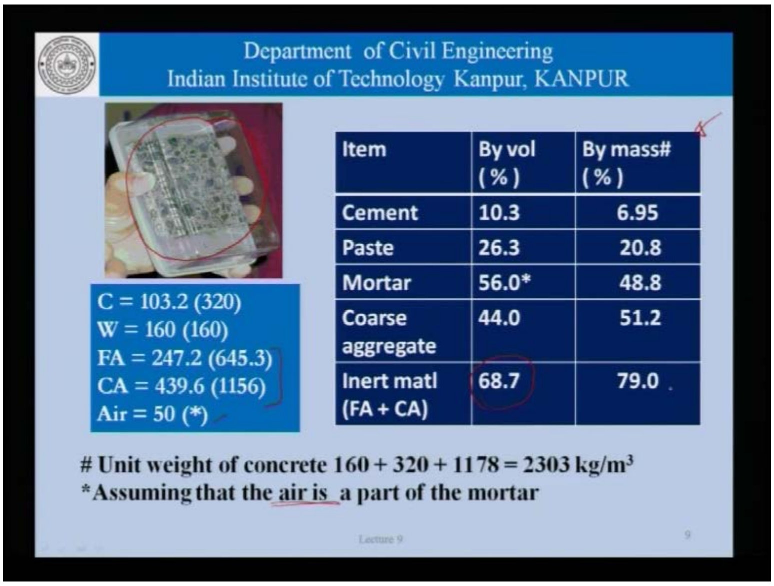

Now, if we look at this distribution that we got, cement of 103.2 liters- 320 kgs, water of 160 liters per cubic meter or 160 kgs, fine aggregate and coarse aggregate as just given here, and the fact that we had 50 liters of air in the concrete. If we now try to look at this table here, and also keep at the back of our mind the fact that finally the concrete looks like this. That is the concrete is basically an embedded composite where or a composite material where coarse aggregates are embedded in the mortar phase. And if there are no coarse aggregates then we can look at sand embedded in paste, and so on.

Then, if we look at the volume composition of cement, paste, mortar, coarse aggregate, and so on, let us look at these numbers a little more. Cement is about 10.3 percent by volume, and about just 7 percent by mass. If we look at paste which is water and cement together then we get 160 plus 103 which is about 263 which is 26.3 percent. So, the paste volume in the concrete is just about 23 or 26 percent. But, in mass terms it is about 21 percent, 20.8 percent, and so on.

Mortar which is a very important constituent because that is what is the host for the embedded coarse aggregate that is about 56 percent. Of course, what I have done with 56 percent is, that I have assumed air to be a part of the mortar, and that we discussed in the last class and the reasons were discussed there that air can be considered a part of the mortar.

The argument can be extended that why should air not be considered a part of the paste; well, you are free to do that so long as you know that that is what you are doing that is assumption that is being made. I am not sure whether there is absolute consensus in the literature on this issue. So, we are going just by rational system where we say that well that air is distributed everywhere in the concrete. And since concrete is a material which we are considering as coarse aggregate embedded in mortar systems, it cannot be with the coarse aggregate. And therefore, we are considering it to be a part of the mortar. And that is the logic or the reason that we are using to say that; well, as far as the present case is concerned mortar is about 56 percent.

Now, coming to coarse aggregate. Coarse aggregate therefore, if mortar is 56 percent coarse aggregate by definition would only be 44 percent. I mean if you look at the volume here it is 439.6 which is approximately 44 percent of the total volume. So, what it effectively now means, is that in the normal concrete and let me assure you that this is quite a normal concrete. In a normal concrete, coarse aggregate percentage is about 40 to 45, 50 percent. As far as economics is concerned coarse aggregate we would like to maximize because that is what it gives us the maximum volume. So, if we are able to push from 44 to 46 percent then we make the concrete mix economical because then we save cement. So, having understood this principle that we need to maximize coarse aggregate in the mix, that is one part of the story.

Now, if we keep increasing the coarse aggregate content we have to sacrifice the amount of mortar. And now comes the other side that is the mortar that we have should be having sufficient properties or appropriate adequate properties in order to be able to host that amount of aggregate. Sometimes when we say that the concrete does not have enough cohesion it segregates, what does it mean? That the coarse aggregate component falls apart. You can imagine that if you push the coarse aggregate content to a very large value, there is no way that the aggregates can be held together in creating a cohesive mass of concrete which can be mixed, placed, vibrated, and so on, to give the required kind of properties. So, keep these numbers in mind.

At the end of it, what is the total inert percentage? What is the total percentage of inert materials? Inert materials is coarse aggregate and fine aggregate, that is about 68.7; may be even in some cases 70 percent. So, the reactive part as far as concrete is concerned the part that reacts chemically is only cement and water, that we have seen when we talked about the hydration of cement in an earlier discussion. So the inert part is close to 70 percent of the total volume of concrete. And of course, if we convert it to mass, the numbers are given here.

And, I would like you to take a closer look at them; try to study more literature and see how they vary from one concrete to another, from one mix proportion to another. And obviously, if we change the water cement ratio, the water content, and so on, all these numbers will change. If the water cement ratio is reduced we put more cement in the system, we have to decide whether we want to keep the mortar same in which case the sand will have to go down, keeping the coarse aggregate the same; or, we can say well, that the coarse aggregate go down and the mortar content go up, and so on. So, that is the kind of discussion that we will have when we talk about proportioning or working with the special concretes.

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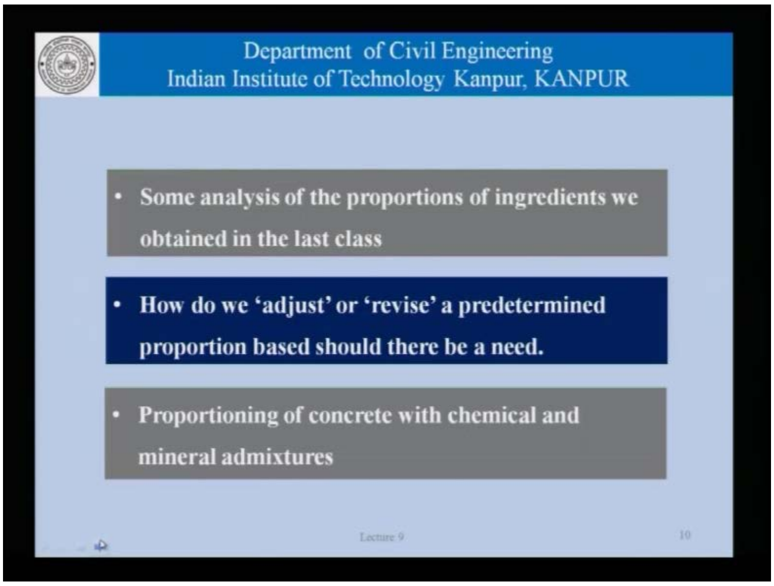

Now, let us come to the second part of the discussion which is how do we adjust or revise a predetermined proportion, should there be a need. What we have done so far? Is that we have created some numbers which tell us that well? If we create a concrete or we mix a concrete, we prepare a concrete with those ingredients in that proportion then the concrete should have certain properties that we started with; now that may not always happen and we may need to revise them, mix that we have determined. So, there is a need to adjust or revise a proportion.

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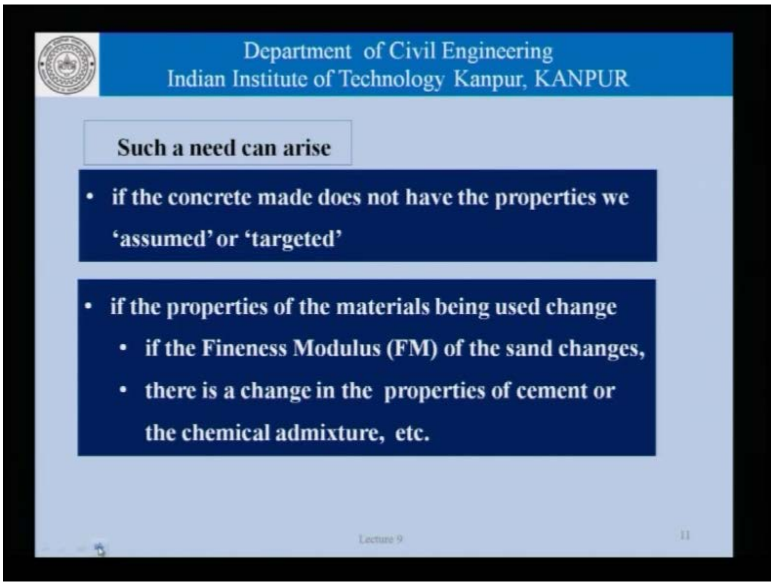

And, that need can arise if the concrete made does not have the properties we assumed or targeted. Or, it can arise if the properties of the materials being used change. That is, for example, the fineness modulus of the sand changes. A concrete project does not get completed in a day.

It takes several months, sometimes several years. And therefore, we use materials over that period of time from perhaps different sources. And the properties of these materials whether it is sand or it is cement they change over a period of time. At the same time, if you are borrowing or taking materials from different sites or different plants, those properties could be different. And therefore, there is a need to have a specific proportions for different sets of material properties. And therefore, that is what we. So, under these conditions we need to or we may need to change the proportions that we have determined. So, getting back to the example that we worked with. We thought that we will get a slump of 8 centimeters or 8 t mm and a air content of 5 percent, and with this target in mind we proportion the concrete mix.

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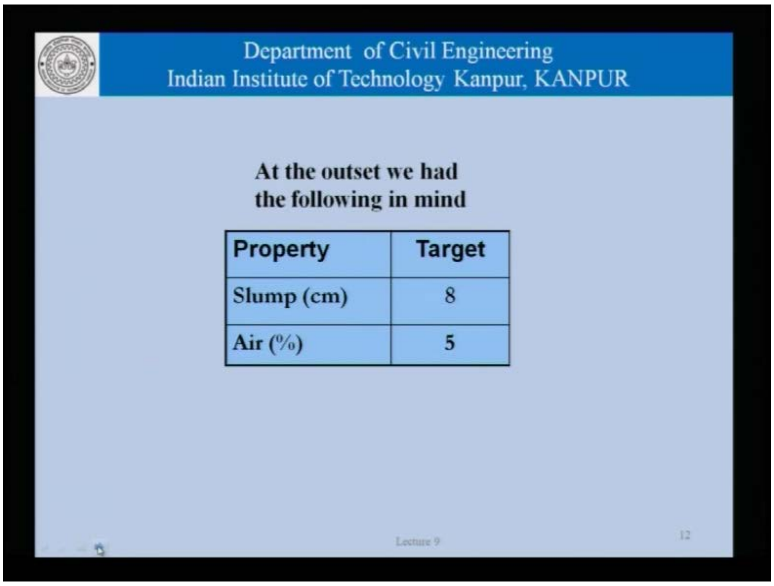

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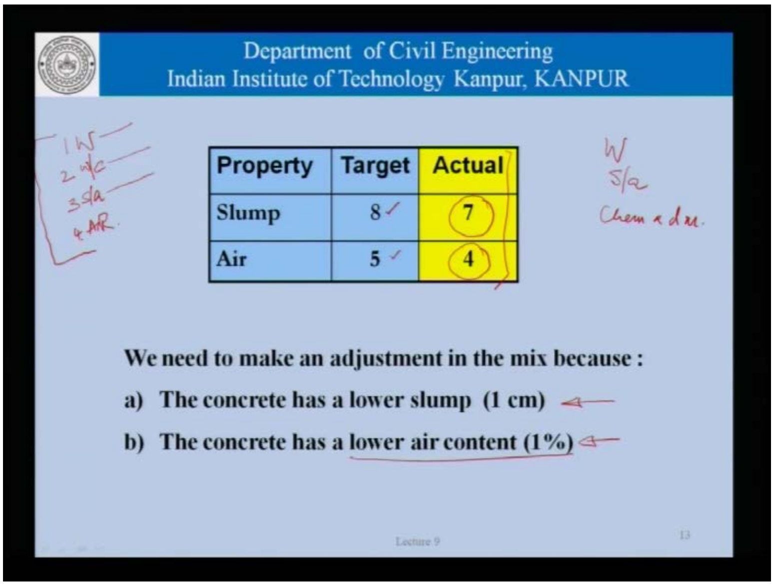

And, we came to the numbers that we have talked about. Now, for example, we actually mix the concrete in the lab, and we find that actually we are getting a slump of only 7 centimeters and we actually get a air content of only 4 percent. This is absolutely possible because we started with the water content. We used an s by a. We used a chemical at mixture dosage which somebody told us would lead to a 5 percent air. Now, depending on the actual properties of the materials used, this might not be sufficient. And these are the actual values that we get.

Now, what do we do? Because, at the end of it we want 8 centimeter of slump and we want 5 percent of air. With that mix that we designed, we got 7 centimeters of slump and 4 percent of air. What we need to do is we need to increase the slump. The concrete has a lower slump by 1 centimeter, the concrete has a lower air content by 1 percent, and both these have to adjusted. Of course, it is eminently possible that the actual values could be higher; or, one of them would match, the other would not match, and so on. So, we need to adjust in any case. So, this is just an illustrative example as to how we need to adjust the concrete mix.

I would like you to recall that algebraically the mix proportion can be completed if we just knew the water content, the water cement ratio, the s by a, and the air content. If we know the air content we fix that, we determine the chemical admixture dosage or whatever we want to do, assuming that that amount of air will be there. We get the water content from the water slump relationship. We get the cement content from the water cement ratio required based on the strength required. Then as far as proportioning the inert material is concerned we use the, s by a, to find out how much sand should be there as a proportion of the inert material.

So, somebody without knowing anything can proportion a concrete mix if these 4 numbers are known. This is a simple excel sheet based exercise. However, what is required of a concrete engineer is an adjustment, is an engineering judgment of how the parameters need to be changed if the target values in terms of slump air content, perhaps strength are not met. Strength is something which we are not taking up in this example because in most cases it takes a lot of time; most cases the strength is given in terms of the 28 days strength. And therefore, we are assuming that the water cement ratio of 50 percent that we used was sufficient to get the strength. And if that needs to be changed that two can be changed in a similar example.

Similarly is the case with air where algebraically it is possible to do it very simply but in order to get the right amount of air we need to play around with the dosage of the chemical admixture; we may have to change the chemical admixture, and so on. And that is something which is not being covered in this initial discussion on proportion of concrete mixtures.

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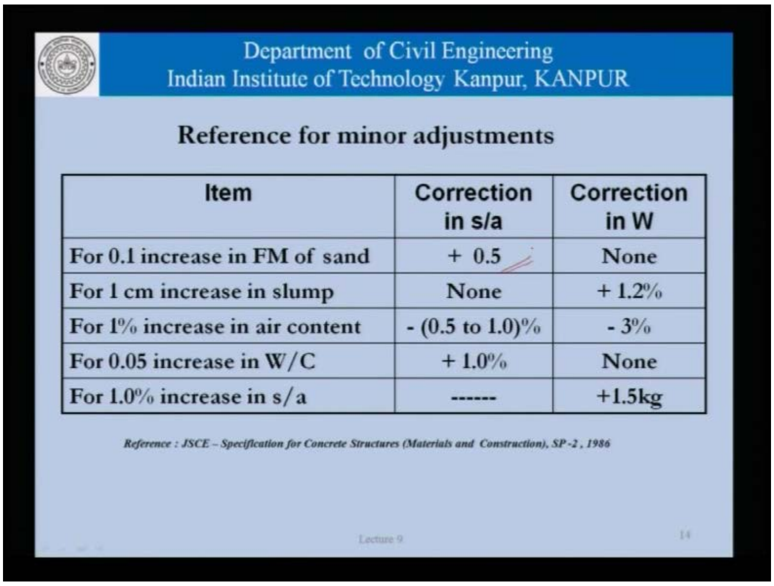

So, now let us carry on, hence go to a table which again has to be given to us and that is largely based on empirical evidence; the numbers are based on empirical evidence, but the logic and the reasoning is fairly simple. What it says is that if we want or if we have an increase of 0.1 in the fineness modulus of sand, what happens when the fineness modulus of sand increases? Does the sand become coarser or finer? Let me give you the answer, it becomes coarser.

If the fineness modulus of sand increases by 0.1, then we need to increase the s by a by about 0.5; we do not need to adjust for water content in the mix. If we want to increase the slump in a concrete by 1 centimeter, we do not need to adjust the s by a, but we need to have more water in the mix. And 1.2 percent is just another number which is based on experience, and that will vary depending on the type of aggregate that you are using. Sometimes, an increase of 1.2 percent may not suffice; sometimes you may have to increase water by little more; sometimes you may be able to get away with increase in the water a little less.

If we need to increase the air content by 1 percent; now, we will increase the air content by 1 percent using a chemical admixture, a dosage in a chemical admixture. But, the implications of that increase will be that the concrete will become more workable and therefore, the slump will increase. Now, in order that the slump increases, to control that what we need to do, is to reduce the water content and that is what is given as a reduction of 3 percent. So, the 3 percent is an empirical number, but the principle behind it is that air content increase gives you increase to workability.

And, in order to get the workability back, because we are wanting the workability back at the same level, but we increase but we want to increase air content; and that is why we need to or we should reduce the water content. Paraphrasing the argument, if we do not increase or if we do not change the water content, what will happen is, the air content will increase and the workability will also increase. If that is acceptability you find, but usually it is not.

Similar is the case with water cement ratio. Now if we need to change the water cement ratio by about 4.5 which is 5 percent, 50 to 55 percent, or 50 to 45 percent, and so on, then we need to correct the, s by a. Please remember that what happens when we increase the water cement ratio? An increase in the water cement ratio means lesser amount of cement being used; and therefore, the amount of fines in the system goes down and we need to compensate that.

And in order to compensate that what is the option that we have? We would like to increase the sand in the system, and that is what is given here. That, if we increase the water cement ratio by 0.45, we should increase the s by a by about 1 percent, and so on, so this is the rough table which serves as the guiding principle for changes in a concrete mix if we have to adjust from known targeted values; or, which we have to adjust using known values to a desired target value.

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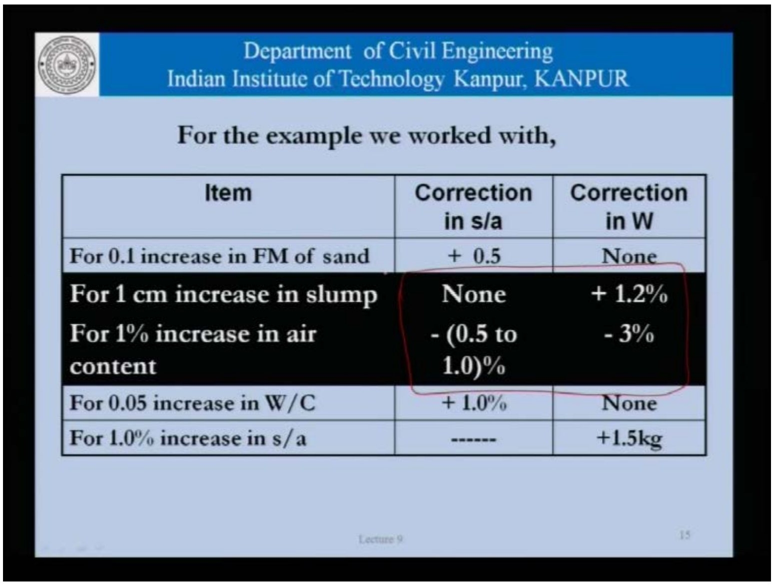

Item	Correction in s/a	Correction in W
For 0.1 increase in FM of sand	+ 0.5	None
For 1 cm increase in slump	None	+ 1.2%
For 1% increase in air content	- (0.5 to 1.0)%	- 3%
For 0.05 increase in W/C	+ 1.0%	None
For 1.0% increase in s/a	------	+1.5kg

Now, how do we implement this in our case? What we had was, we would like to increase the slump by 1 centimeter and we would like to increase the air by 1 percent. So, what it means is that, as far as the slump is concerned we do not need to adjust, s by a, but we need to increase the water by 1.2 percent. At the same time, we want an increase of 1 percent in the air content. What does that mean? The table tells you that we need to adjust the s by a, by about negative that we need to reduce the s by a, anything between 0.5 to 1 percent. And we need to reduce the water content by 3 percent. So, based on this prescription we need to make modifications in our parameters and then try again.

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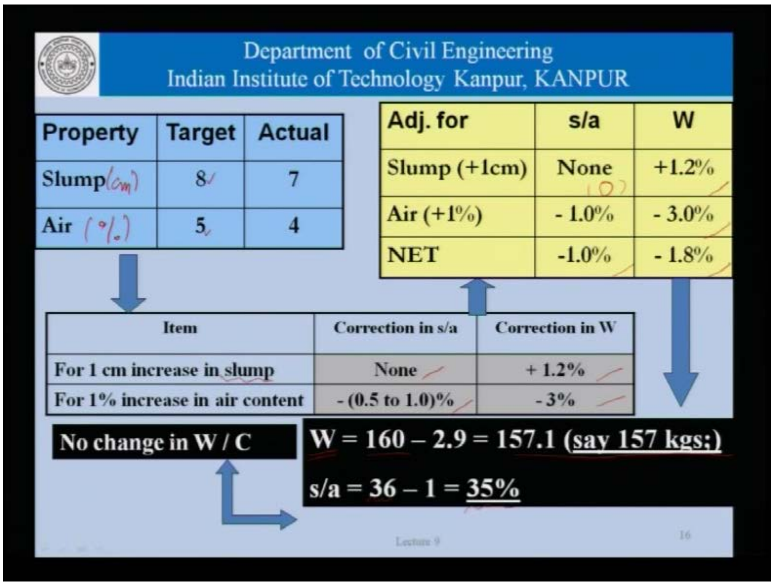

So, effectively what we are trying to do is that we wanted 8 centimeter and 5 percent of air content in an 8 centimeter slump; if this was a centimeters and this was in percentage then we wanted 8 and 5; we got 7 and 4. And therefore, what we need to do is we want to increase the slump by 1 centimeter, we want to increase the air content by 1 percent, s by a we do not need to correct here but for this parameter here air content we need to do something with s by a which is reducing it a little bit as far as correction in water is concerned. Slump alone dictates that we increase it by 1.2 percent. Air content increase demands that we reduce it by 3 percent.

What does that mean? If we just convert this into a table like this what we are saying is that, well, let us add it up; that is the simplest way to do things. It is a simplistic way; it is not necessarily the best way, but that is the almost the only way that we have mechanically. And therefore, this 0.5 to 1 has been made 1, and the net result of this which is basically 0, and a minus 1 is minus 1. We will reduce the s by a by 1 percent, and the net result of plus 1.2 and minus 3.0 is minus 1.8, that is we will reduce the water content by 1.8 percent. We will reduce the s by a by 1 percent. And we will do something as far as the chemical admixture dosage is concerned in order that the air content is increased from 4 to 5 percent.

With this as a basis now, we do the proportion exercise again and for that water content has to be now reduced from 160 what we started with, to let us say 157 that is a 1.8 percent reduction; s by a, we used 36 percent in the last example and reducing it by 1 means it will work with 35 percent. We will not change the water cement ratio because we do not have any information about it and we really do not need to change it in this example.

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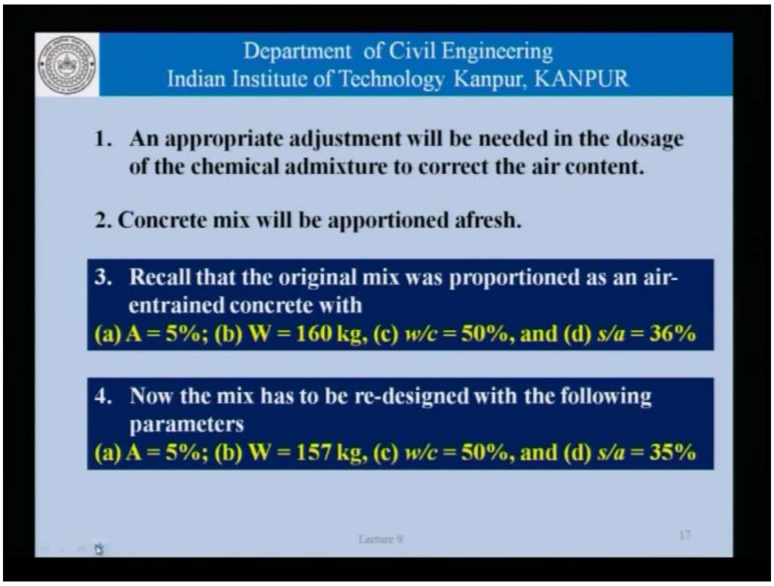

Now, to recall what we have done, an appropriate adjustment will be needed in the dosage of the chemical admixture to correct the air content. The concrete will be apportioned afresh. And beginning with this example that we had, we will now work with the parameters- air content is 5 percent, water content is 157, water cement ratio is 50 percent, and s by a is 35.

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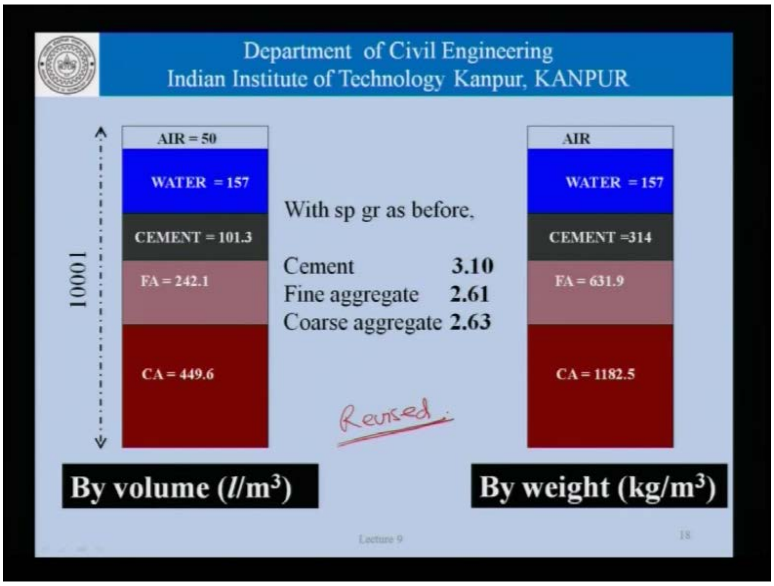

Now, if we change these numbers and we keep the specific gravities as previous example, and there is no reason to change those specific gravities because they are the material properties that we used and the same material is being used in the revised mix, we get these numbers as far as volumetric proportions are concerned: air is 50 percent, air is 50 liters, water is 157 liters, cement has gone down a little bit because water has gone down a little bit. So, cement becomes 101.3. Fine aggregate is 242.1, coarse aggregate is 449.6. And if we convert it to mass, these are the numbers that we get.

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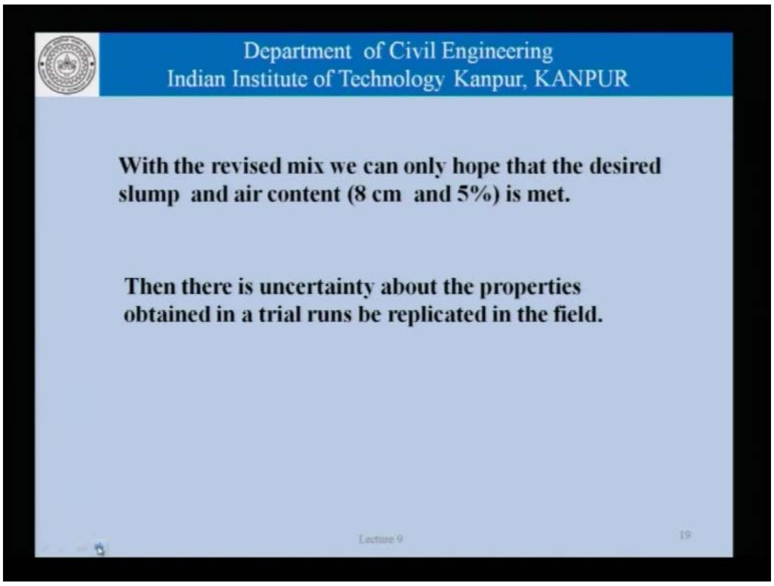

So, this is the revised mix. So, what we have done is we have gone through an iteration where we started with target slump and target air content values, did a proportioning exercise, found that the mix was not good enough, we went to a reference table which helped us change these parameters- the water content, the s by a. We did not change the water cement ratio this time, but we can do that as well; and we revised the basic parameters and came up with fresh numbers.

Now, what we have to do is, with the revised mix we can only hope that the desired slump and air content which is 8 centimeters and 5 percent is met. Then there is an uncertainty about the properties obtained in trial runs being replicated in the field. It is possible that these exercise, that this kind of an exercise which is done in the lab when we take the concrete mix to the field the mix is not so robust; that is, with a small change in material property which is always likely to happen; the aggregate might just be a shade smaller or just a shade larger, the particle site distribution from one lot to another lot may change, the cement might change, and so on. How do we ensure that whatever prescription we have given or whatever proportion we have determined through laboratory trials is going to deliver at site; it will stand the variations at site which can be expected.

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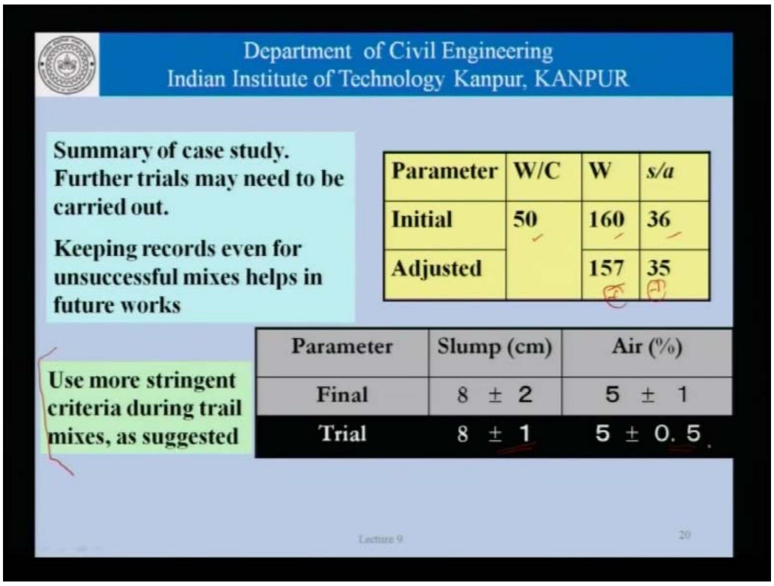

The way to do that is this. If we go to this example what we have done is, with this water cement ratio this is what we had initially, this is what we had finally, and we hope that we got the right results. What we need to do, to ensure that the mix is robust and is able to withstand this minor variations that are likely to occur at site; what we need to do is, use more stringent criteria during trial mixes. That is to say, if finally, the allowed variation in the field is let us say 2 centimeters; that is, the requirement is that the mix should have 8 plus minus 2 centimeters of slump, it should have 5 plus minus 1 percent of air; and that is as usual way of specifying things, slump, air content, and so on are extremely variable.

They vary within a certain range; it depends on whether I measure it or you measure it; it could also vary whether it is measured right now, or 5 minutes later, and so on. So, there has to be a slight margin or a range which the specification is need to specify. And usually slump is given in terms of plus minus 2 centimeters for 8 plus minus 2, and an air content of 5 plus minus 1. Then as far as trial mixes are concerned we should make sure that the variation that we give in the mix, we tried several times, and the variation should not be more than 1 centimeter let us say for slump or may be half half percent as far as air is concerned.

So, what we are effectively doing is, that in the laboratory trails we are following a more stringent criteria for acceptance, we say that, well. In the field if the margin allowed is 2 centimeters, as far as the lab is concerned we will not accept anything more than 1 centimeter. In the field if the air content is allowed to vary by half a percent, by 1 percent, then in the lab the chemical admixture dosage and cement and so on, we should try to make sure that the variations that we get is not more than half a percent.

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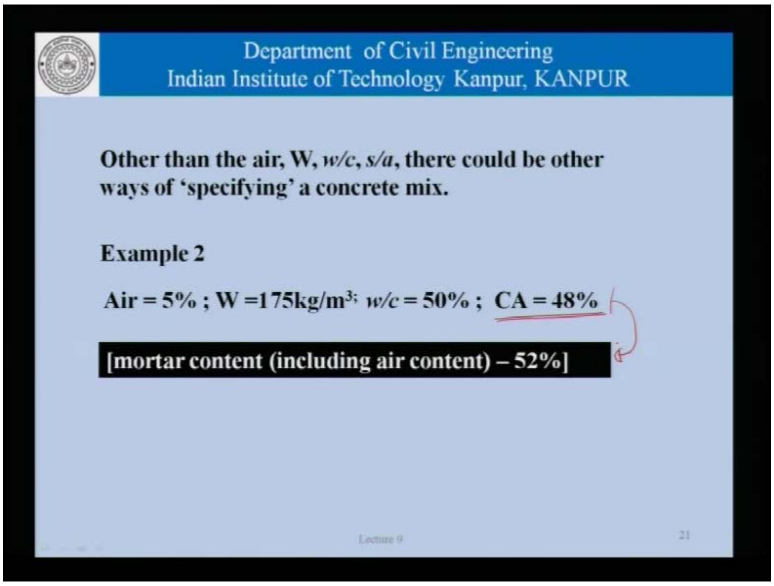

Hoping there that this stringent criteria that we have used, even if the site conditions change a little bit, the concrete will still need the requirements, in terms of the slump and the air content which are the basic properties that we want to satisfy as far as basic concrete engineering is concerned.

Now, let us look at another example. So far we looked at an example where we said that air, water content, water cement ratio, and the s by a, these are the parameters that are fixed, as far as working out a concrete proportion is concerned. Now, in another example, we can work with fixing coarse aggregate content at 48 percent. We want at least 48 percent or atmost 48 percent or whichever way we want to do it, we fix the coarse aggregate content in the concrete mix. What this implies is that we are fixing the mortar content to be 52 percent.

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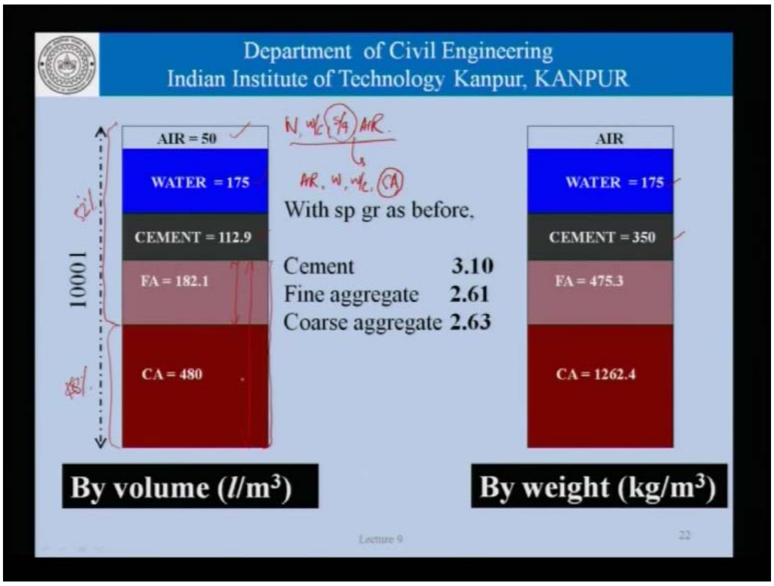

So, now what we are doing, if this is how we are specifying the mix, then the volume matrix becomes something like this. That we fix the air, we are given a water content because now instead of using water, water cement ratio, s by a, and air, what we are now using is air is given to us, water is given to us, water cement ratio is given to us, but the coarse aggregate content is given to us instead of the s by a. So, the process, till such time as cement is been determined will be the same. Air is known, water let us say 175 that will be known, water cement ratio; this is a mass version of this table. So, the water cement ratio being 50 percent, 175 and 50 percent gives you 350, which gives you 112 liters of air, of cement.

Now, the only difference is here. How do we apportion the fine aggregate content and the coarse aggregate content? In the, s by a, route we said that well we will apportion this in a manner that the sand content which is this part, is a part or a fraction of the total inert material or the total aggregate content- the coarse aggregate and the fine aggregate. In this example now or in this approach now, we are saying that no that is not what we want to do. We are fixing this content to be 52 percent and we are fixing this to be 48 percent. So, the aggregate content or the coarse aggregate content is known to us to be 48 percent.

And, the sand content now is determined from 520, and the sand content is determined based on the volume of mortar. And the volume of mortar, if 48 percent is the coarse aggregate, the volume of mortar is 522 liters; from there we reduce the amount of air, then we reduce the amount of water. So, the sand content is determined based on the mortar content; that is, if we know that the mortar is finely 520 liters, the sand content will be 520 liters minus the air, minus the water, minus cement, whatever is left is the sand.

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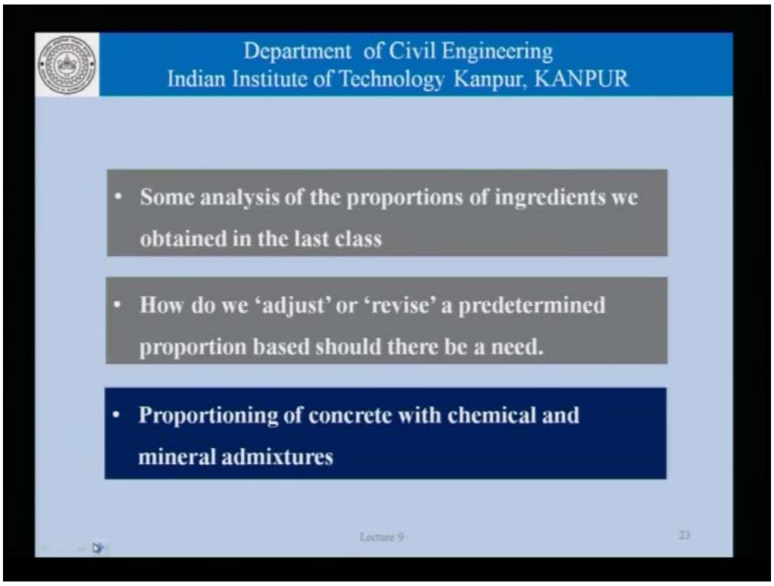

Now, let us come to the last part of the discussion toady which is proportioning of concrete with chemical and mineral admixtures. We will take some examples on how this is done.

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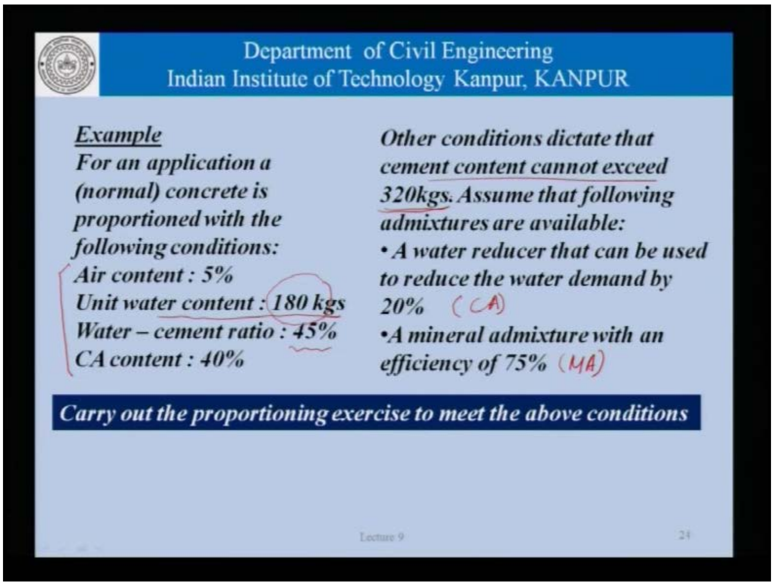

Let us say, for an example that there is an application of normal concrete and is proportioned using these conditions: air content of 5 percent, unit water content of 180 kgs, water cement ratio 45 percent, and a coarse aggregate content of 40 percent. We are not using, s by a; we are giving a coarse aggregate content to be 40 percent. Other conditions dictate that the cement content cannot exceed 320 kgs. There can be all kinds of reasons for which there can be a maximum cement content which is imposed, and in this case it is given to be 320 kgs.

Now assume that the following admixtures are available: a water reducer that can be used to reduce the water demand by 20 percent; so this basically is a chemical admixture available to us. A mineral admixture with an efficiency of 75 percent; so this is the mineral admixture available to us. And what we are required to do is, to carry out the proportioning exercise to meet the above conditions.

So, to retreat the problem, this is the requirement. That is the concrete that we proportion should have an air content of 5 percent, unit water content of 180, water cement ratio of 45 percent, then is coarse aggregate content of 40 percent. When we say that the unit water content is 180, what do we mean? We mean that that is the amount of water that is required in a concrete that will have the required workability. The prescription here is not in terms of slump of 80 mm or 100 mm or whatever that is, but it is given at a next step itself that is we are giving the water content. Otherwise, what will be required is that we give the slump and we give the information relating the slump to the water content.

So, in this case, the slump is not given, the water content is given. So, we need a concrete of 180 kgs of water, so that it has the required amount of slump. We need a concrete which has of water cement ratio of 45 percent, so that it has the required strength. Gap with this is the restriction that the cement content cannot exceed 320 kgs. And of course, we have these options in terms of chemical admixtures and mineral admixtures available to us.

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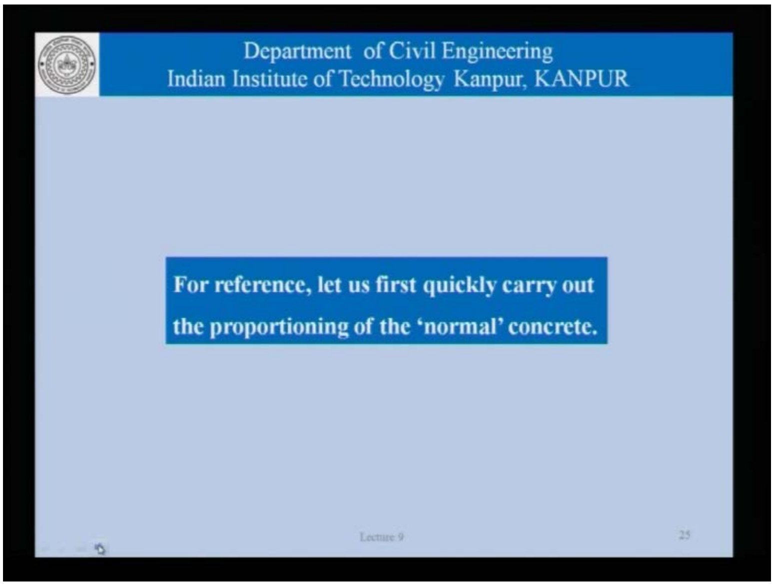

Just for reference, let us first quickly carry out the proportioning of the concrete as if it was a normal concrete.

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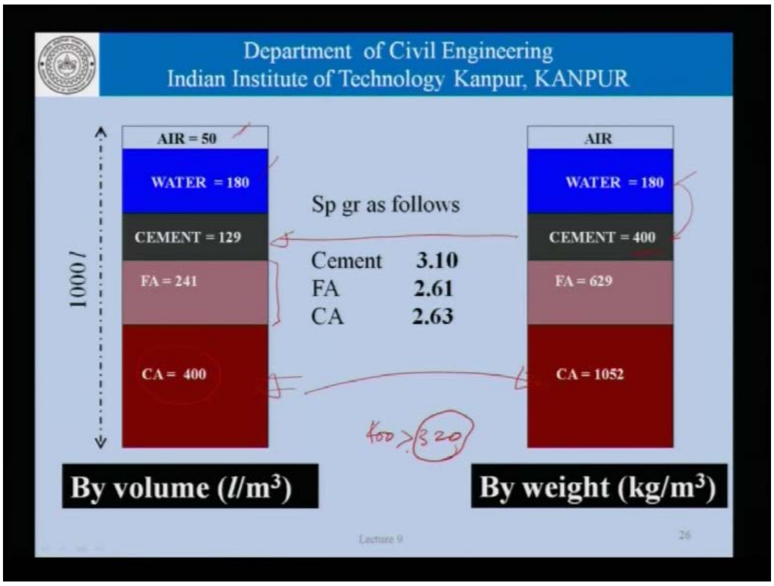

And, what we will land up doing is that we have a 5 percent air that is 50 percent, 5 percent air means 50 liters. If we look at the mass, it is like this. We have air to be 50 liters, water to be 180 liters or 180 kgs; 45 percent of water cement ratio gives us 400 kgs; 400 kgs gives a 129 liters; and given the fact that the coarse aggregate is 40 percent; we have 400 liters of coarse aggregate sitting in the concrete which translates to so much of coarse aggregate in terms of kgs per cubic meter; and we have the sand content given here.

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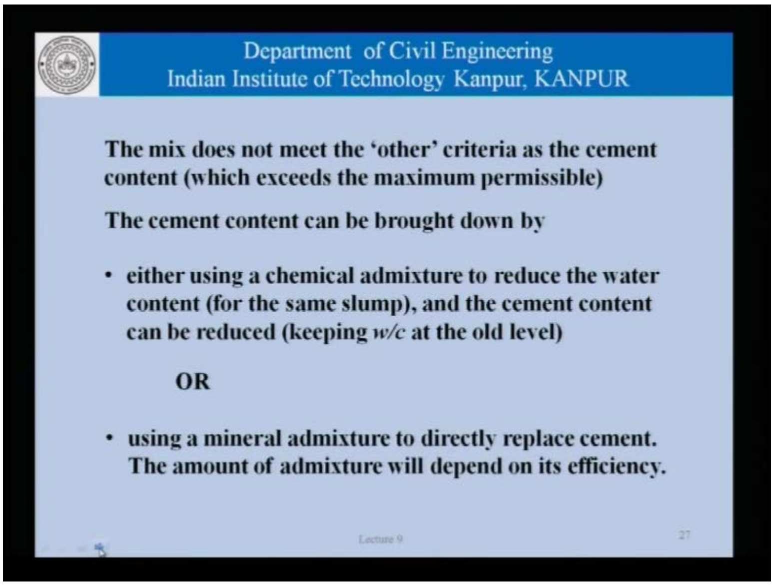

So, if we do this we realize that the mix does not meet the other criteria as the cement content exceeds the permissible value. We have a cement content of 400 kgs, and this 400 is greater than the 320 which is allowed; and that is where the problem is; what do we do with that? The cement content can be brought down by either using a chemical admixture to reduce the water content for the same slump, and the cement content automatically gets reduced keeping the water cement ratio at the same level. We will see this, an example just now. Or, we use a mineral admixture to directly replace the cement. And the amount of mineral admixture, of course, will depend on its efficiency, and that too we will see in this example.

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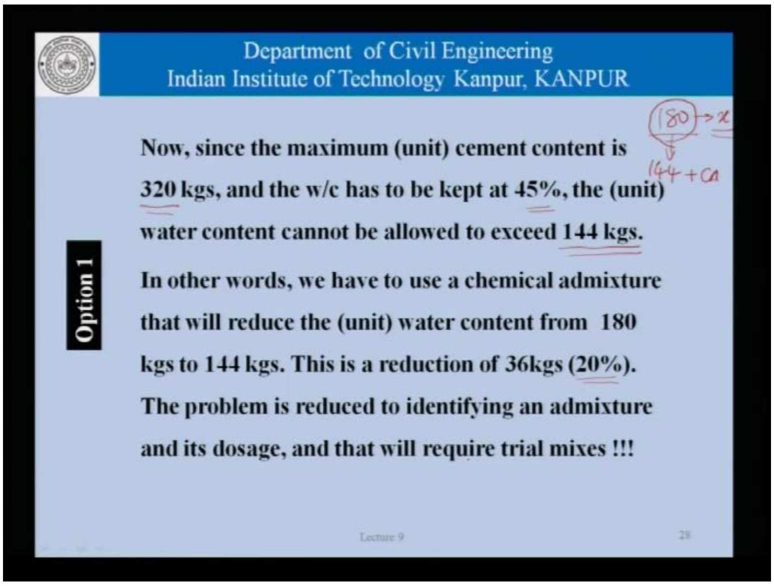

Now, let us look at the option one which is using a chemical admixture. Since the maximum unit cement content is 320, and the water cement ratio has to be kept at 45 percent, the water content cannot be allowed to exceed 144 kgs. This is the text or a statement of the problem. We had 180 kgs of water which was giving us some slump x. With this we were not able to satisfy the cement criteria. And therefore, now water criteria is not coming from the slump side. The water criteria is coming from the water cement ratio side and the cement content side. So, the cement content being 320, water cement ratio being 45 percent, the water content cannot be more than 144.

Now, what we are faced with the challenge that, how do we get the same slump x which we were getting with 180 kgs of water, with 144 kgs of water plus a chemical admixture, because challenge is that how do we get the slump x, which we were getting with the 180 kgs of water, using only 144 kgs of water with the addition of a chemical admixture. In other words, we have to use a chemical admixture that will reduce the unit water content from 180 kgs to 144 kgs. This is a reduction of 36 kgs or 20 percent. And the problem is reduced to identifying an admixture and its dosage that will require trial mixes.

So, we already have a chemical admixture which can reduce upto 20 percent, that was given to you. And we need to adjust its dosage; whether we need 1 percent or half a percent, 1 and a half percent, without affecting the durability and other properties of concrete, and we are in business. With 144 kgs of water and appropriate amount of a suitable chemical admixture we should be able to get the same slump, as we were getting with 180 kgs of water. So, that is the discussion as far as option one is concerned.

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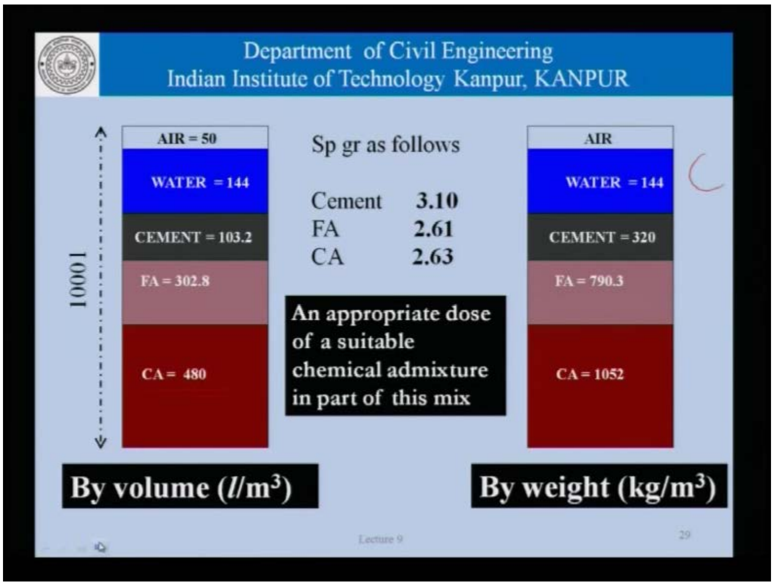

And, if you proportion the mix, this is what happens. We have air, we have water is a 144, we have cement which has been reduced, we have the coarse aggregate is still being kept at 400, we reproportion this concrete mix with 144 kgs of water, and this what we get, by volume and by weight.

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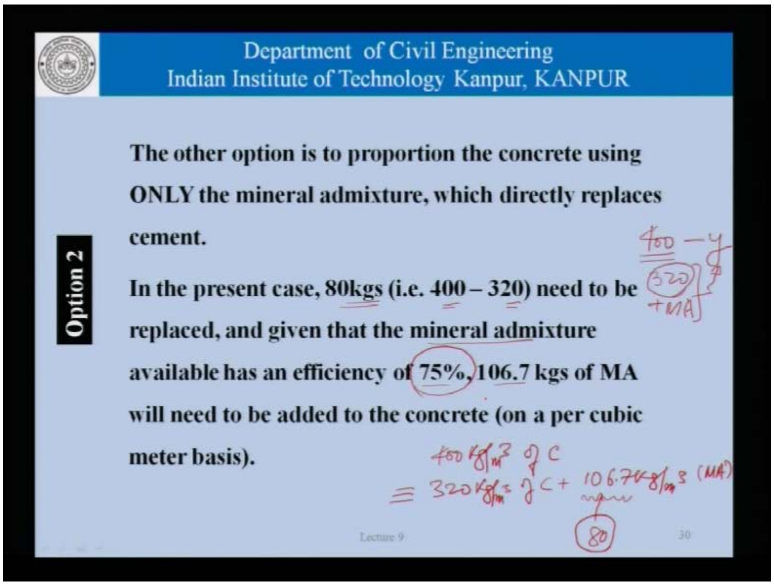

Now, let us look at option two. Option two says, use only the mineral admixture and replace the cement directly. In other words, instead of using 400 kgs of cement which give us a certain strength, we use only 320 kgs of cement plus we use a certain amount of mineral admixture, in order that the strength is still remains y; the same strength is achieved. The strength cannot be compromised. Only thing what is happening is that instead of cement alone we are using a mineral admixture to supplement the cementitious material content.

So, what we have done is, we have, we will replace a part of cement by the mineral admixture. So, in the present case we need to replace 80 kgs of the cement which is 400 minus 320. And given that the mineral admixture has an, and given that the mineral admixture available has an efficiency of 75 percent, a 106.7 kgs of the mineral admixture will be needed to be added to the concrete on a per cubic meter basis.

So, we were using 400 kgs per cubic meter of cement. This will now be equivalent to 320 kgs per cubic meter of cement, plus a 106.7 kgs per cubic meter of the mineral admixture. We need to replace or use 106.7 kgs of the mineral admixture to replace the 80 kgs of cement because the efficiency of the mineral admixture is 75 percent. If the efficiency was something different then we will need to use more or less of the mineral admixture. If we are able to identify an admixture, a mineral admixture which has the same efficiency as cement, then we can replace it on a 1 to 1 basis. Instead of using cement, we use the same amount of mineral admixture. Typically, the mineral admixtures that we have in the market, kind of things which are available with us, they have an efficiency which is lower than 1. And therefore, we need to have more of the mineral admixture than the parent cement.

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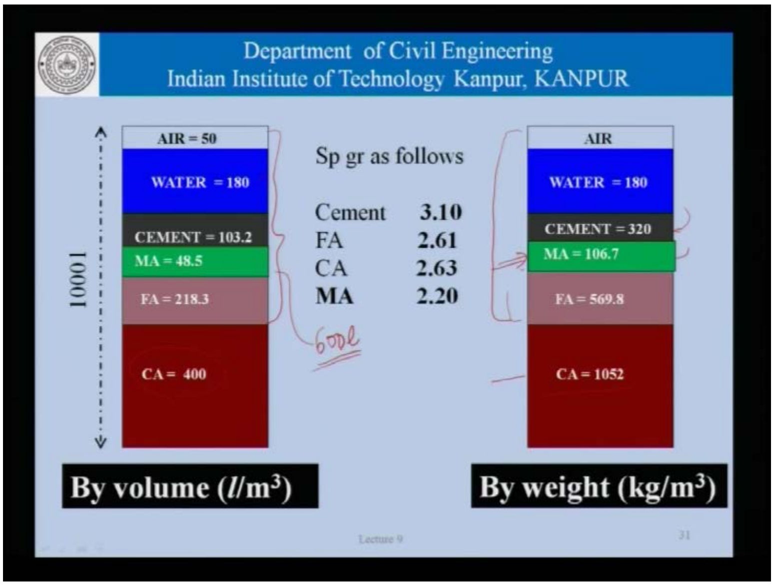

And, if we do that exercise then this is what we get. We have air, water, cement has been reduced to 320, 106.7 is the mineral admixture which has been added, keeping this coarse aggregate at 400 which is what was the requirement, which that means the coarse aggregate content does not change, the fine aggregate changes to certain amount. We determine the fine aggregate content from again the mortar volume that still being kept at 600 liters or 60 percent because the basic condition was that the coarse aggregate content will be 40 percent in the mix.

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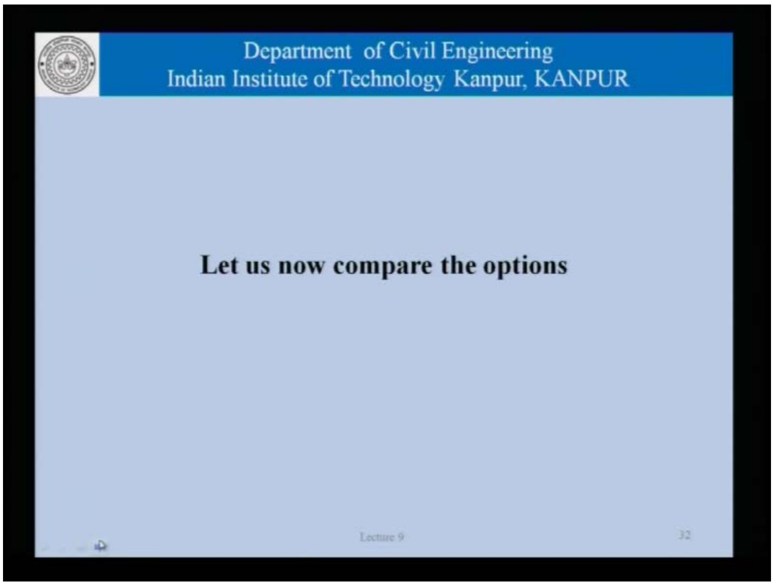

So, well, now let us compare the options.

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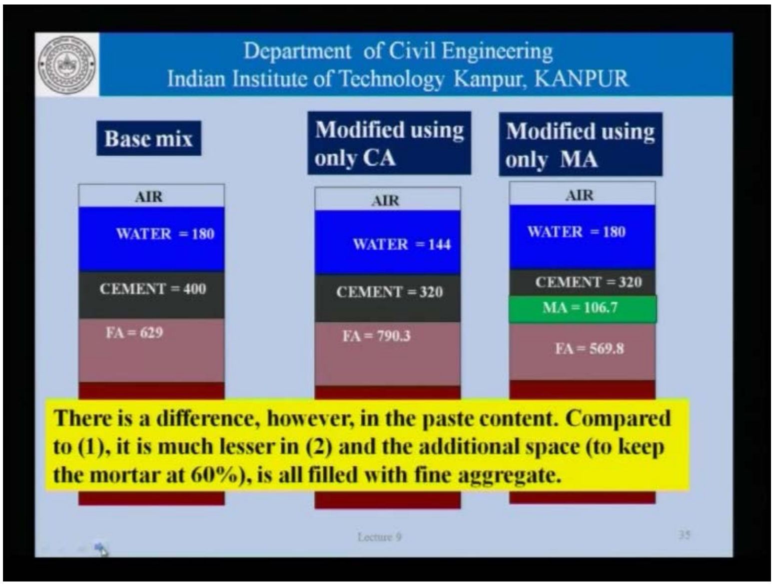

To begin with, as far as basic concrete is concerned, this is what we had and this is what we found that was not meeting our requirement. The cement content here was higher than the acceptable or required maximum of 320. So, we explode an option one where we said we will use a chemical admixture alone to get the water demand down 244, and then use the same amount of cement, and so on and so forth. Another option that we considered was using only the mineral admixture. There we let the water demand be at the same level of 180. We brought, we just replaced the excess cement that we had with a mineral admixture, and everything else remains the same.

Now, what do we notice when we bring these options together? In all cases, having kept the coarse aggregate content at 40 percent we have the total mortar content in the mix at 600 liters. There is no change in the total mortar content. That is one thing which you must remember. And the second thing is that the difference in the paste content, compared to one it is much lesser in two and the additional space to keep the mortar at 60 percent is filled with fine aggregate.

So, I am not going to discuss this aspect too much. And we leave it to you to look at these three mixes, and see how the volumetric has actually changed, how the paste volumes have changed, how the mortar volumes have remained constant and therefore, the required sand volumes have changed. Now, having said that please also think about the definition of paste in this context. Basically what we said, paste is water and cement.

In the case, when we are talking of mineral admixtures, should the mineral admixtures be counted as paste or not, or should they be counted as contributing to the paste volume or not. Well, my answer is yes, because their fineness is comparable to that of cement. If the any admixture we use is coarse then it will be part of sand and therefore, we will contribute to the mortar content, may not contribute to the paste content. So, the definition of paste, of mortar, also come into question when we are working with concretes using chemical admixtures or mineral admixtures. And I would like you to use this example as a basis for understanding the concept a little more.

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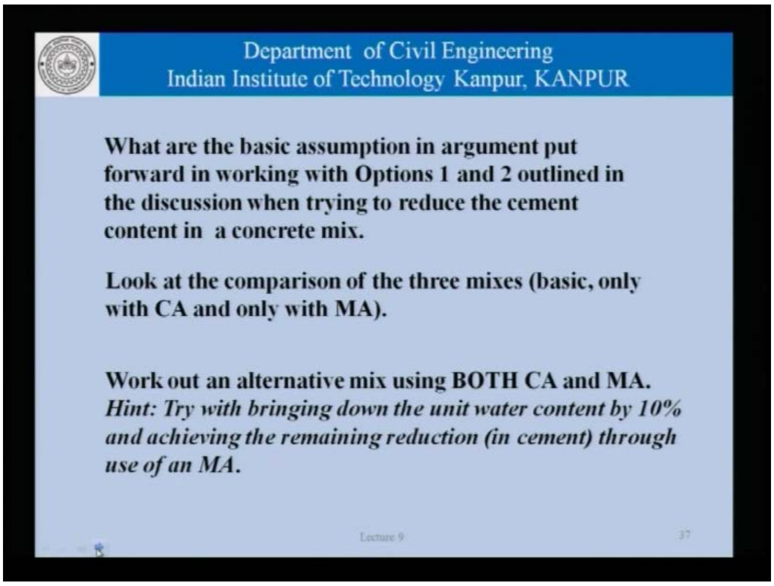

Now, coming to the end of the discussion today. Just think about, what are the basic assumptions in argument put forward in working with options 1 and 2 outlined in the discussion when trying to reduce the cement content in the concrete mix. Even though I made it look simple, and just reduced the water content from 180 to 144 and said that there will be a chemical admixture which is available to us which will do the trick or we replaced 80 kgs of cement by 106.7 kgs of the mineral admixture; we said that well; everything else will remain the same; the water content of 180 kg will suffice, and so on. There are some problems with that, and I would like you to understand them or think about them.

Look at the comparison of the three mixes- the basic, the one with only the chemical admixture, and the one with only the mineral admixture carefully, and try to see what has happening with them. Work out an alternative mix where both chemical admixtures and mineral admixtures are used. In the example that we took we reduced the water to the extreme value that was required from the cement content point of view. In the other example, we replaced all the cement that needed to be replaced by a mineral admixture; there can be combinations. So, you can try with bringing down the unit water content by 10 percent and achieving the remaining reduction in cement through the use of a mineral admixture. I am sure, if you work it out you will find interesting combinations, and then study them in terms of what is happening to the paste content, what is happening to the mortar content, sand content, and so on, in the mix.

Thank you.