Development and Applications of Special Concretes

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Lecture 05
Review of Normal Concretes Fundamentals of Proportioning Concrete Mixes

Namaskar and welcome back to this series of lectures on development and applications of special concretes under the MOOCS scheme of the Government of India. We start our fresh module today module 2 and still we will continue with our concepts of normal concretes which I hope will help you better understand special concretes and the discussion today is focused on fundamentals of proportioning concrete mixes.

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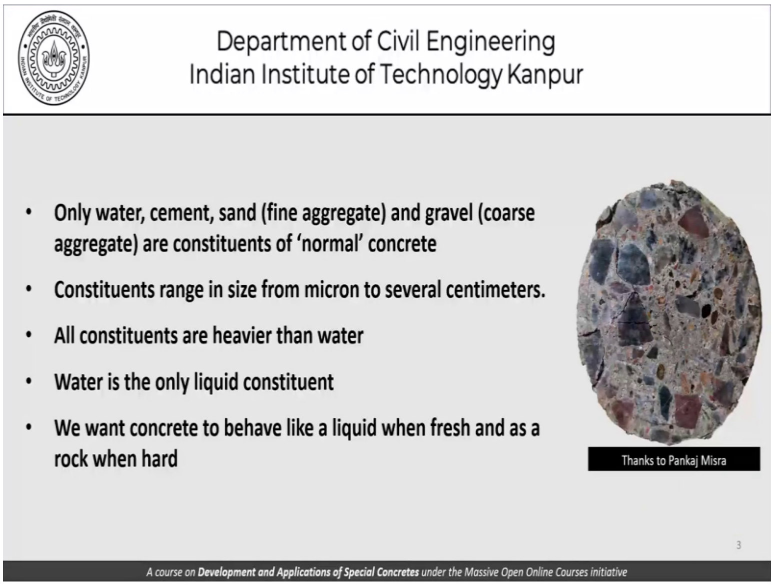

This picture we have seen before and the reason why I keep showing you this picture all the time is that I want this picture to become a part of your thought process. When you see a concrete, when you think of concrete, you must be reminded of this picture, which tells you what does the inside of concrete look like.

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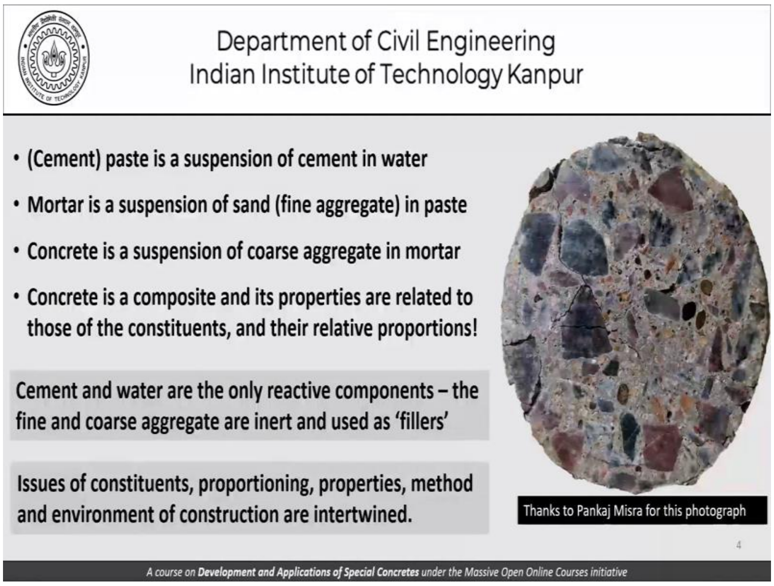

This one too we have seen before just things to remember from here are that concrete aggregate particles within this material are separated from each other, the properties of this material are related to its constituents and their relative proportions, the fact that cement and water are the only reactive components. And, the coarse aggregate and the fine aggregate are only fillers and of course the issue of constituents, proportioning, properties method and environment of construction are largely intertwined. So, today discussion is focused on proportioning issues, the concepts.

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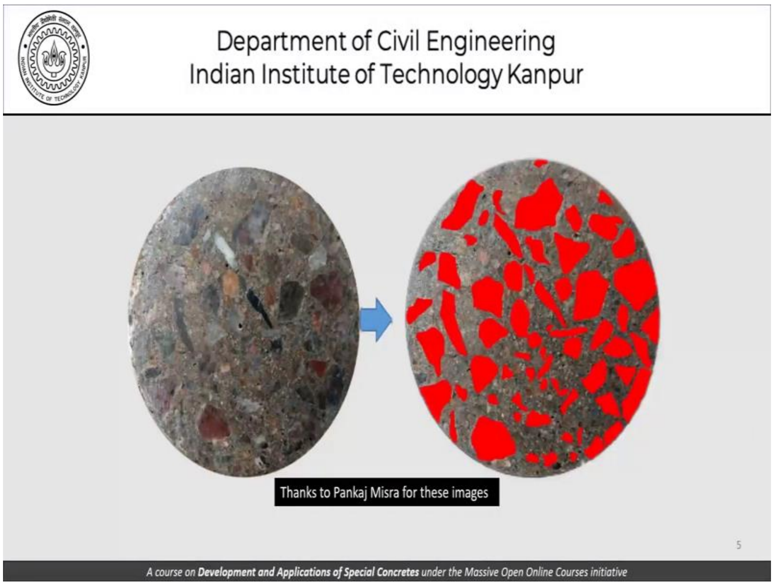

This clearly shows that the coarse aggregates are separated from each other.

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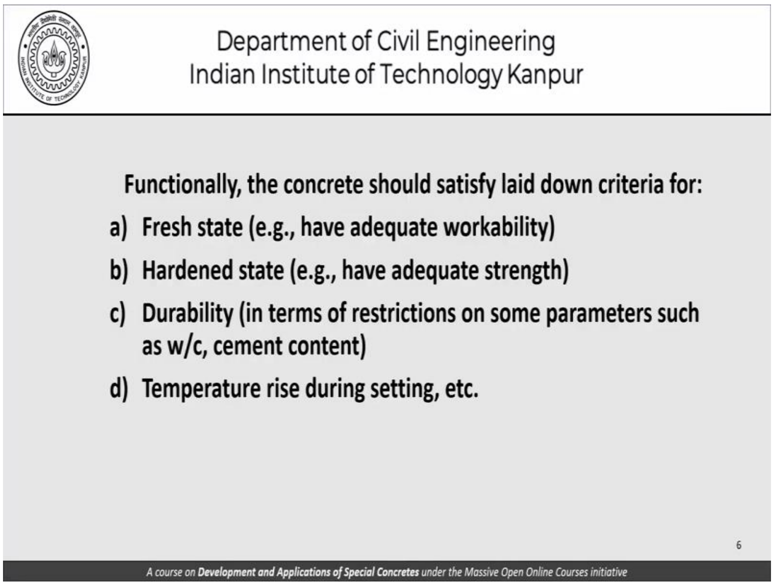

So having said, that we know that functionally the concrete should have properties in a manner that may satisfy laid down criteria for both the fresh state the hardened state any other requirements like durability, temperature rise and so on.

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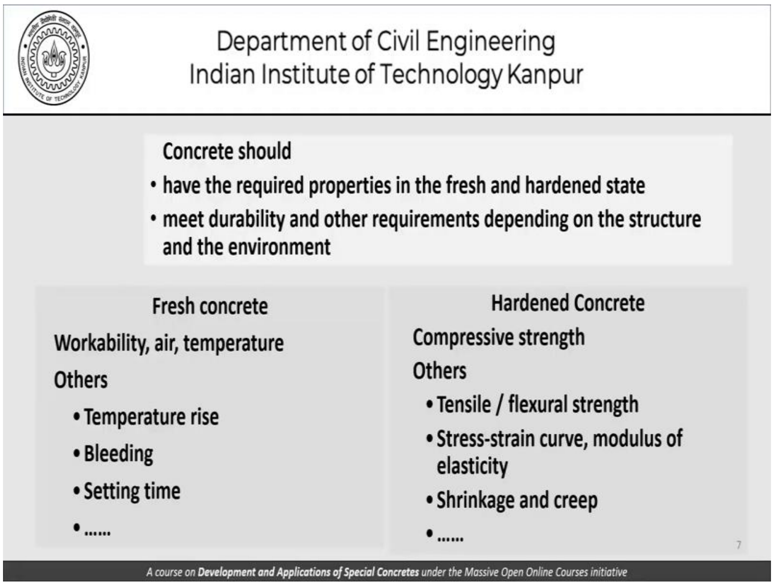

And, we have seen these properties of concrete as well, in the fresh state it could be workability, air temperature others could be temperature rise, bleeding, setting time. We have seen how these properties are measured and in the hardened state it could be compressive strength and other than that tensile strength, flexural strength the stress-strain curve and so on.

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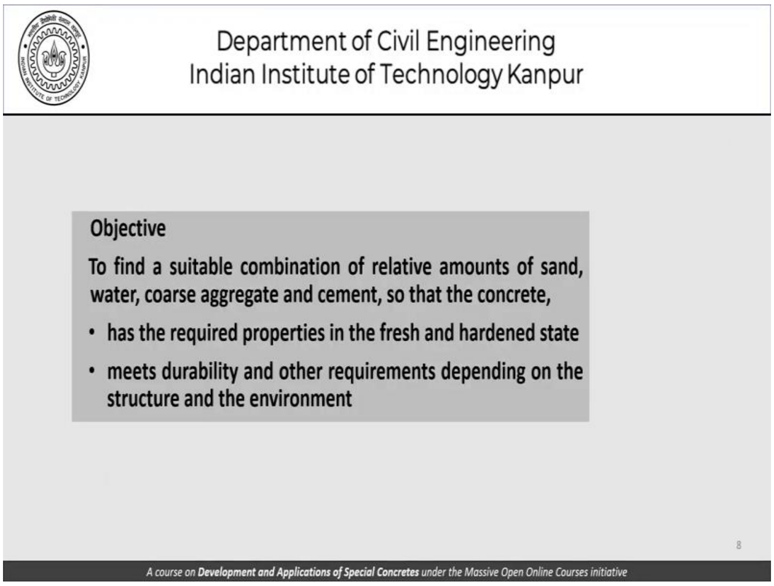

Moving forward and coming to the idea of proportioning. What is the objective? The objective is to find a suitable combination of the relative amounts of sand, water, coarse aggregate and cement so that the concrete that we get from there has the required properties in the fresh state and the hardened state and also meets the requirements for durability or any other requirements that the client or the environment or the construction may actually require.

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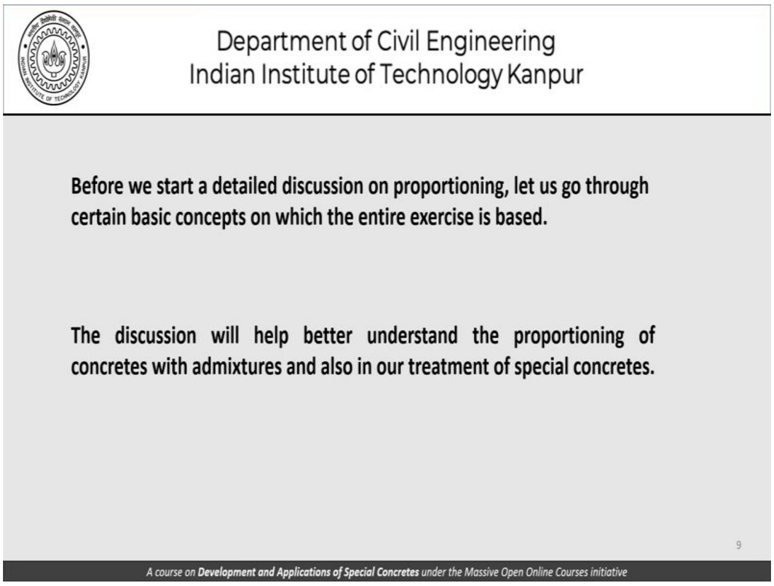

But, before we start a detailed discussion on proportioning, let us go through some basic concepts, which will be very important and will serve as the basis for the entire exercise. The discussion will help us understand the proportioning of concrete mixes with admixtures and also in our treatment of special concretes.

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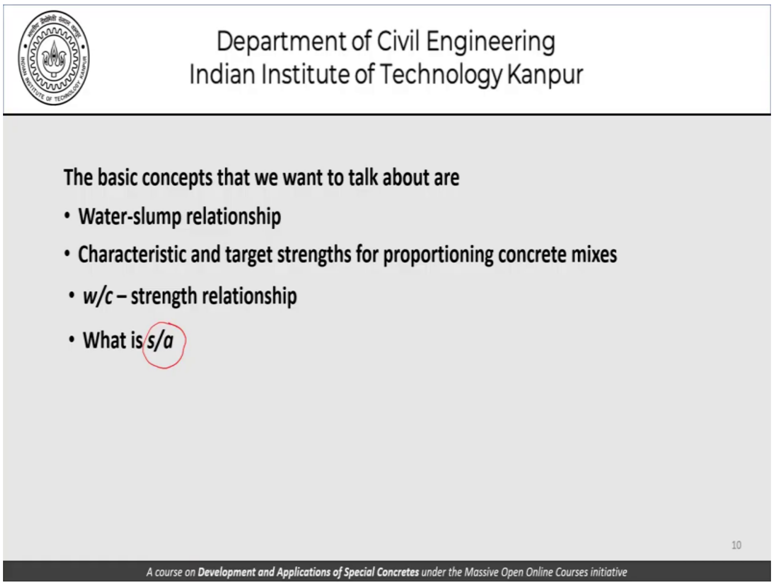

What are the basic concepts that we will talk about, one is the water-slump relationship, remember that water is the only liquid constituent in concrete and therefore it has a large say in determining the workability of concrete as measured by slump. Characteristic and target strengths for proportioning concrete mixes, this is something which you already know and we will just quickly run through this concept once again.

Water-cement ratio to strength relationship, now it is well known and this is only a revision that the strength is primarily governed by the water-cement ratio of the concrete. Why that happens, is something which we will touch upon perhaps later in this module and then finally we talk about a parameter called the s by a, i.e., the sand component in the overall aggregate volume. We know that sand and coarse aggregate are both inert so this s/a only tells us how much is the sand component of the total inert material.

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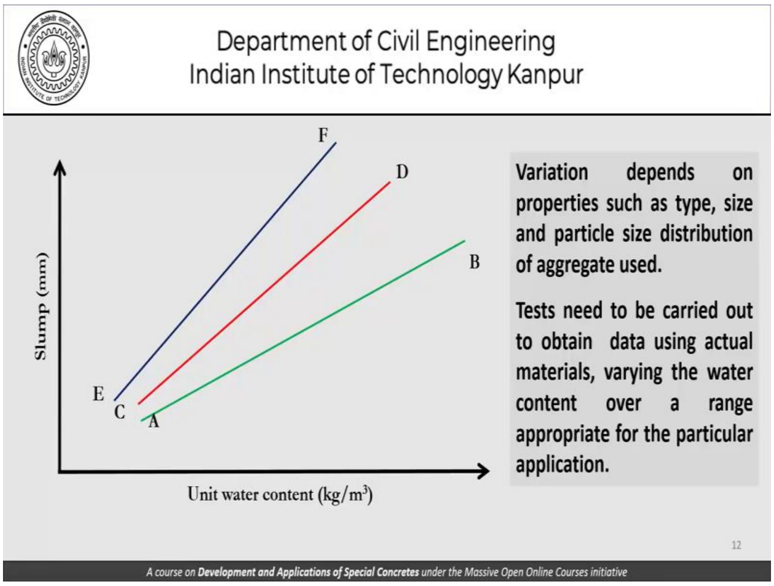

Coming to the first part, that is the water slump relationship, we have already agreed that as the water content in the concrete will be increased, the slump will increase, water being the only liquid component in the mix. Now only, whether the line will look like this and the line is of course the simplest relationship that we can think of or it will be something different or it will be something yet different that would depend on what kind of material we use.

Primarily, what kind of aggregates, the particle size distribution of those aggregates, the sand and the coarse aggregate what that is? Of course, for a given project, for a particular construction, we need to carry out tests in order to obtain this unit water content versus slump relationship in a range which is more relevant as far as that particular project is concerned.

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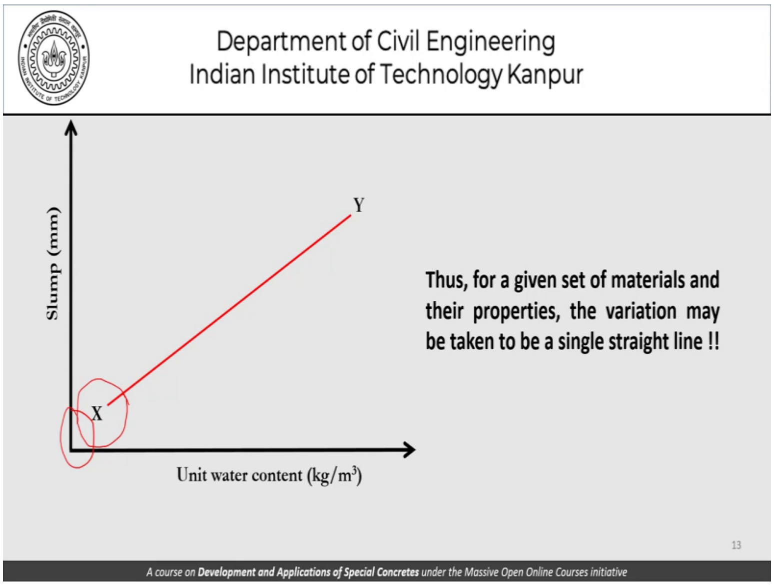

Having said that, let us assume that for a given set of materials and their properties the variation has been determined and has been found to be following this line x-y, which has a certain slope and so on. Remember that, I have never tried to take this line to its logical conclusion and trying to get the behaviour of the unit water content versus slump relationship at very low water contents and so on.

And, it is only within a certain range that this relationship will be linear, keep that in mind all the time.

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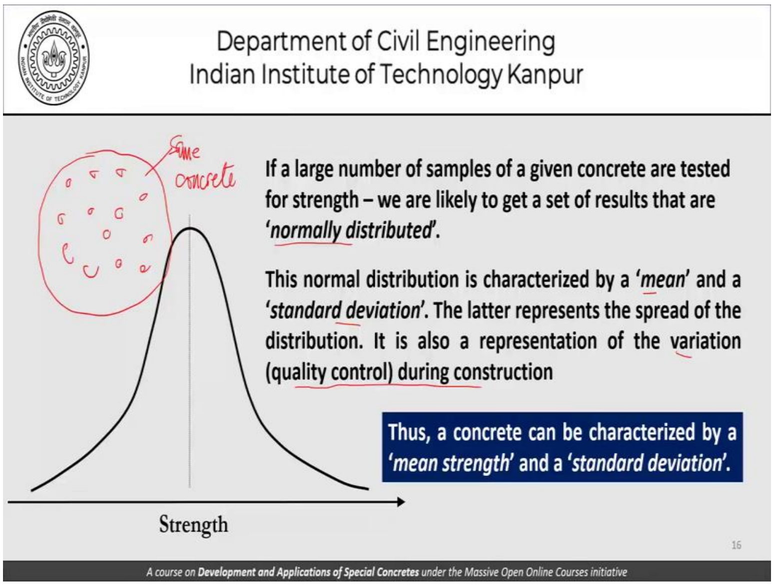

Now, coming to the second concept that we talked about characteristic and target strength. What is the definition of target compressor strength? For that, we must understand that if I have a large mass of concrete and we try to take this strength measure this strength at different locations. This strength regardless of the fact that it is the same concrete, it will not be the same, it will show a certain amount of variation.

Why that varies, will come to that in a minute. But it will show variation and this variation will be normal in that sense of and this distribution will be normal in the statistical sense of the word. This normal distribution we know is characterized by a mean value and a standard deviation. Now, the latter represents the spread of the distribution and is also a representation of the variation or the quality control during construction.

What this effectively means is, that if I take all these values here, there will be a certain spread now that spread depending on what is the kind of quality control that we followed in creating this concrete mass, will depend on that. If the quality control is good, the spread will be small, but if the quality control is poor, we can expect a large value of the spread. Thus, a concrete is characterized by a mean strength and a standard deviation

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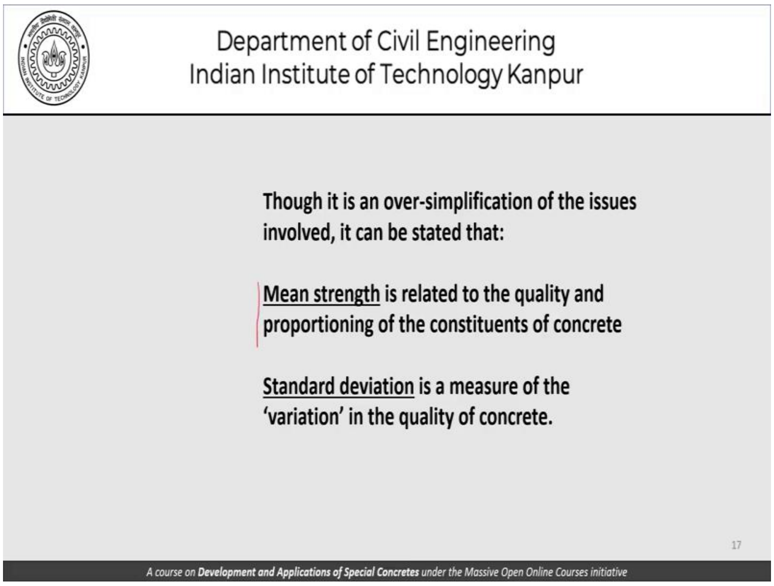

Though, it is an over simplification of the issues involved, it can be stated that the mean strength is related to the quality and proportioning of the constituent materials of concrete and the standard deviation therein is a measure of the variation in the quality of concrete. What that means is something, which we will come to in a minute.

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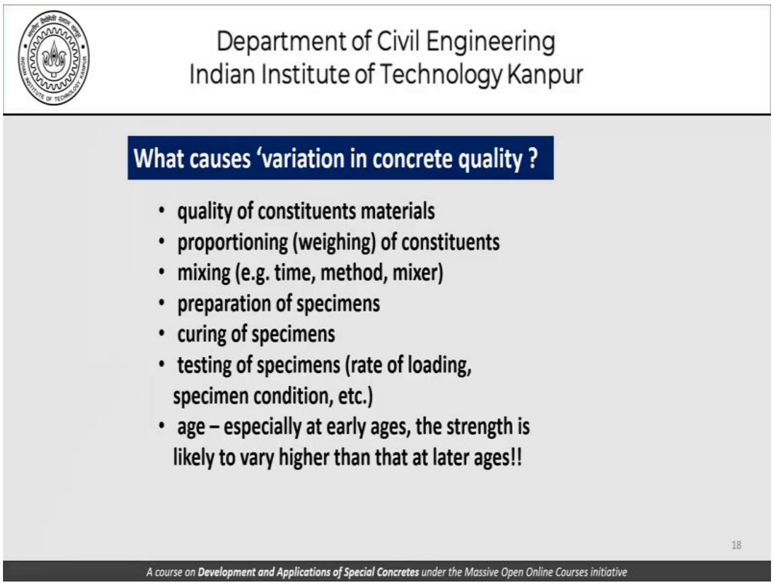

Let us first look at the causes of variation in concrete quality there can be many, many causes. There can be variations on account of quality of constituted materials, there could be differences in the proportioning, the balances that you use there are errors in weighing, there could be differences in mixing, time, method or the mixer involved, preparation of specimens, curing of specimens, testing of specimens which could include things like rate of loading specimen condition and so on.

And of course, the age the concrete age or the age at which the strength is determined is of course a major factor as far as concrete strength is concerned and we know that for a lot of quality control and so on we use the 28-day age. And of course, the age at seven days will be very different, but there are a host of factors which are listed here and there are several others which cause variations in the strength of concrete. And, it turns out to be a normal distribution.

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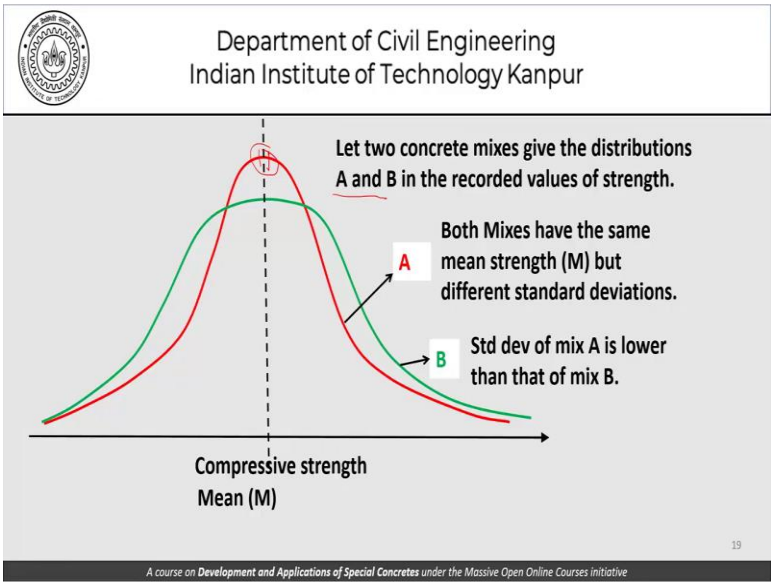

Now, what does this effectively mean or let us consider two concrete mixes which have distributions a and b in the recorded values of strength. Both mixes have the same mean strength m but different standard deviations that you can see from the graphs that I have plotted. The standard deviation of a is lower than that of b, so this peak is sharper here and therefore the standard deviation is lower, which means that as we have better quality control, we will have the concrete more of the concrete.

I should say falling within this mean value. There will be fewer deviations, but if the quality control is bad there will be larger amounts of concrete deviating from this mean value.

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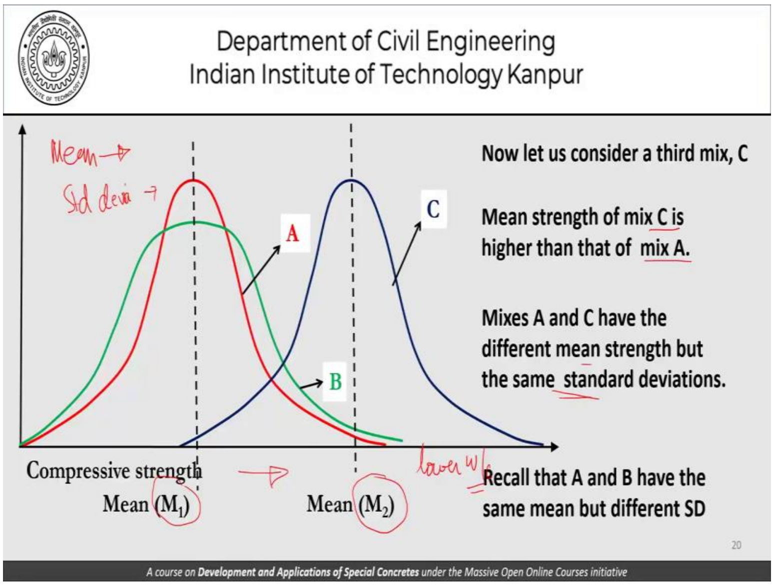

Now let us add a concrete mix C to the A and B what is the characteristics of C with respect to what we saw in A and B? The mean strength of C is higher than that of A and B the mean strength of C is somewhere here and the mean strength of A and B is somewhere here. And, if the strength is increasing this way this M 2 is clearly greater than M 1. Having said that, mixes A and C have almost the same standard deviation even though their means are the not same.

Now, try to relate this discussion to what we had in terms of what does the mean represent. I said in an earlier slide that the mean represents the proportion and the kind of quality of material in the larger sense of the word. The standard deviation on the other hand represents the quality control of construction. So as far as, this particular case is concerned concrete C perhaps has a lower water cement ratio and that is why its mean strength is higher than that of mix A.

And, the quality control of the two situations being the same the standard deviations are the same. Of course, that is what I am saying here recall that A and B have the same mean but different standard deviations.

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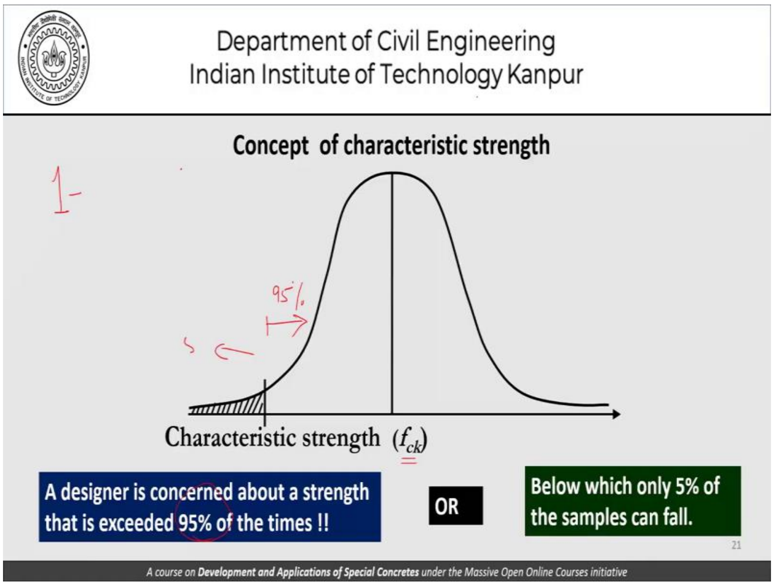

Now, the concept of characteristic strength is that, we define a strength value here which is called the characteristic strength and often represented as fck and that is the strength that the designer is concerned about. The designer says that this is a strength which is exceeded 95% of the times. Please remember that the area under this curve is one unity and the area beyond this point beyond the fck should be 95% that is what is the definition of characteristic strength or in other words below which only 5% of the samples can fall that is this area here is only 5% of the total which is one.

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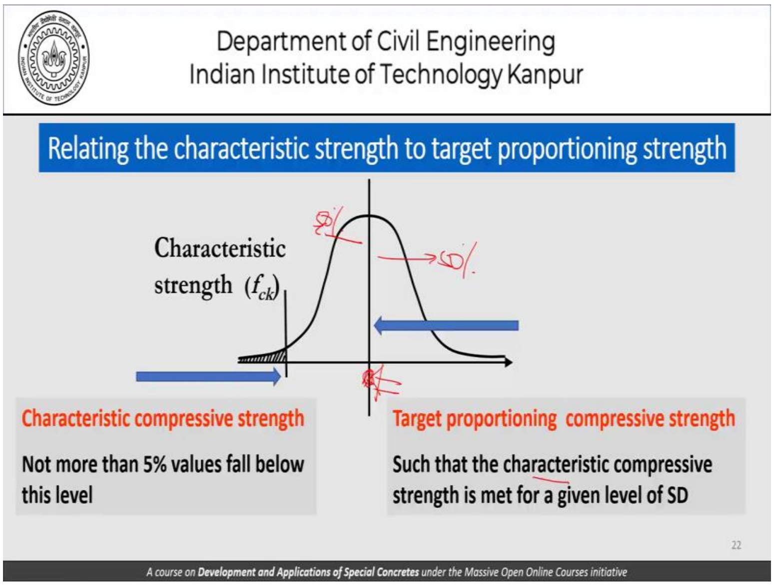

Now, relating the characteristic strength to the target proportioning strength, let us try to examine this concept. If this is my characteristic strength fck which is the value, which is such that not more than 5% values fall below this level. So, we need to target our concrete to have this strength here which is the mean value. So, the target proportioning compressive strength is such that if we target the concrete mix to be at this value and this area being 50%.

This area being 50% then for a given set of standard deviations this point here will be such that this area here is 5%.

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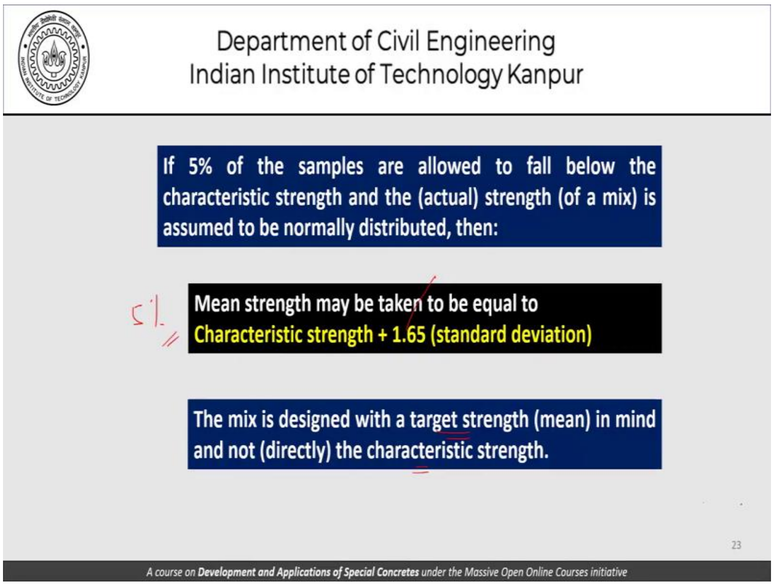

Now, if 5% of the samples are allowed to fall below the characteristic strength and the actual strength of a mix is assumed to be normally distributed then the mean strength can be taken to be characteristic strength + 1.65 times the standard deviation. Now, this comes from the fact that, we are taking 5% samples falling below the characteristic strength. So, this 1.65 comes from this 5% and you can look up the statistical tables and find out how it is 1.65 and how this will change if this 5% was changed to some other number.

Further, the mix is designed with the target mean strength in mind and not directly the characteristic strength. We of course have the characteristic strength of the back of our mind because that is what determines the target mean strength but the mix itself the compressive strength the mean compressive strength of the target mix or the mix that we use is the target mean strength.

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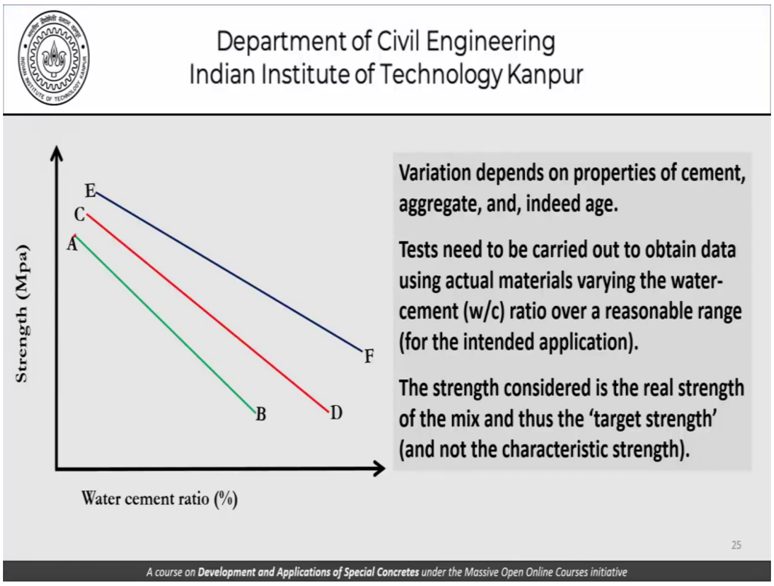

Now, let us come to this concept of water-cement ratio versus strength relationship. Much as we talked about in the case of the unit water content versus slump relationship, we know that the water cement ratio increases the strength decreases. But whether the change follows the line AB as shown here or it is something like CD or EF that would depend on the conditions which are listed here.

The variations could depend on the properties of cement aggregate and indeed age tests need to be carried out again to obtain the data using actual materials varying the water cement ratio or the reasonable range for the intended application. And, the strength considered is the real strength of the mix and thus the target strength and not the characteristic strength.

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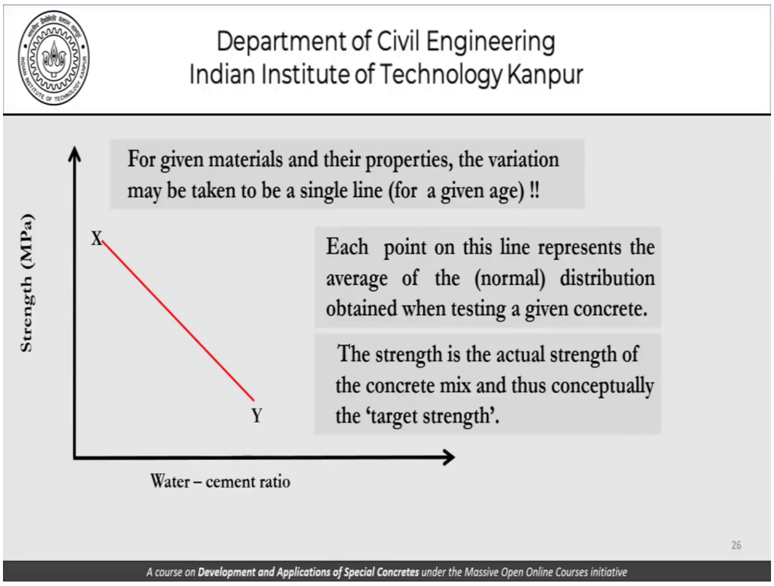

Which means that we will finally agree or we will have to determine this unique line. Let us say, x-y such that for a given material and their properties, the variation is taken to be this line for a given age. Each point on this line represents the average of the normal distribution obtained, when testing a given concrete and the strength is the actual strength of the concrete mix and thus conceptually the target strength.

What does this mean all this means is that for a given water cement ratio let us take this one we will get this strength. Now, will we always get this strength, no this strength will be distributed about this point in a manner which is normal. This is what we had talked about earlier and this is what is being said here this water-cement ratio gives you an average value of the concrete strength, which is somewhere here, it will vary between these ranges depending on the kind of quality control that you have.

Remember this, keep this at the back of your mind all the time, the mean strength, the average strength of the concrete that you use is actually the target strength for which the mix was proportioned. The characteristic strength was only a tool that you used to get the target strength.

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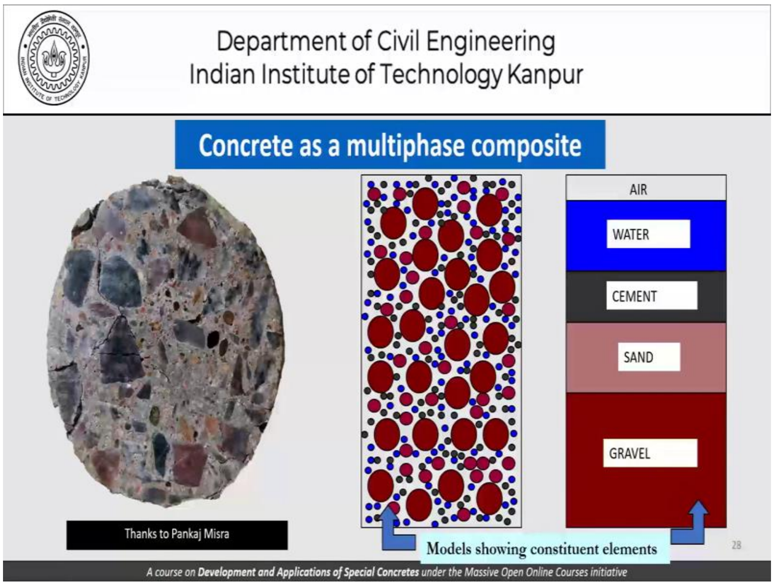

Having said that, let us come to the concept of s by a. Now, let us look at this concrete once again more closely. This is modelled like this coarse aggregate, fine aggregate cement and the rest of it is water. Of course, this is not to scale, do not try to read too much into it, this is modelled here. But all these colours are taken here, all this is the solid volume or the absolute volume of gravel, the absolute volume of sand, cement, water and air.

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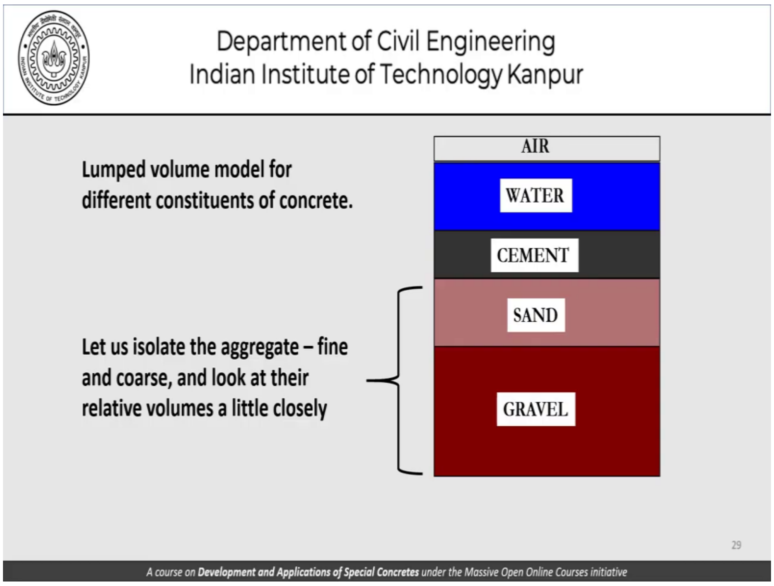

Now, once you understand this, we have used the lumped volume model for different constituents i.e., what we did, we had that concrete, which is coarse aggregates in mortar and so on. We use the lumped volume model to come to something like this. Now, let us isolate the aggregate, the fine aggregate and the coarse aggregate and look at their relative volumes a little more closely.

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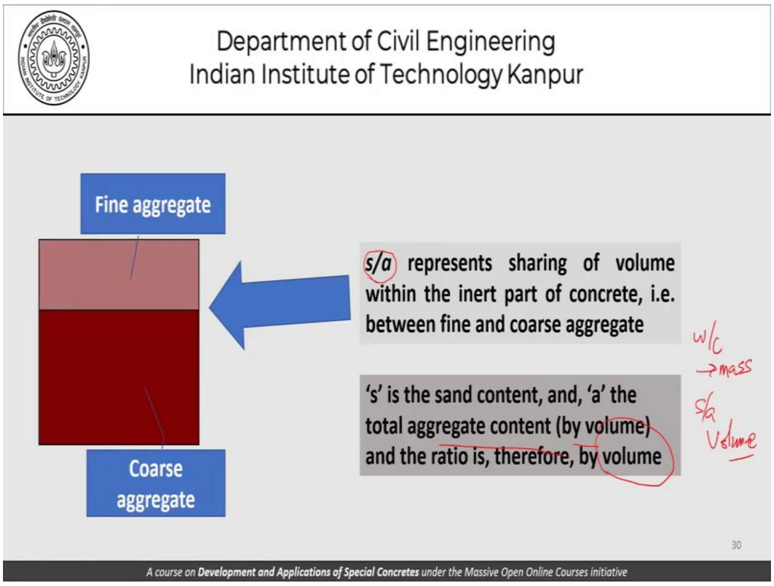

S by a; represents the sharing of volume within the inert part of concrete i.e., between fine and coarse aggregates. Now in this case, s represents the sand content and the total aggregate content by volume and therefore the ratio that is s/a is therefore by volume. This is against water-cement ratio, which is what a cement ratio is by mass, s/a is by volume that is what we will follow, as far as our discussion is concerned.

What does this mean? It means that if we have a total volume of inert material shown here this is my fine aggregate and this my coarse aggregate. This is my s and this is the a. So, s by a; represents the sand fraction in the total aggregate volume.

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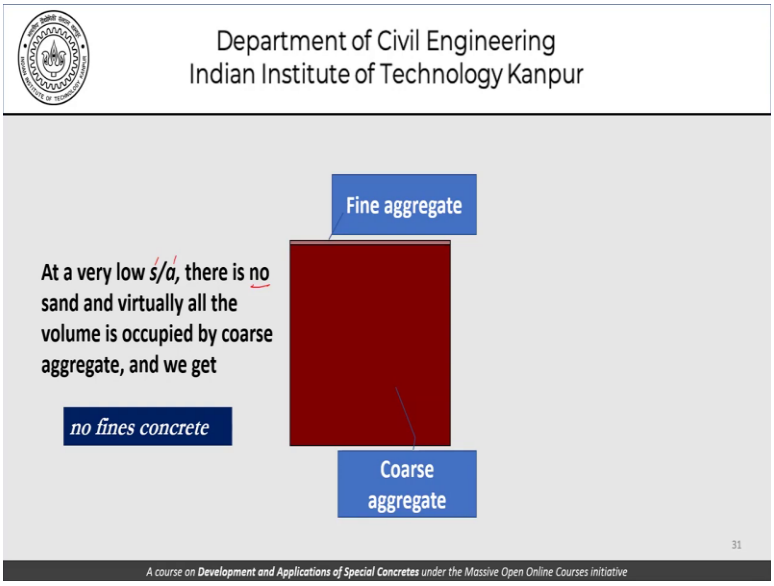

At very low values of s by a, there is virtually no sand. Of course, if you have s/a and if the s/a is very small, you are saying that there is no sand in the concrete, all this volume is basically occupied by coarse aggregate and we get what is called no fines concrete.

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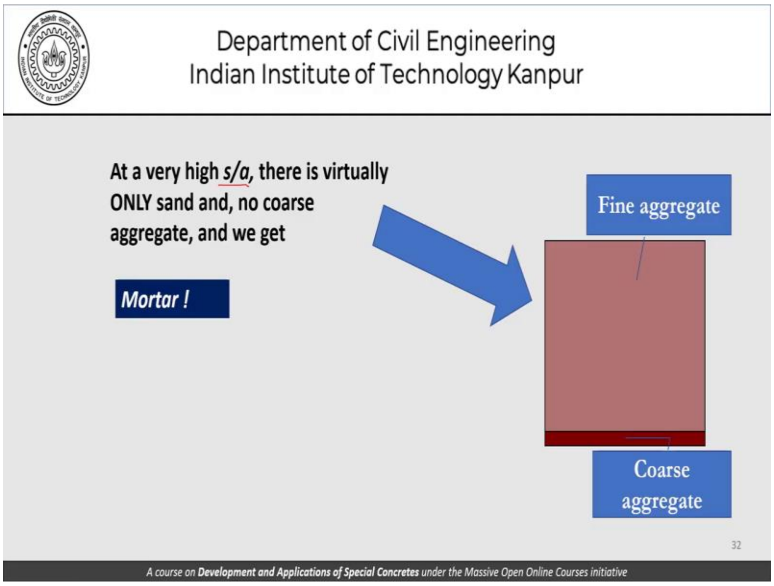

On the other hand, if we go to a very high s/a then what do we have most of it is sand virtually no coarse aggregate perhaps what is this mix called? This mix will be called a mortar because of course, we are not showing the water and cement here. So, if we show the water in cement this will be basically mortar.

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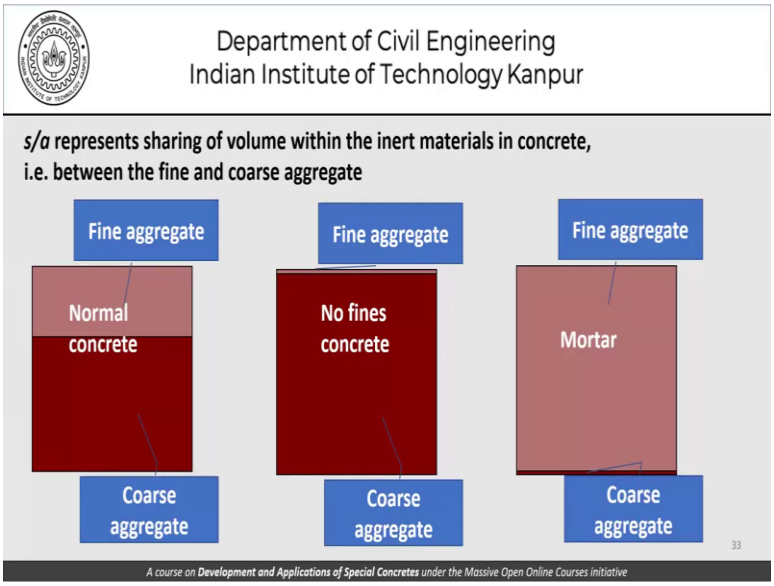

So, keep that in mind, s/a represents the sharing of volume within the inert materials concrete between the fine and the coarse aggregates. So, this is what is normal concrete, there is no fines concrete and this is water. So, what we have varied here is s by a. So, this is a normal s/a perhaps in the range of about 30 to 45%, this is no fines concrete which means that s by is pretty close to zero and here we are talking of virtually mortar, which means that we are talking of a s/a virtually 100%.

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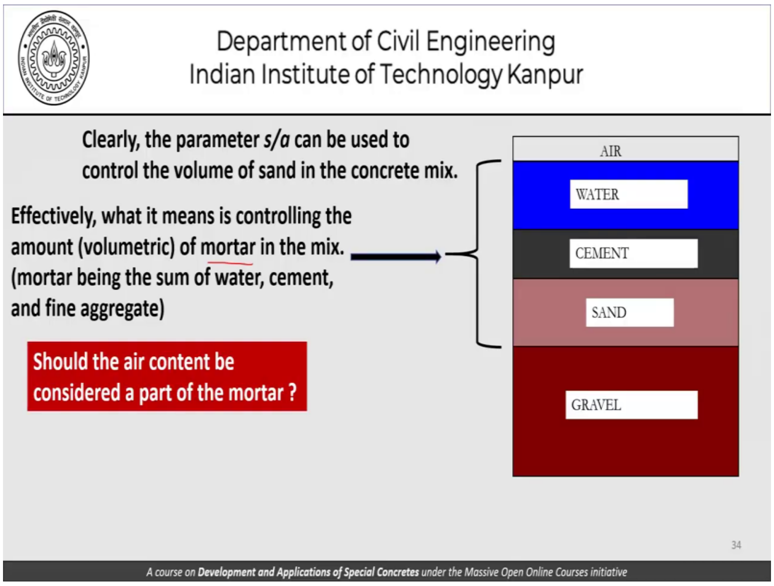

So having said this, let us try to take a look at this picture once again. The parameter s/a can be used to control the volume of concrete mix that has been established. Now, what that means is that effectively, if we change the volume of sand here through the s by a, it also becomes a means of controlling the amount of mortar in the mix because mortar is nothing but the sum of water, cement and sand of course air will be part of the mortar.

So, if I vary my s by a, I control my sand content and through that the mortar content. The question is should air be considered a part of mortar, I already answered it, it is, try to think about it and convince yourself.

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Now the question is, how much mortar do we need in a concrete mix. Look at this picture once again and try to see this picture from a slightly different point of view. This shows all the aggregates in contact because that is what will be, if we just dumped all the aggregates together. We have talked about before. In concrete, there coarse aggregates are not actually in contract, are not actually in contact with each other as shown here, which means that the mortar fills the space in the coarse aggregate structure matrix.

And, the quantum of mortar should be in excess of the void content. So, if mortar was to occupy only the void that is shown here, that is the bare minimum amount of mortar that is required, the aggregates will still be in contact with each other. Only if, I have more mortar in this system than the voids within the aggregates, then we will get to concrete, keep that in mind.

With that, we come to an end of the discussion on the principles that will define our proportioning of concrete mixes.

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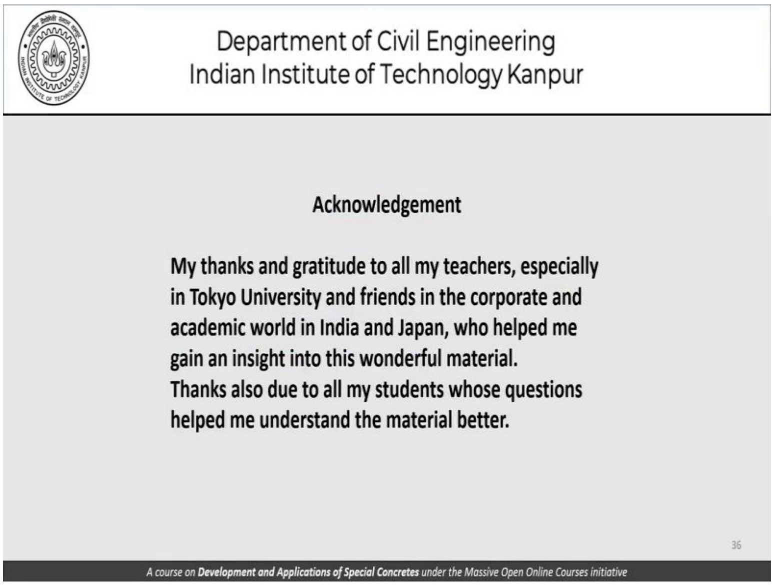

I of course acknowledge my teachers, my students and my friends who have helped me understand this material better. In the next class, we will try to look at an actual example and do the proportioning of concrete mixes, thank you once again.