Development and Applications of Special Concretes
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Lecture 06
Review of Normal Concretes Fundamentals of Proportioning Concrete Mixes

Namaskar welcome back to the series of lectures on development and applications of special concretes. We continue our review of normal concretes and we will carry on our discussion from where we left last time. Last time we talked about fundamentals involved in proportioning mixes today we will carry that forward and try to do some actual examples.

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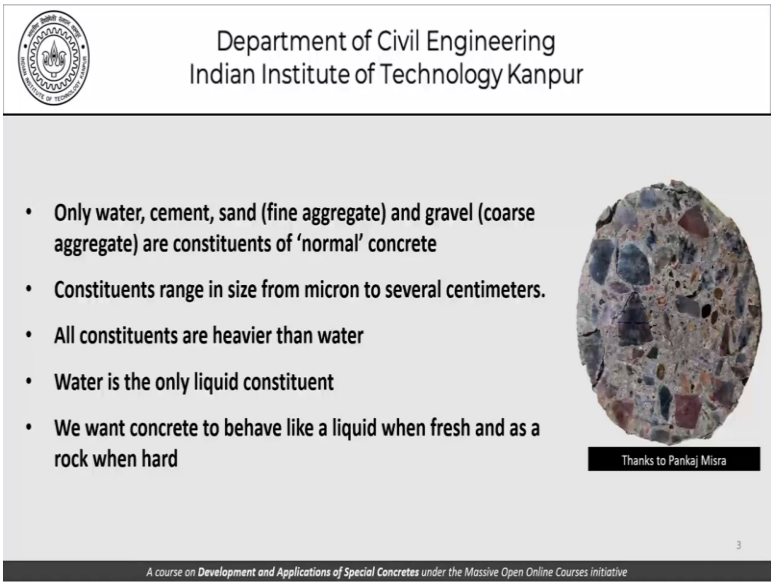

This is our customary slide and I have already told you the reason why I keep showing this to you again and again at the start of every lecture virtually to make sure that you think of this slide this is a model for concrete. Every time you have to model concrete, every time you have to do quality control with it, design concrete structures. Think of how will concrete move in a particular structure in a particular beam or in a slab or through congested reinforcement that is what we are going to be talking about in this course. So, we must get this picture very clearly in our minds to guide our thought process.

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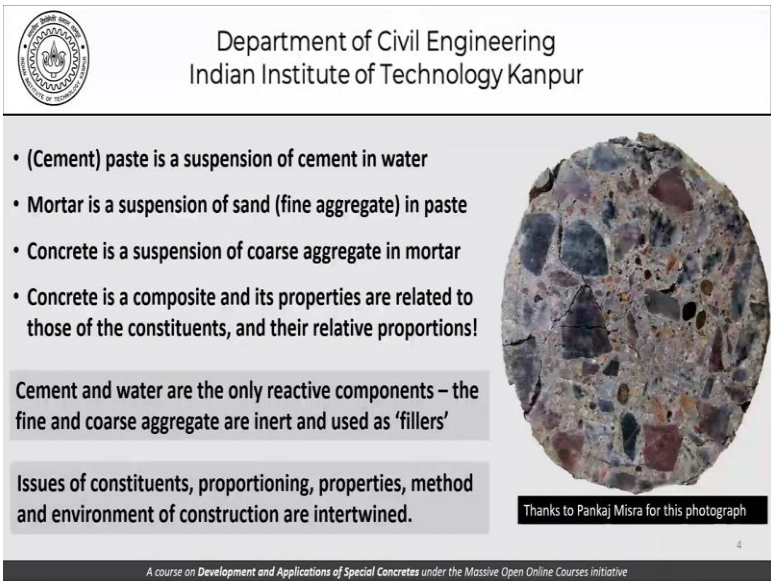

The principles laid down here are equally important and that is why I keep showing them to you once again.

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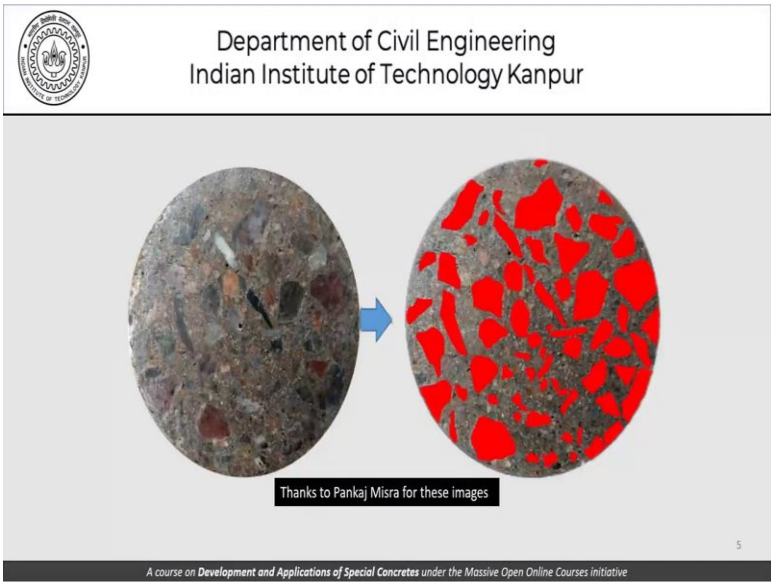

And of course, this picture which tells us the fact that concrete is really a suspension of coarse aggregates in mortar and the coarse aggregates are separated from each other.

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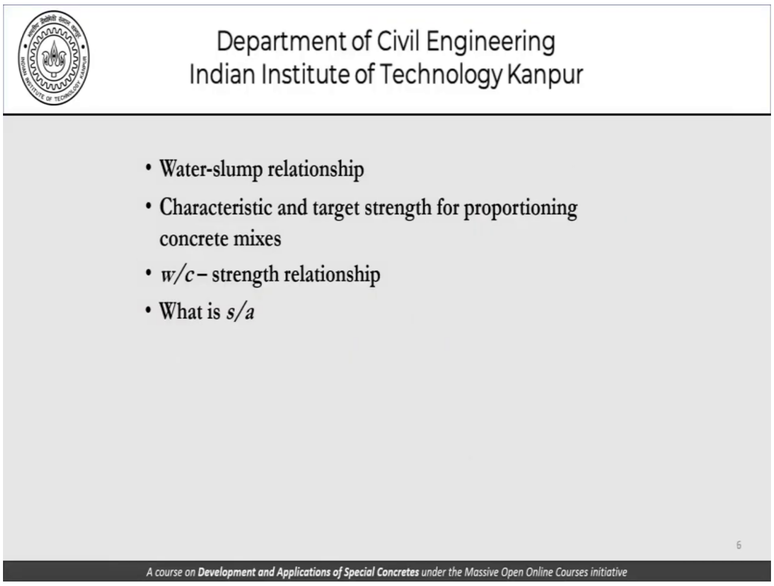

Moving forward, these were some of the principles that we covered last time that is going to govern our proportioning of mixes.

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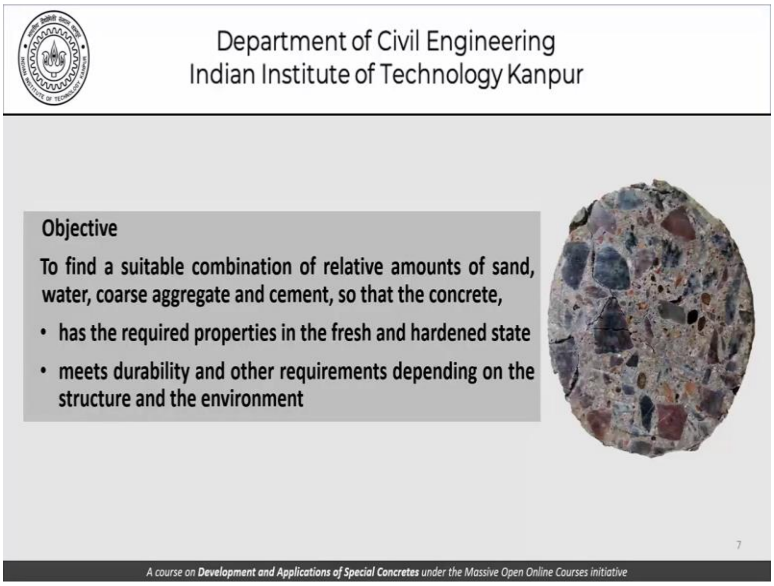

The whole idea of proportioning is to find a suitable combination of the relative amounts of sand, water, coarse aggregate and cement, so that the concrete has the required properties in the fresh and hardened state. And, also meets the requirements in terms of durability and any other requirements that may be imposed on account of the environment or the client or the special structure that we are building.

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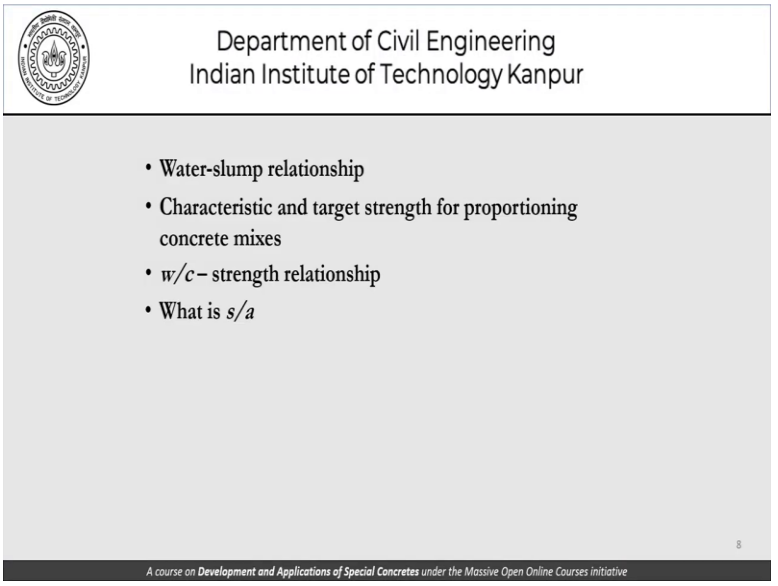

Here are the characteristics once again let us move forward and see how they are going to be actually implemented.

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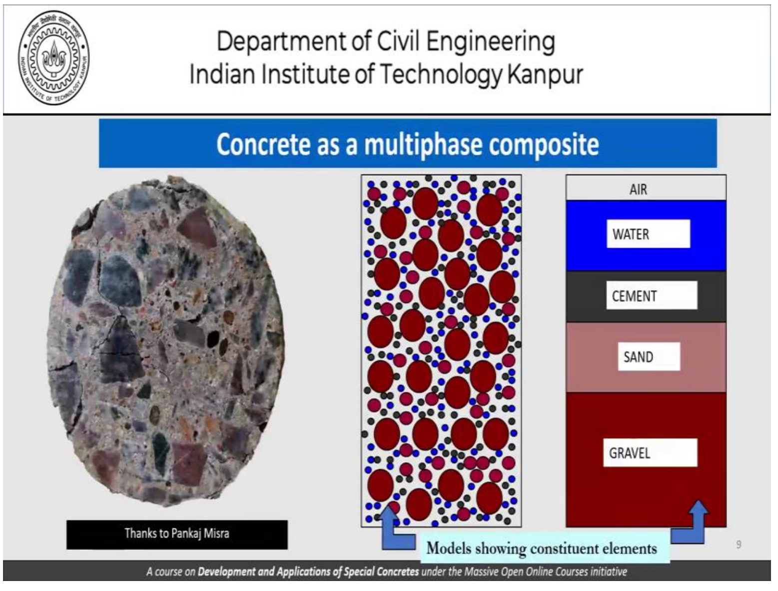

We have seen that the concrete is a multi-phase material this is the lumped volumes of the different constituents the gravel, the sand, cement, water.

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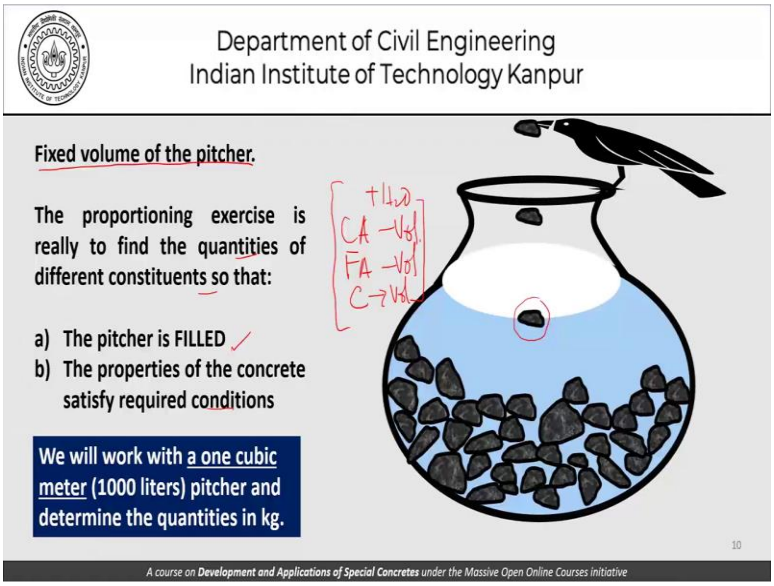

This is a picture which is very important to us when we think of proportioning concrete mixes. What it shows us is the old picture and the crow dropping this stone into the pitcher and the water continues to rise. The idea basically is that there is the fixed volume of the pitcher and the proportioning really boils down to an exercise and find out the quantities of the different constituents.

So that the pitcher is filled and the properties of the concrete that we get satisfy all the required conditions. No matter what we drop into this picture whether it is the coarse aggregate or the fine aggregate or even the cement that has a certain volume this has a certain volume. So, all these volumes + the volume of water should add to the total volume of this pitcher that is the thought process.

And, I have already told you that this thought process for this model for proportioning concrete mixes is just one of the models that is available commonly used. There are other ways of looking at proportioning as an exercise and you are welcome to read about them. We will work as far as this lecture is concerned that this series of lectures is concerned, we will work with a one cubic meter or 1000 litre pitcher and determine the quantities of coarse aggregate, fine aggregate and cement in kilograms because that is much easier to measure than volumes especially the absolute volumes.

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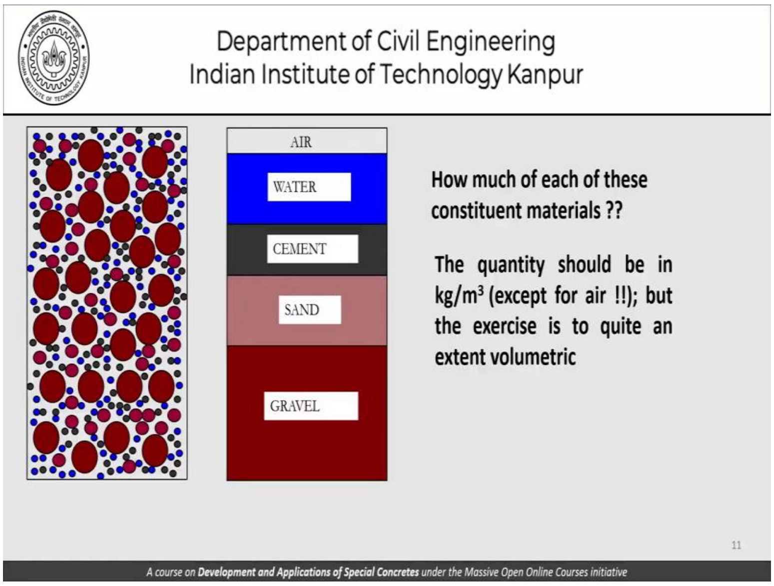

Now, let us look at these pictures once again basically we are trying to find out how much of each of these materials that we need to add we will try to get the quantities in kgs per cubic meter except for air and the exercise to quite an extent will be volumetric.

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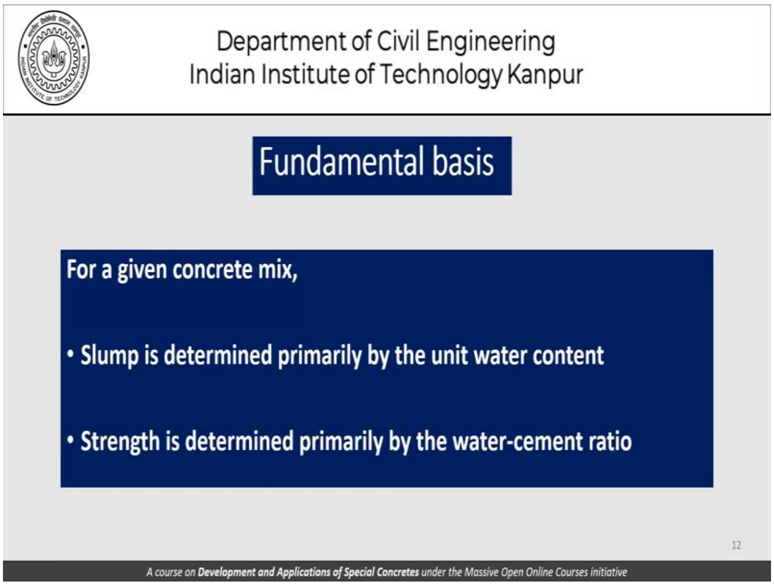

For the fundamentals, the slump is determined primarily by the unit water content we already talked about it. Strength is determined primarily by the water-cement ratio, we have talked about this as well.

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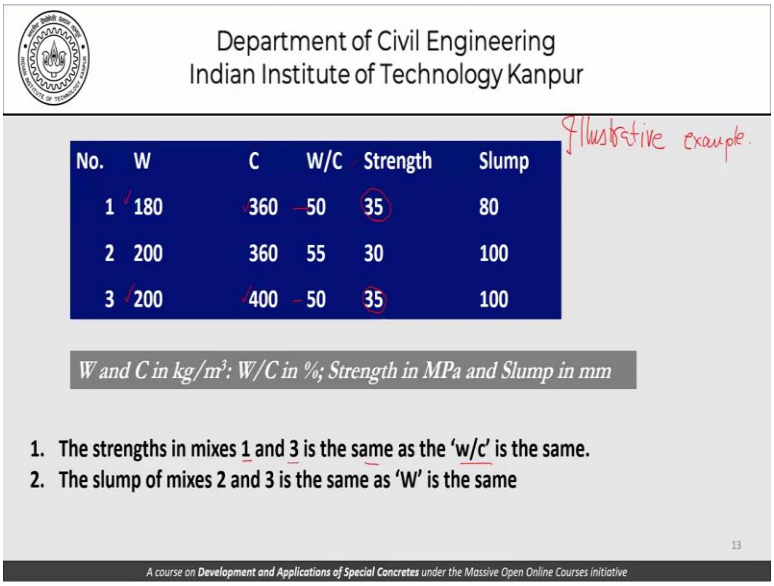

Try to take a look at this slide here 3 mixes the water content, the cement content, the water-cement ratio, the strength and the slump this is given to you as an illustrative example. Do not try to read too much into the values given only the principle involved. Water and cement are kgs per cubic meter, water-cement ratio is in %age, strength is in MPa and slump is in mm. Now, if this is what we have then my argument or the model that I am trying to explain to you would say that the strength in mixes 1 and 3 is the same as the water-cement ratio is the same.

So, here we have 180 and 200, we have 360 and we have 400, the water-cement ratio in both these cases are 50%. Therefore, the strength is the same. The second conclusion the slump of mixes 2 and 3 is the same as the water content is the same. So, if we look at 2 and 3 both of them have 200 kgs as a unit content of water and therefore the slump is the same. Do not care about the values 100 or 95 and so on. The principle is that since the water content is the same the slump will be this.

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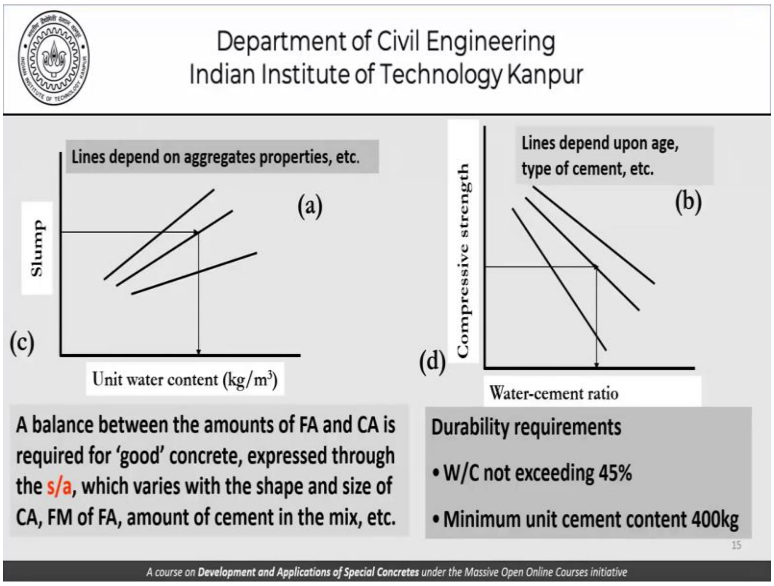

Now let us quickly look at the governing considerations once again. We already talked about this unit water content was a slump several lines, compressive strength was the water-cement ratio the lines would depend upon age type of cement and so on. A balance between the amounts of fine aggregate and coarse aggregate is required for good concrete expressed through the s/a which varies with the shape and size of the coarse aggregate, the fineness modulus the fine aggregate, the amount of cement in the mix and so on.

And, as far as the concrete is concerned there could be other than the workability and strength requirements which could be durability. For example, it could say that water-cement ratio not exceeding 45%, minimum unit cement content being 400 kgs or whatever that number is.

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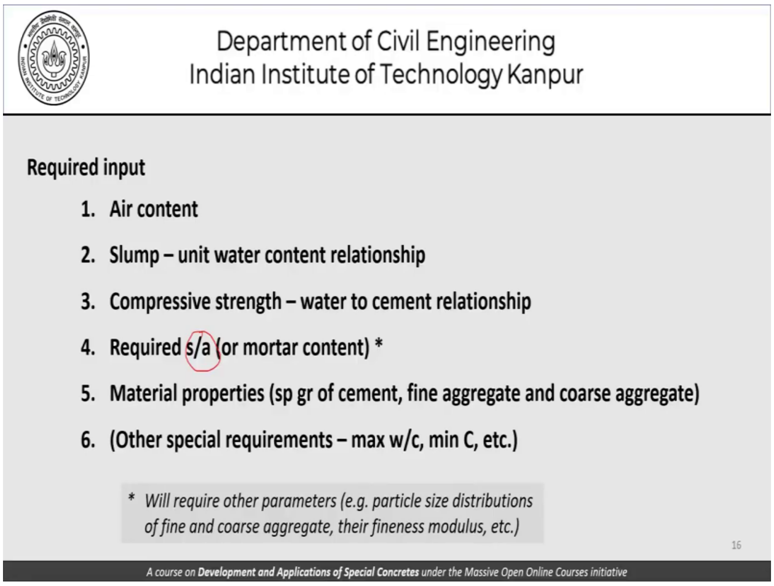

Now, the required input to be able to carry out the proportioning of concrete mixers is air content that is the first thing that we need, the slump unit water content relationship, the compressive strength versus water to cement ratio relationship. The required s/a or the mortar content, now that is something which we will talk about. We will of course require other parameters like the particle size distributions of fine and coarse aggregates their fineness modulus.

So, that we are able to start with an s/a value. A material property which is specific gravity of cement fine aggregate and coarse aggregate and any other special requirements that is maximum water-cement ratio, minimum cement content, maximum cement content and so on. So, with this data we are ready to embark on our proportioning exercise.

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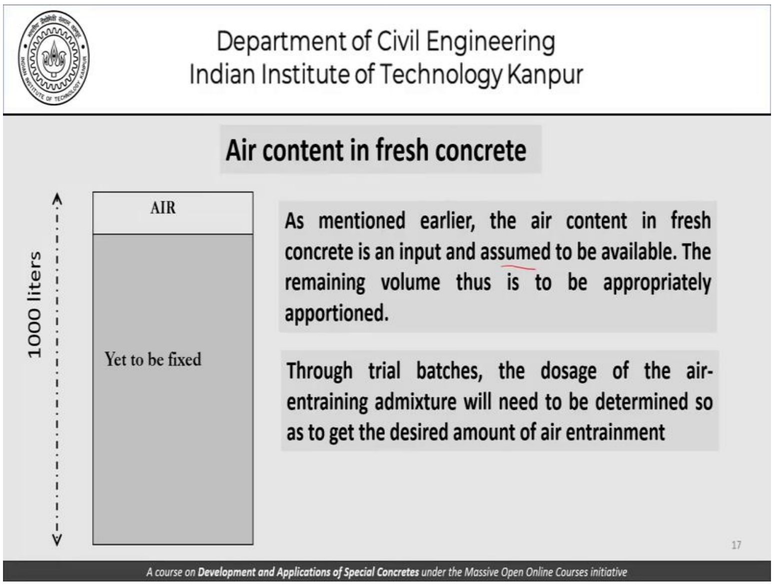

First comes the air content in fresh concrete, that is out of the 1000 litres we need to know how much air do we have, what %age, if it is 2% it is 20 litres, if it is 5% it is 50 litres from the 1000 litre pitcher. As mentioned earlier, the air content in fresh concrete is an input and assumes to be available like I said it could be 2%, 5% whatever the number is. And, the remaining volume has to be appropriately a portion between the other constituents.

Through trial batches, in case of air entrained concrete, the dosage of the air entraining admixture will need to be determined so as to get the desired amount of air. The manufacturer of the air entraining admixture can tell you that okay if you add 1% of this admixture you will get 4% air. So, you really need to carry out an exercise where trial batches are done with 1%

admixture and trying to find out whether this 4% becomes 4 and a half, 3 and a half, 5 and so on.

Because at the end of it, the manufacturer also would have carried out certain trials and have determined that number. So, the material that we are using in a particular construction site could be different from that used by the admixture manufacturer. And therefore, there is no reason to believe or to just believe blindly at least that 1% will give you 4% if the manufacturer says so.

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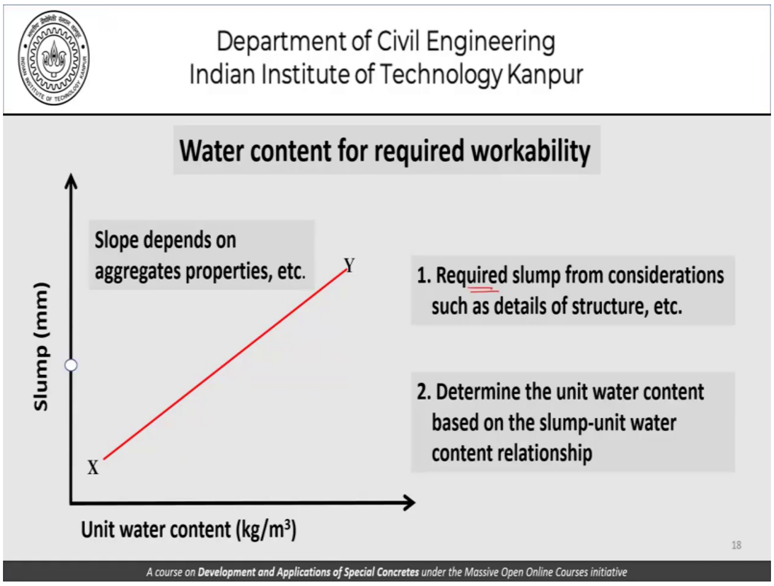

Coming to the next part, we need the water content for the required workability, now this slope again, we have already discussed depends on aggregate properties and so on. What we need is, what is the slump that you want, this slump would depend upon the details of the structure, we need to determine the unit water content based on the slump unit water content relationship. That is, if we want this slump then this is the amount of water that we need.

So as far as, the slump is concerned and its dependence on the structure, certain structures such as slabs concrete is easy to place and therefore, we may say that the concrete need not be very workable. We can do or we can make 2 with a smaller slump but if the structure is such that the concrete has to be placed in congestive reinforcement then we might need a higher slump. So that is what it means when we say that the required slump is determined from consideration such as the details of the structure.

And, that is where the designer comes in, they have to prescribe, what is the kind of slump that you need, it also depends on the method of construction. If you are trying to construct using a transit mixer or by taking it in smaller wheelbarrows and taking it to the site, these are the kind of things which will determine the slump that you need. For purposes of proportioning, once the slump is known through this graph, we know the unit water content.

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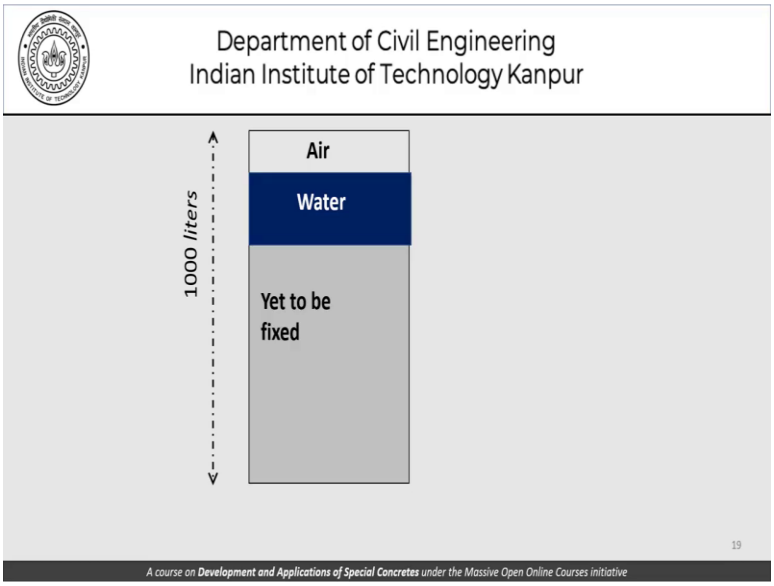

Translating this discussion into our 1000 litre pitcher, we already have the air content, we fix the water content now. That is the volume of water and the rest of it is yet to be fixed. The next part comes the cement content.

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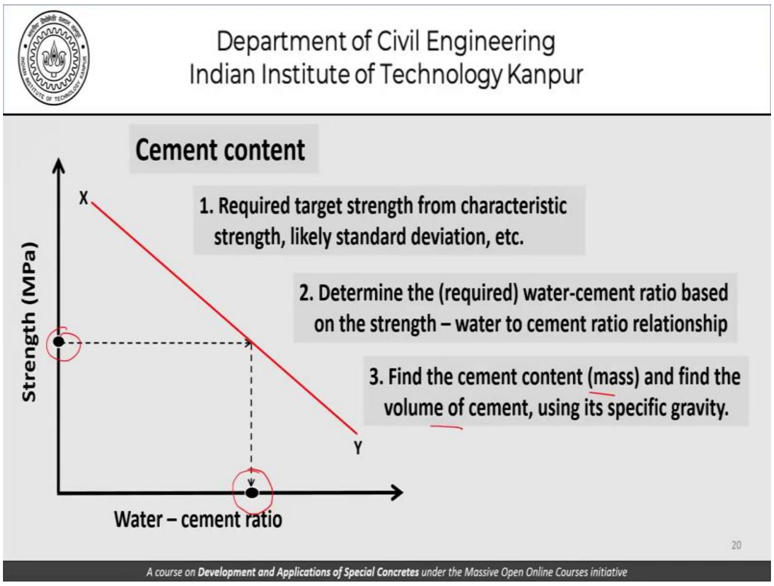

For that we need to know the target strength from the characteristic strength the likely standard deviation and so on. So, once the target strength is known the water-cement ratio will have to be determined. Determine the required water cement ratio based on this relationship here and as shown in this graph, it goes from this point here and we get this water-cement ratio. So, this is the water-cement ratio we need and find the cement content by mass and find the volume of cement as a next step using its specific gravity.

Remember that water cement ratio is given by mass. So, we already know the amount of water from our workability considerations. We now find out the cement content from the water-cement ratio considerations, which means now that air was known water was known.

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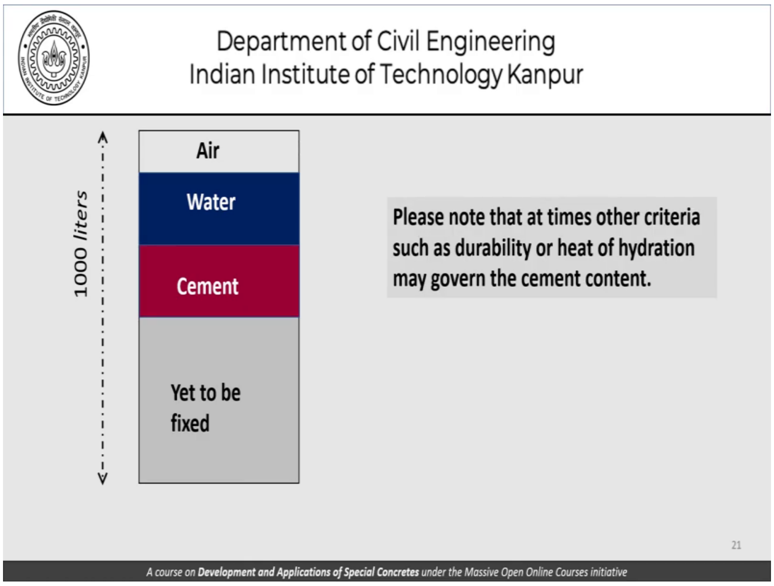

And, now cement is also known the rest of it is yet to be fixed there are at times criteria such as the durability or the heat of hydration may go on the cement content. But that is something which we will address at a later point in time. So, for the time being we are going straight from normal concrete proportioning air content, water, cement. Now,, we have to find out the fine and coarse aggregate content.

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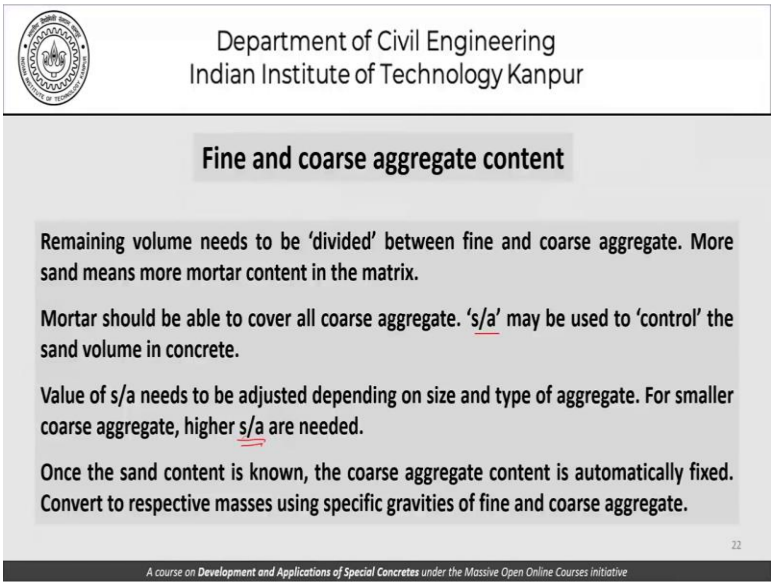

The remaining volume of course needs to be divided between fine and coarse aggregate more sand means more mortar in the content of the matrix, we know that. Mortar should be able to cover all coarse aggregate, s/a may be used to control the sand volume in the concrete and thereby the mortar content. The value of s/a need to be adjusted depending on the size and type of aggregate, for smaller aggregate a higher s/a is needed.

Simple reason, if the aggregate size that is the coarse aggregate size is smaller. The surface area that the mortar has to cover is more. More water is required, you will get more mortar if you use a higher s by a. And, once the sand content is known the coarse aggregate content is automatically fixed. Convert to respective masses using specific gravities of fine and coarse aggregate. Remember that this exercise in principle was a volumetric exercise.

We need to convert all these values to mass, we see that as we go along with the numerical example as well.

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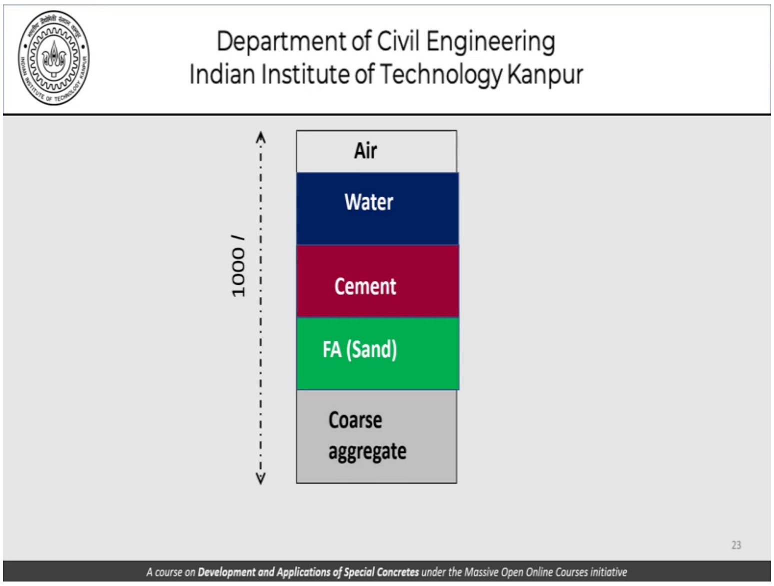

So, here we have air water cement then we fix sand through the s/a and the remaining part is coarse aggregate.

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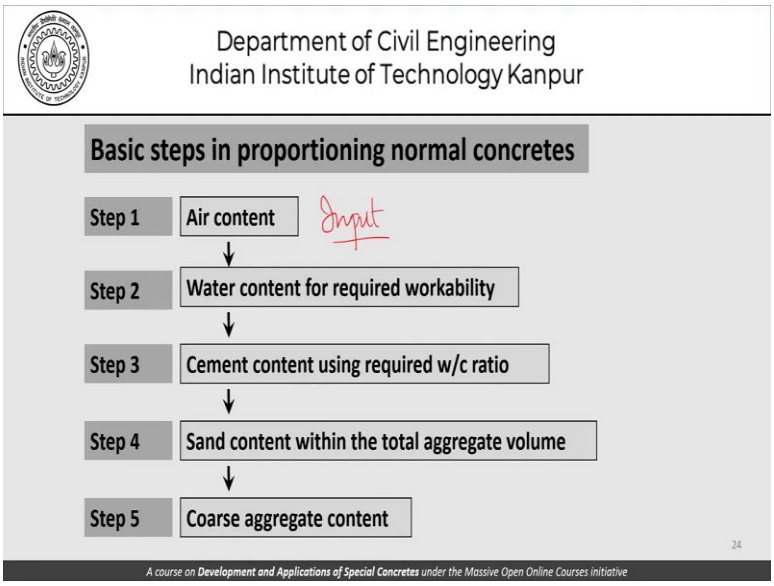

To recapitulate the basic steps in proportionally normal concretes would be first the air content this of course is known to you as an input. How much air do we have, in air in entrained concrete it could be 4% 5% 6% 7%, but in non air entrained concrete it can be taken to be 1% or 2% may be ignored depending on what you talk, what may be ignored depending on the specification or the method that you are following.

The next step is the water content, determine the water content for the required workability from the slump versus unit water content relationship. Knowing that, how much slump you need for a given structure the next step then would be to get the cement content based on the water cement ratio and you get the water cement ratio from the target mean strength which you get from the characteristic strength.

At this point now, fixing the air volume, the water volume and the cement volume, all that is left is the total aggregate volume. From here, you find out the sand volume using the s/a and the coarse aggregate content in terms of volume gets fixed. Then of course, it is an algebraic exercise remaining converts these volumes to mass. Remember that as far as water is concerned it is much simpler.

As far as cement is concerned, the quantity was originally in kgs and we converted it to volume using a specific gravity given that the water-cement ratio is given by mass, it is only the s/a which is given in volume. And therefore, that is something where you have to be careful in converting the volumes of sand and coarse aggregate to their respective masses. Remember that all the time when we are talking of these volumes, we are talking of absolute volumes. We are not talking of bulk volumes remember this.

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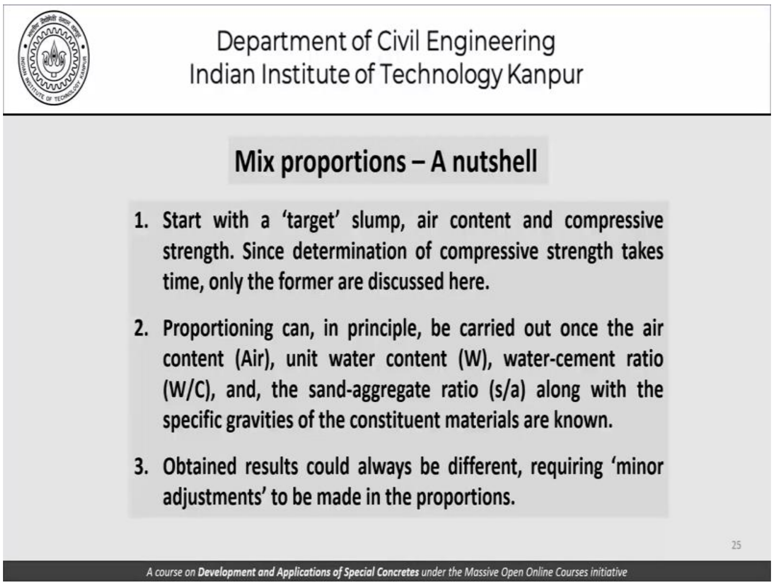

Once again, to make sure that everything is clear to you start with the target slump, air content and compressive strength. Since, determination of compressive strength takes time only the former will be discussed here. That is, we will be talking about only the slump and air. The compressive strength part of it will have to be taken care of separately and that is much simpler, you can do it once you understand the whole idea of propositioning, it is much simpler to do that.

Proportioning can in principle be carried out once the air content, the unit water content and the water cement ratio and the s/a is known along with the specific gravities. Obtained results could always be different requiring minor adjustments to be made in proportions. And, this is something which we possibly touch upon, not necessarily today but in the next class.

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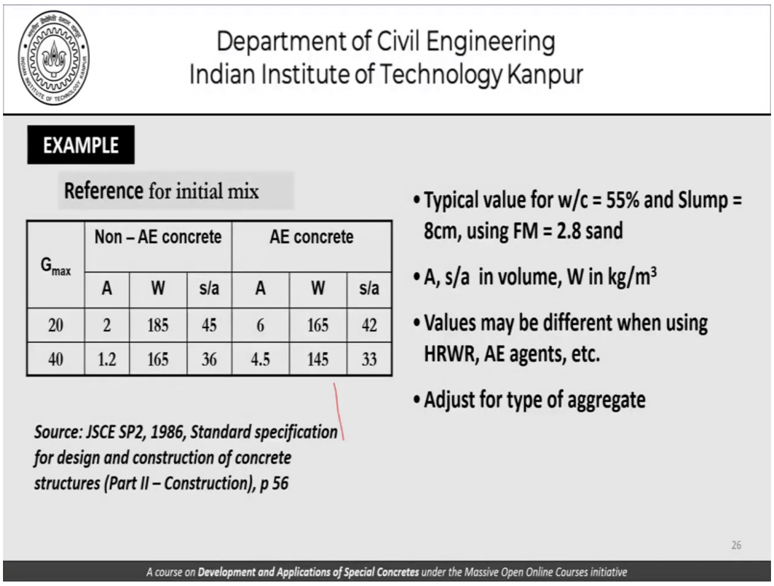

Now, here is an example of a table which is available to you in different codes or guidelines. This one is from the JSCE SP2 standard specifications for design and construction of concrete structures. A similar table is available with us in India also IS-10262 gives you a similar table the values could be slightly different please do check it out. What this tells you is that for an initial mix these are the values of air content, the water content and the s by a, that you can use.

You will notice that the water cement ratio is not mentioned here. The water-cement ratio cannot be mentioned here because water-cement ratio will depend upon the actual compressive strength that you are talking about. For non-air entrained concretes these values are slightly different and you will see that. As far as, the air entrained concrete is concerned water content is 185 here it is only 165 here.

It is 165 here, it is 145 here means that for air entrained concretes for the same workability the amount of water required is lower. These mixes or these values are for a typical value of water cement ratio being 55%, slump being 8 centimetres and the FM of sand being 2.8. Using this as the base, we are expected to design our concrete mixes. If we require a different slump, we change these values we decode.

We require a different water-cement ratio, we change these values. How these changes are to be done is something which we will surely see. Air, s/a are in volume, water is in terms of kgs per cubic meter and values may be different when using high range water-reducers agents and so on. And, we need to adjust a little bit for the type of aggregate. The idea being that when I said that you need to do some trial batches.

The trial batches are always difficult to get started with. So, this kind of a table for this kind of a standard concrete helps us getting started.

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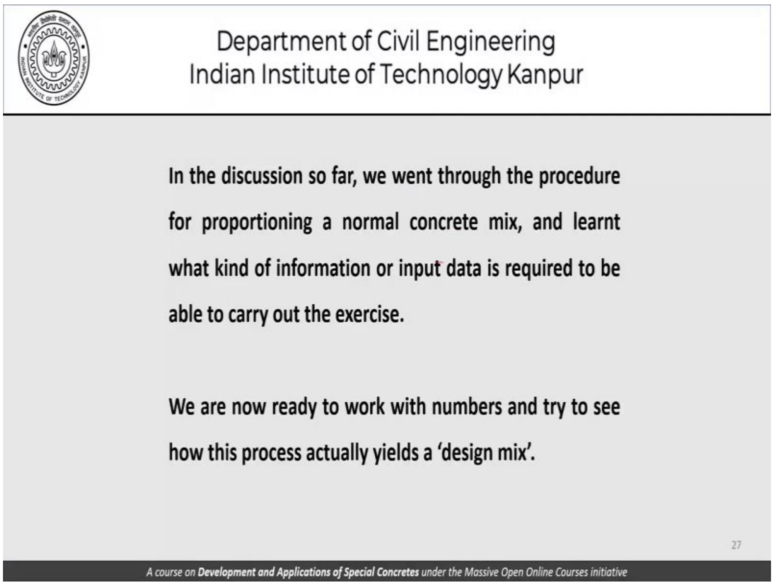

So now so far, we went through the procedure for proportioning a normal concrete mix and learned what kind of information or input data is required to be able to carry out that exercise. And, now we are ready to work with numbers and see how this process actually yields a design mix.

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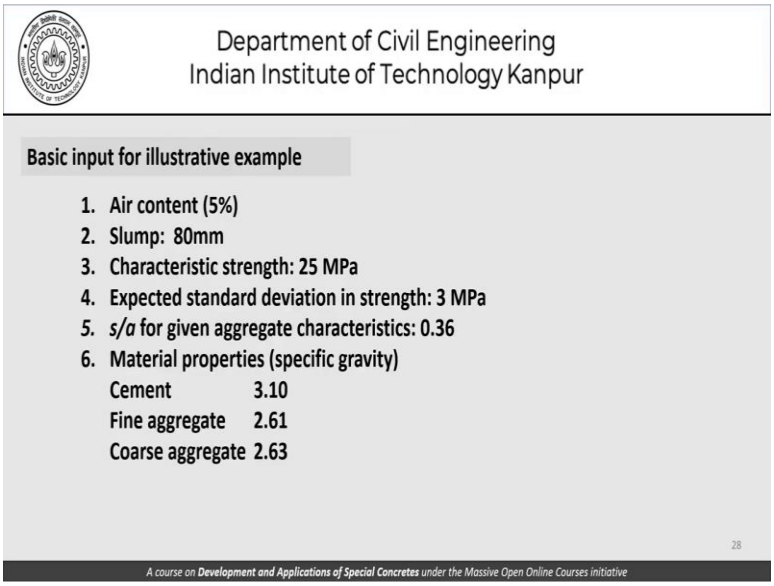

The basic input for the illustrative example air content 5 %, slump 80 mm, characteristic strength 25 Mpa, expected standard deviation strength 3 MPa, s/a for the given characteristics of the aggregates 0.36 and material properties in terms of their specific gravities is known to be 3.1, 2.61 and 2.63 for the cement, fine aggregate and the coarse aggregate.

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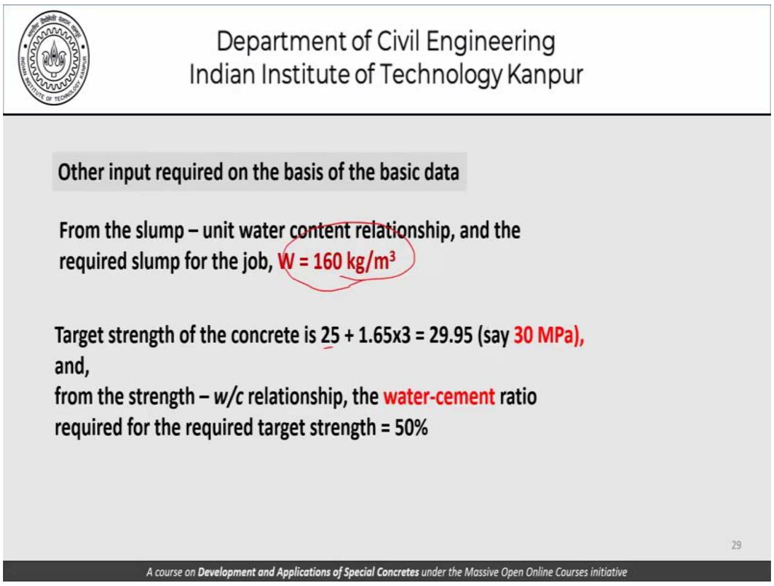

Other input that is required for the proportioning exercise, which becomes available to us or had better be available to us on the basis of the basic data. The first thing is, from the slump unit water-content relationship and the required slump for the job, we should be able to get the water-content that is something which should be known to us or will have to assume something. The target strength for the concrete is 25 MPa, which is the characteristic strength + 1.65 times 3 which is the standard deviation that gives us the strength of about 30 MPa.

And, from the strength water-cement ratio relationship for this strength, it should be known that what is the water cement ratio we need? For example, in this case it is known or have assumed that for this strength we need a water cement ratio of 50%, s/a is already known to us.

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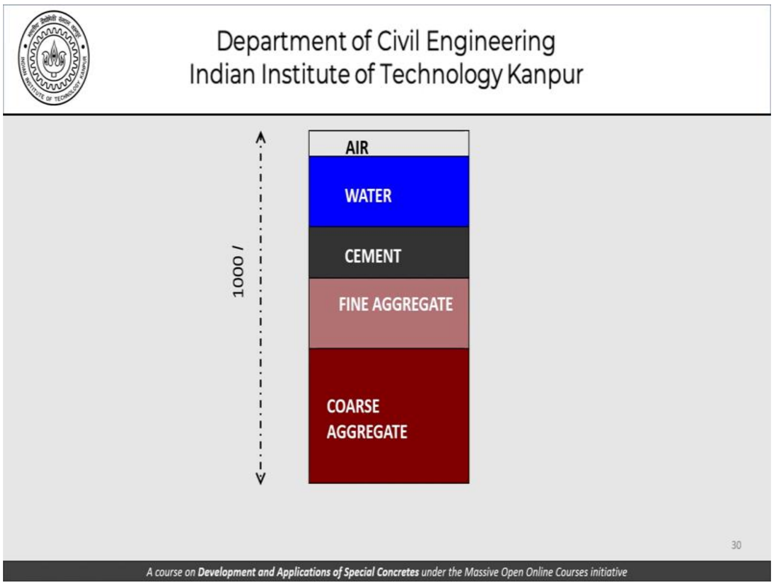

And therefore, we are ready to start plugging in those values into our pitcher kind of calculations.

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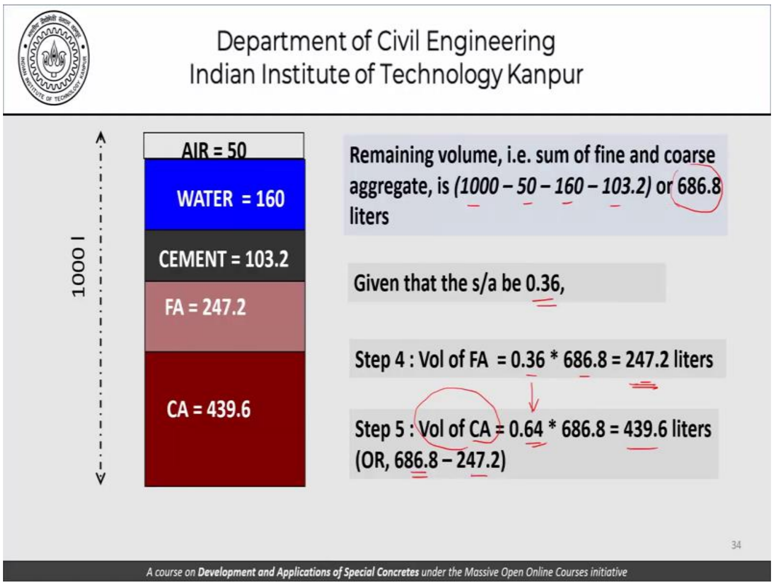

The first step is air content being 50 litres 5% by volume that is known. The next step water is 160 litres, given that this is the unit water content from the required slump this becomes fixed remember all the time that we are trying to fill up 1000 litres of this pitcher. We already fixed 50 litres for air, 160 litres per water coming to the cement content. We have to go through the water cement ratio route and given that we need 160 kgs of water and our water cement ratio requirement is 50%, we get 320 kgs of cement.

Given the fact that, water-cement ratio is always given by mass also given the specific gravity of cement to be 3.1 this translates to 103.2 litres of cement. Now, that adds to this pitcher here 50 liters of air, 160 of water and 103.2 litres for cement that leaves the inert volume to be 1000 - 50 - 160 - 103.2, which gives us the total volume of coarse and fine aggregates to be 686.8.

Now, given that the s/a is 0.36, the sand volume turns out to be 0.36 times this number here which is 247.2 and then we are left with only the volume of coarse aggregate which can be determined as 0.64, this coming from 1 - 0.36 or we could simply reduce or subtract this volume from the total inert volume and we get this as our volume of the coarse aggregate. So, this is the picture of the pitcher 50 kgs of or 50 litres of air, 160 litres of water 103.2 litres of cement, 247.2 a fine aggregate and 439.6 of coarse aggregate.

This tells us that in this configuration about 44% is coarse aggregate by volume i.e., 56% of this mix is virtually mortar. So, these are the kind of analysis and comments commentary we will do at some point later on.

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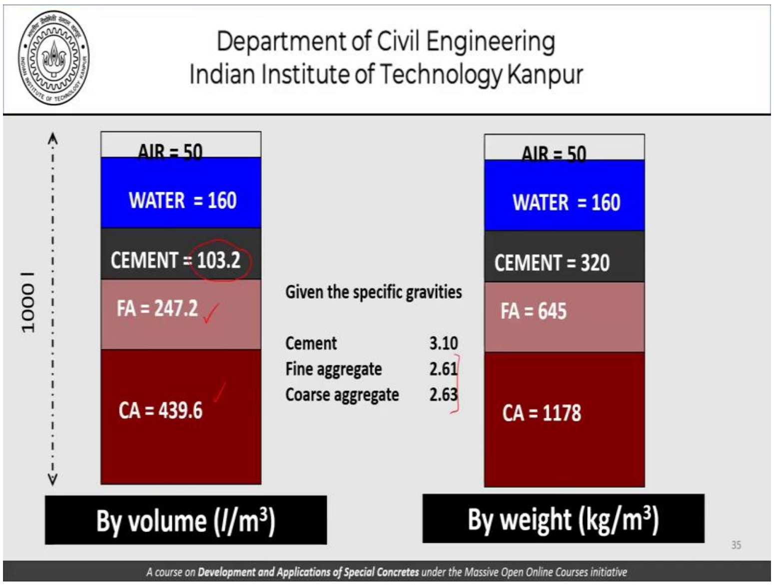

We need to convert these values especially because this was determined from the mass itself. So, these 2 values have to be converted to mass, we need these specific gravities and once we have them, we use them we get 320 kg of cement 160 kgs of water 645 kgs of fine aggregate and 1178 kgs of coarse aggregate. This is the proportion of the concrete mix by weight. So, if this is the proportion by mass or weight and this is the proportion by volume.

This is what we started with, we wanted an air content of 5%, we wanted a slump of 80 mm, we wanted a characteristic strength of 25 MPa for which we determined the target mean strength to be 30 MPa and we proportioned the mix using a s/a of 0.36 in these specific gravities. Now, we have to verify whether the mix that we proportioned actually met these parameters or not that is something which we need to remember.

That our determining or our thinking that 160 kgs of water will give you an 80 mm slump may not turn out to be really true it might give you 70 mm or 90 mm and so on and so forth. Similarly, the dosage that we used for the air entraining admixture need not give you 5% air, the moment we try to adjust that, a lot of other things will change this is something related to fresh concrete.

As far as the strength is concerned, we may have to wait for 28 days before we know whether or not the 50% water-cement ratio that we used actually yielded the 30 MPa that we thought it will. And if it does not, then we may have to make an alteration in our water-cement ratio itself. Those are the kind of things that we really need to be concerned about.

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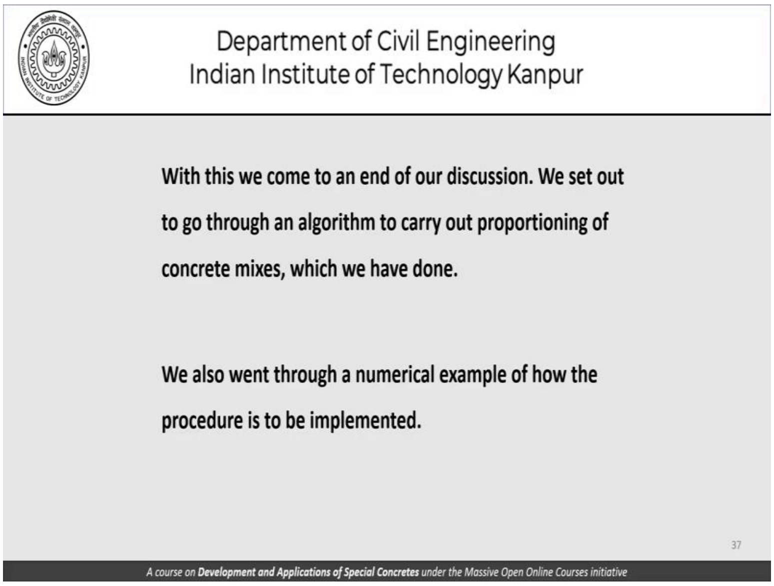

With that, we come to an end of our discussion today, we set out to go through an algorithm to carry out the proportioning of concrete mixes which we have just done. And, we also went through a numerical example of how the procedure is to be implemented, what however remains to be seen is that if the results do not turn out to be what we anticipated. What we thought then we have to make certain adjustments and that is something which will take up in the next class.

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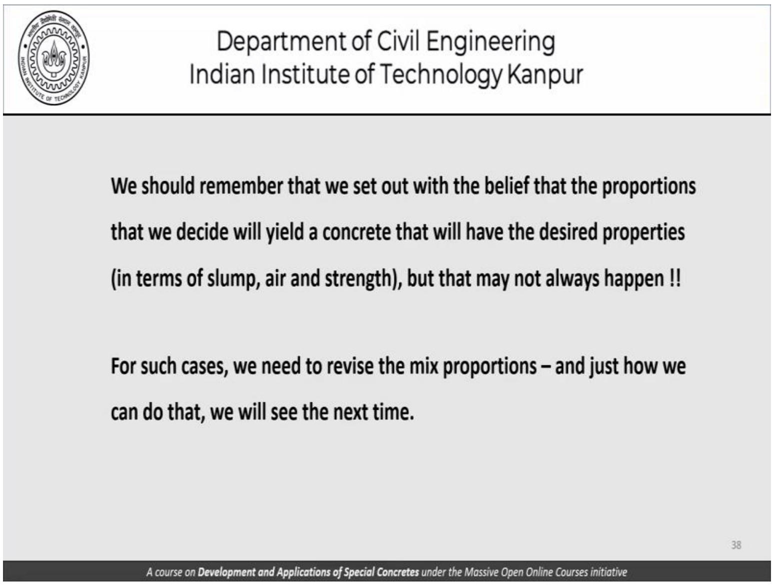

Having said that, this is what I just said we should remember that we set out with the belief that the proportions that we decide will yield a concrete that will have certain desired properties in terms of slump, air and strength. But this may not happen and in such cases, we need to revise the mixed proportions and just how we do that we will see the next time.

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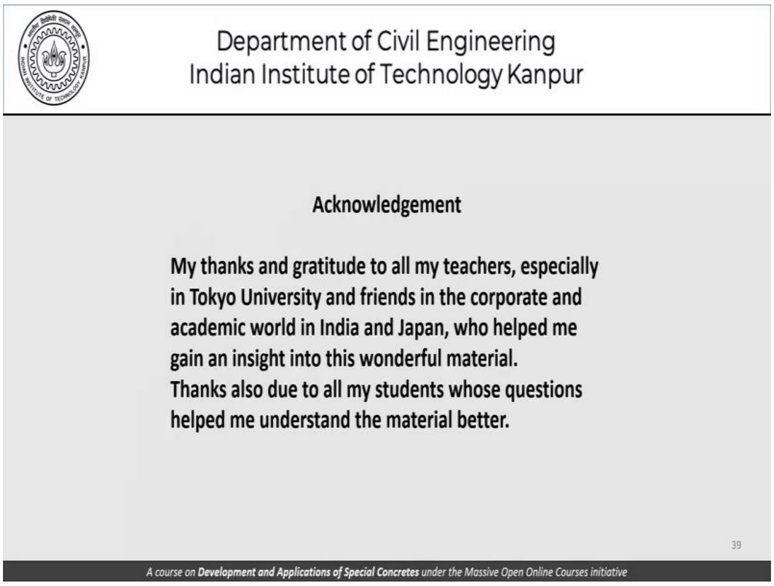

With that my acknowledgement and gratitude to all my friends, teachers and colleagues I look forward to seeing you in the next class where we will try to talk about adjustments and analysis of proportions of a concrete mix, Thank you.