Development and Applications of Special Concretes
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Lecture 20
Self Compacting Concreting III

Namaskar and welcome back to another lecture, now, Series Development and Applications of Special concretes under this program of massive open online courses initiative of the Government of India. We will continue our discussion today on self compacting concrete. Today the discussion will focus on Proportioning of a self compacting concrete mix. This will be the last lecture as for as Self compacting concrete is concerned.

And possibly the close of this module which has largely concentrated on self compacting concrete. The idea in this model has not been to create an expert out of you as far as self compacting concrete is concerned but to make you aware of the issues involved, the basic approach that is used, the history that went into the creation of self compacting concrete, the testing of this special concrete, in terms of the different test that we use and advances involved.

What are the details, how exactly the tests to be carried out, please remember that Knowledge of merely how the test is carried out does not make you an expert. You have to have the right kind of specifications. For example, if you are carrying out the slump flow test, you should know what to look for what Small details are required, for example, in the slump flow, you can make a judgement about segregation resistance from the V funnel, from the U box, from the L box and so on.

We have to be careful when we choose one test or the other in specifying a self compacting concrete. To reiterate once again today is discussion is on the proportioning of this special concrete mix.

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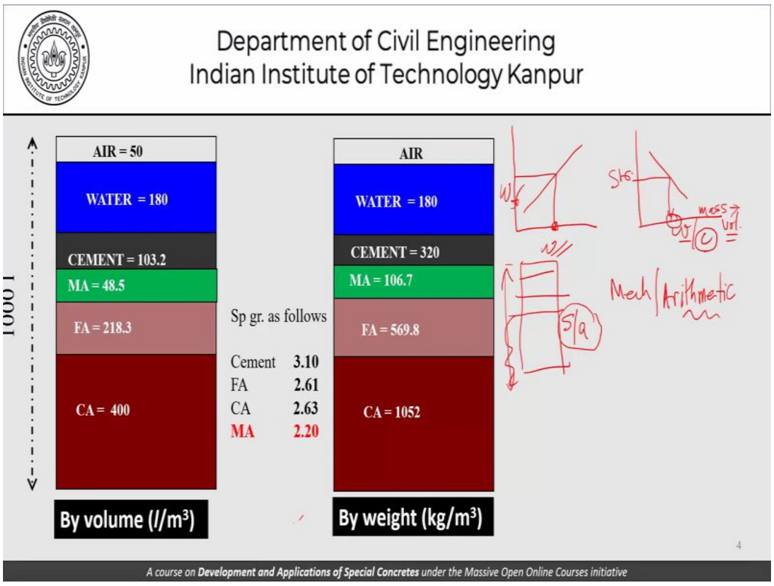

Now, this is an old slide from the proportion that we carried out for normal concrete as a part of the review your understanding, or our understanding of normal concrete. We can see the coarse aggregate constitutes about 40% of the Concrete mix by volume. Fine aggregate is another 22% mineral admixtures about 48 litres cement is about 100 litres and water is about 180 litres. That is about 18% cement and mineral admixtures constitute about 150 litres.

That is about 15% of the concrete by volume. Air been taken as 5%. By weight, this proportion translates to what is given here and let me recollect what we did very simply to get these numbers. We said that we will have a workability versus water content relation known to us and if the workability increases for a given workability, we first get the water content and we had a similar discussion for strength versus water cement ratio.

This relationship was known to us for a given strength we know the water cement ratio, therefore, knowing the water content from here, we know the cement content. We calculate the cement content by mass convert that to volume using specific gravity of cement. And then, we were using this picture all the time that we knew how much of the air is there. Then, we say water then we say cement and this is space that we had left here.

We divided using the concept of s/a. This was the purely mechanical arithmetic kind of an exercise that we did. Principles behind it, we had revised and it turned out that this was one of the approaches so that we can use to proportion of concrete mix using primarily a volumetric balance using this thousand litre pitcher. So, we use the story of the crow to say that as far as the pitcher is concerned, the solid volume, absolute volume of all the constituents must total to 1000 litres or a cubic metre.

Now that principle is pretty much inviolate and we have to stick to the principle as far as self compacting concrete is concerned. Except that we may not be able to stick to this algorithm. And that is what we will see as we go along our discussion today.

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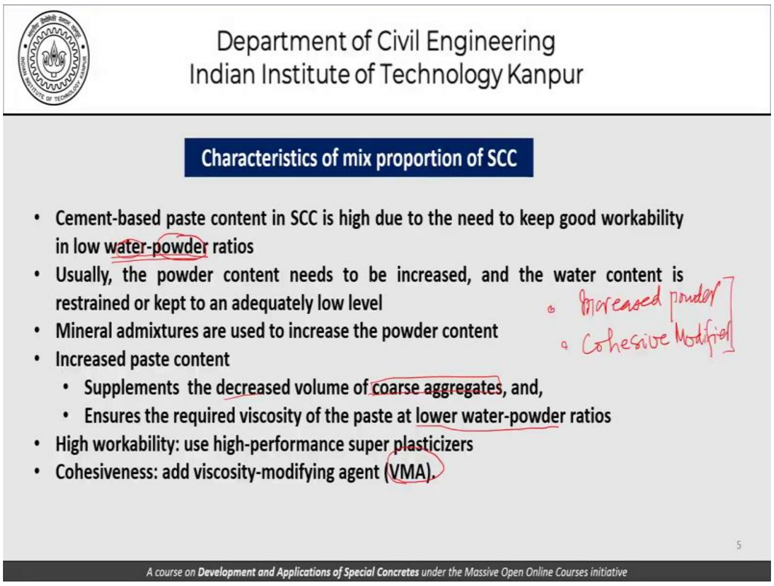

As far as the characteristics of proportioning self compacting concrete is concerned, cement paste content is self compacting concrete is high due to the need to keep good workability in low water to powder ratio. So, we need to keep low water to powder ratios. That is the powder content has to be high, the water content has to be low, moving forward the Powder content needs to be increased, Water content is restrained or should be kept at an adequately low level.

Mineral admixture are used to increase the Powder content which increases the paste content. And if that happens, it leads to a decreased volume of coarse aggregates and ensures the required viscosity of the paste at the low water to powder ratios. So, if we increase the Powder content viscosity, Segregation resistance of the paste increases. High workability is also achieved through using high performance super plasticizers and we get cohesiveness from using viscosity modifying agents.

We possibly talked about this earlier that as far as self compacting concrete are concerned, we have two important routes. One is increased, powder content and the other is using cohesive mixes or a cohesive modifier that is your viscosity modifiers. So these are two routes that we can take, a combination of these two things that we do to normal concrete to get self compacting concrete.

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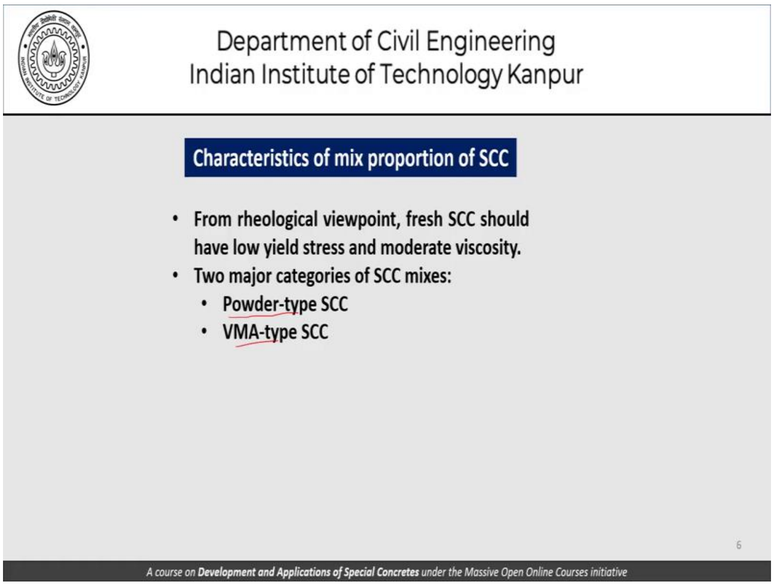

From rheological point of view, fresh self compacting concrete should have a low yield stress and moderate viscosity. 2 major categories therefore emerge. Powder type SCC and VMA type SCC. Powder type SCC means primarily we are trying to push the Powder content. VMA type means the primarily we are trying to impart viscosity through viscosity modifier.

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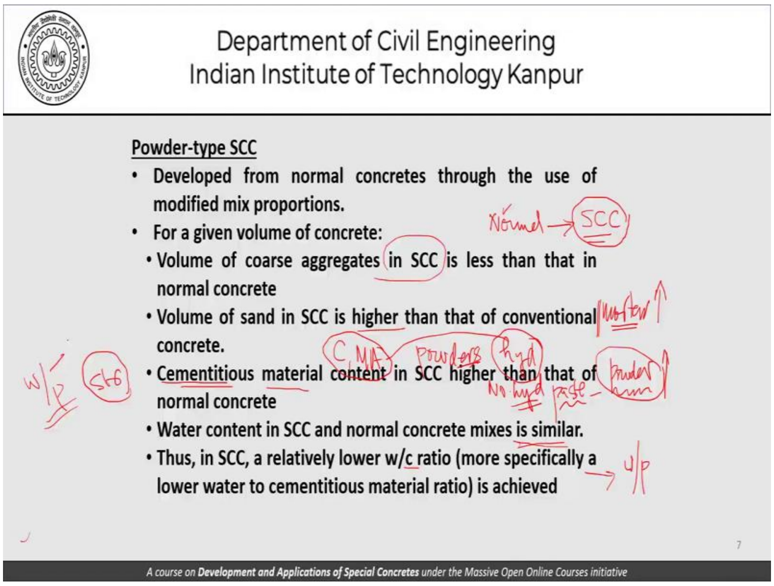

Now, let us review some basic features of the Powder types of compacting concrete mixers. This is developed from the normal concretes through the use of modified mix proportions. And for a given volume of concrete, what we try to achieve is, we limit the volume of coarse aggregates. That is, the volume of coarse aggregates in self compacting concrete is less than that in normal concrete.

The volume of sand in self compacting concrete is higher than the conventional concrete and this contributes to the mortar content. So the mortar content in self compacting concrete is high. Cementitious material content is also higher than a normal concrete. When we talk of cementitious material, we are talking of cement and mineral admixtures. But please remember that apart from mineral admixtures, we also, sometimes use other powders which do not necessarily take part in the hydration reaction.

So if they take part in hydration reaction. They become part of the mineral admixture. If they do not take part in the hydration reaction, they can still be part of the paste because they are comparable in fineness to normal cements, mineral admixtures and contribute to the higher Powder content. And what we are actually interested to do is to increase the Powder content. Please remember that the cementitious material content, the terminology is very useful when we talk in terms of strength.

But, when we are talking of Water to the Powder ratio then, we are really interested not so much in strength, but the segregation resistance or viscosity or the kind of properties of the paste in the fresh state. To continue further, the water content is self compacting concrete and normal concrete mixes is more or less similar. What we should keep in mind is that from the historical perspective, self compacting concrete were developed largely from normal concrete.

And therefore the effort was that in self compacting concrete to the extent possible, we should not try to tamper the procedure, the material specifications and so on which are already known to Engineers by way of normal concrete. Thus, in self compacting concrete relatively low water to cement ratio. more specifically the lower water to cementitious material ratio and actually more specifically we can talk in terms of a low water to powder ratio is achieved.

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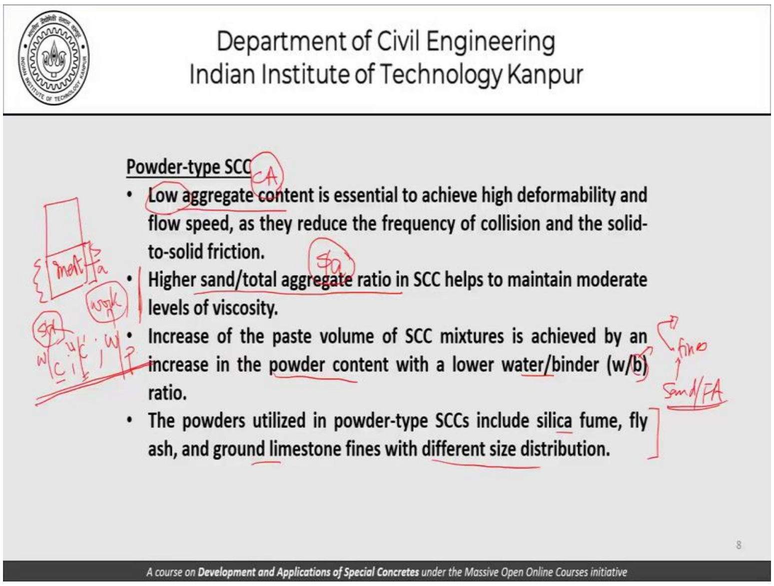

Continuing with our discussion on powder type self compacting concrete, low aggregate content is essential to achieve the high deformability and flow speed as they reduce the frequency of collision and solid to solid friction. So, basically we are trying to control or restrict the amount of coarse aggregate. We try to restrict this coarse aggregate content to a low value. How much is that low value, is something what we will see in the subsequent slides.

We go for higher sand to total aggregate ratio in self compacting concrete to maintain the moderate levels of viscosity. Now, this Higher sand to total aggregate ratio, essentially refers to the good old parameter s/a, except that we often we do not approach it from the direction of s/a. But that is what it will boil down to given the fact that we are familiar with the concept of s/a, which is the parameter, which we used to divide the space of inert material that we have in the pitcher of thousand litres into sand and coarse aggregate.

I have included this approach or this sentence, here just put the discussion that we have in perspective. The increase in the paste volume of self compacting concrete mixture is achieved by the increase in the Powder content. That is what we talked about just now. We said that ok there is a water cement ratio, there is water to cementitious material ratio and there is a water to powder ratio. They are not the same thing as for as self compacting concrete is concerned.

I have already explained to you that water cement ratio and water cementitious material ratio really refers to the contribution or understanding from the point of view of strength, whereas water powder ratio is more important from the point of view of workability or the viscosity of the concrete that we are talking about. And of course, what is written here is with the lower water binder ratio of the word Binder here refers to cementitious materials.

The Powder utilised, the Powder type SCC include silica, fume, fly ash, and ground limestone fines with different size distributions. Of course, we should also remember that the sand that is fine aggregate also has a certain amount of fines. And as far as self compacting concrete are concerned, as we shall see later the fines of the, from here also are considered as part of the paste as we will see in the subsequent slides.

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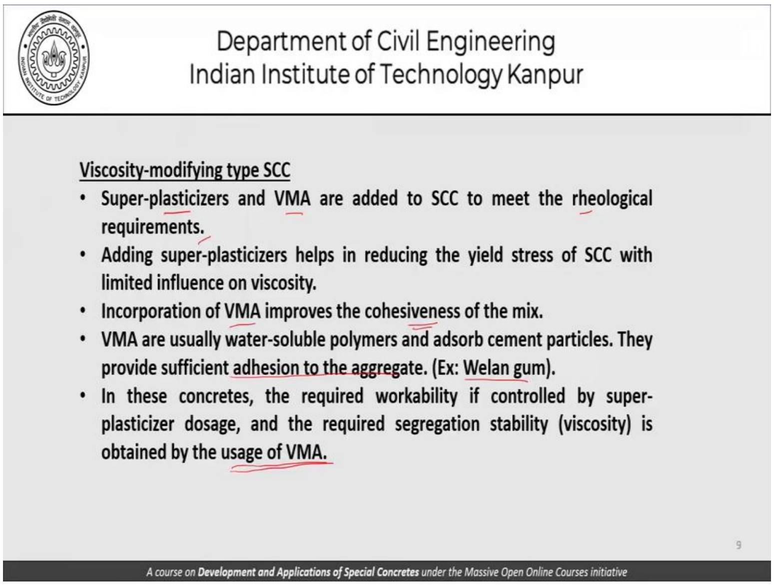

So, now coming to the second class of the self compacting concrete, that is a viscosity modifying type, SCC super plasticizers and viscosity modifiers are added to the mix to meet the rheological requirements. The rheological requirements, is in terms of the workability and so on and then, parameters that define the Rheology with which the engineers are not necessarily very conversant with at times.

Adding super plasticizers helps in reducing the yield stress of the self compacting concrete with limited influence of viscosity incorporating the VMA, improves the cohesiveness of the mix. VMA are usually water-soluble Polymers and adsorb cement particles and they provide adhesion to the aggregate. One of the examples of VMA is the Welan gum. In this concrete the required workability, if controlled by super plasticizer dosage and the required segregation stability that is viscosity is obtained by a particular dosage or an appropriate dosage of the viscosity modifying agents.

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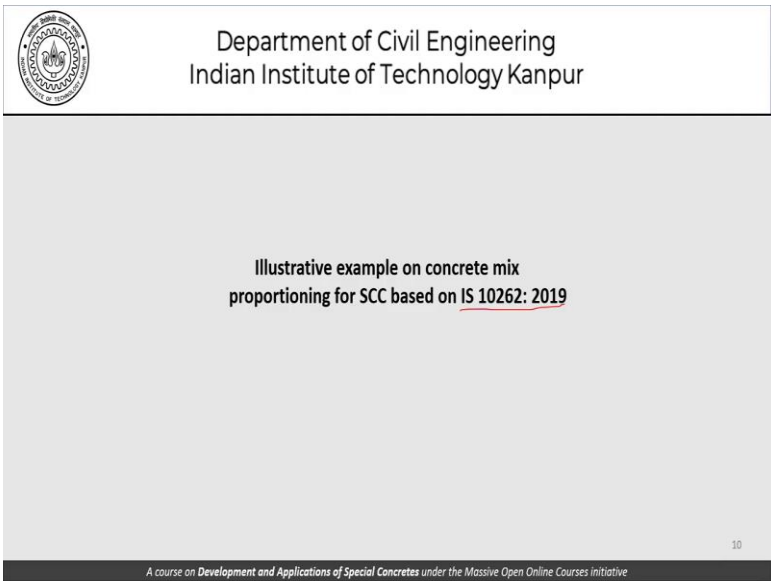

Now let us try to do illustrative example of a concrete mix proportion for a SCC based on IS 10262-2019.

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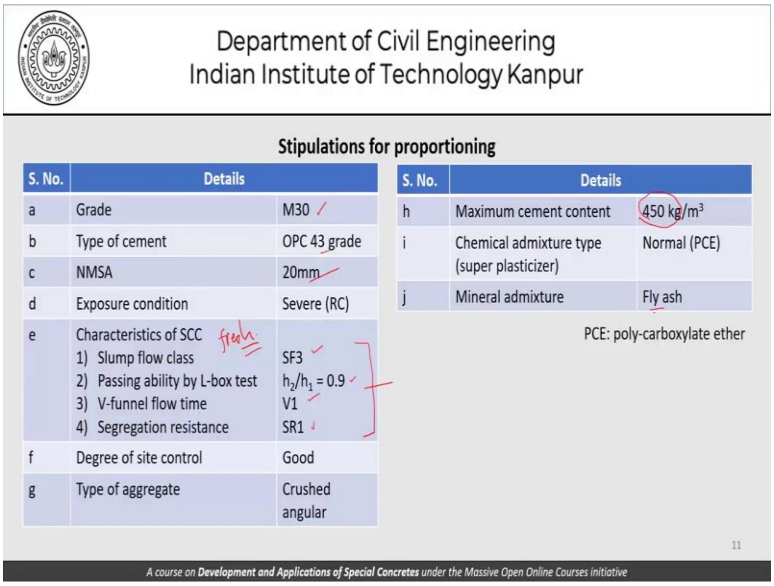

These are the conditions that are known to us. We want M30 grade concrete we know that we use OPC, 43 Grade Cement, the nominal maximum size of aggregate is 20mm, exposure conditions severe for concrete and the characteristics that we give is slump flow class is SF3. The passing ability using an L-box test is h_2/h_1 is known to be 0.9. V Funnel flow time is the class of E1 and segregation resistances is in the class of SR1.

As far as these terms or requirements are concerned we have covered this discussion when we talked about testing of self compacting concrete mixers and you can go back and see what are the kinds of values that we are looking for but what it also draws your attention to is that as far as the properties of self compacting concrete in the fresh state is concerned, it is not only the air content and so on.

Or workability is given just in terms of slump but there is a lot of test which are given to you that all these criteria need to be satisfied. The degree of Site control is good. The type of aggregate is Crushed and angular. The maximum cement content is required to be limited to 450 kgs per cubic metre. Normal super plasticizer of the poly-carboxylate ether is available to you and we are expected to use fly ash. This information is known to us as you start proportioning the self compacting concrete mix.

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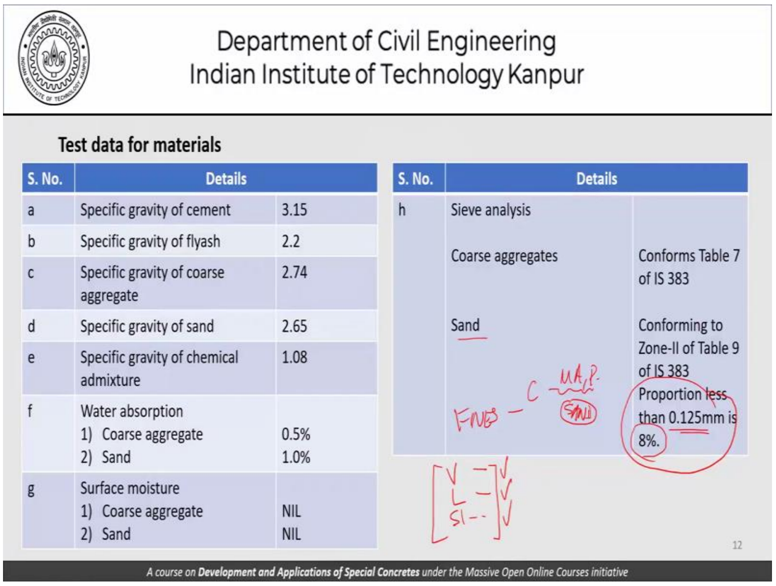

The details of material available are here. Specific gravity of cement fly ash, coarse aggregates and chemical admixture all these are known to you 3.15, 2.2, 2.74, 2.65 and so on. Water absorption for coarse aggregate and sand is known to you. We say that Ok there will be no surface water on coarse aggregate and Sand. Sieve analysis is known to you from coarse aggregate. It conforms to table 7 of IS 383 and sand conforms to zone 2 of table 9 of IS 383.

And also the information about the material finer than 0.125 mm is known to you from sand and that is given to be 8%. So, what I said in one of the slide just now was that as far as the fines are concerned, in Self compacting concrete come not only from cement and related things which is the mineral admixtures any kind of other powder that you may use, but also from the part of sand depending on how much is the fines present in the sand.

I would also like to remind you that when we give the properties of fresh concrete like you was given in the previous slide, in terms of the V funnel test or the L Box test, box test or the slump flow and so on. Then, all these tests have to be carried out in the fresh state and somebody has to determine and verify that all these criteria are met. If one of these criteria are not met then we have to go back to the drawing board make a modification in the mix.

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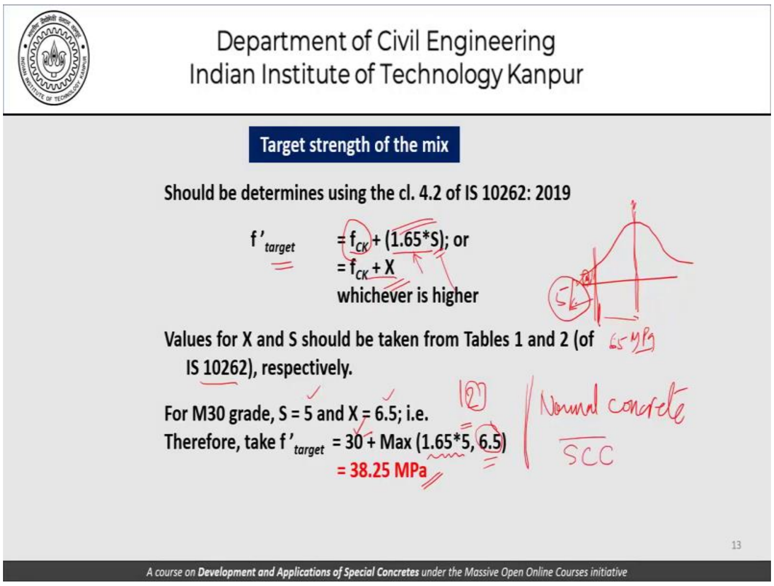

And try to evolve or try develop a mix were all these criteria are satisfied. So, the first step we know that as far as the strength is concerned, we try to get this target strength of the mix. Using the characteristic strength, you know in this case we work with M30 using this factor of 1.65s or factor, which is f_{ck} + X whichever is higher. So, in this case, from the tables which are already known to you, S is supposed to be 5 and X is supposed to be 6.5.

We take f_{target} that is the target mean strength of the concrete that we are trying to proportion as 30 + maximum of these two numbers which turns out to be 38.25. I am sure you remember this part of our exercise where we are trying to determine the mean strength of the concrete. And this mean strength will help us ensure that only 5% of the specimens fall below this number.

And as you can see here, this mean strength is from here because 5% Failure is allowed 1.65 is that factor that you will get and S is the standard deviation that we get from the site conditions. And apart from this, a certain fixed number is also given to you. So, obviously if you are able to reduce the standard deviation to lets say one or two. Then this number will become very small.

What the code is telling you is that in those cases, the proportioning cannot be too close to M 30 but it should be at least 6.5 MPa away from this characteristic value. So, you are allowed to or you are encouraged to bring your standard deviations in a certain range, but you should be targeting a mean strength at least 6.5 MPa above the characteristic strength, please go back to the drawing board at check these provisions for normal concrete. And see if they are very different from this provision in self compacting concrete.

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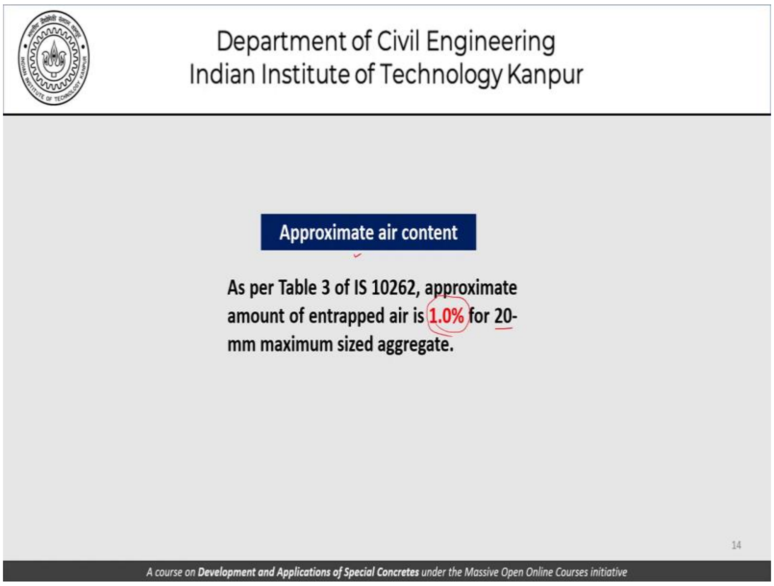

Then we go back to try to figure out the approximate air content that you want to assume and as per table 3 of 10262 to the approximate air and trapped in a 20 mm size aggregate is 1%. And so we know that 10 litres out of the 1000 litre should be gone as far as air is concerned.

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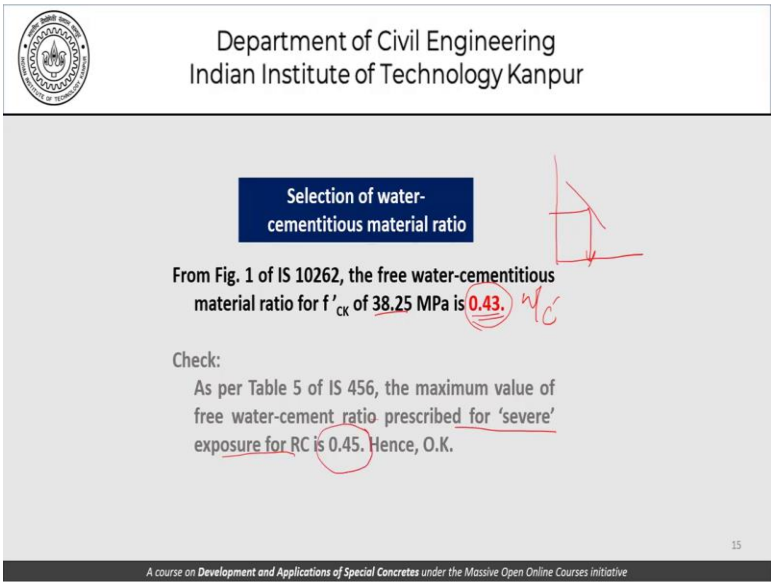

Then, the next step here is to find out the water cementitious material ratio. So see we are not trying to determine the water first. We are trying to determine the water cementitious material ratio. And if some data or some guideline is available to us for a given strength, how much is the water cement ratio the water cementitious material ratio that we need then it is a very straightforward exercise.

If you do that for 38.25 which was our target mean strength, we find that the water cementitious material ratio is 0.43 And we can always check this value with respect to any prescription that we may have a IS 456 or any other document for a given exposure conditions. For example in this case, we were told or we knew that the reinforced concrete that we are proportioning or the concrete we are proportioning is for a reinforced concrete structure in severe environment where the water cement ratio should not exceed 0.45 and since we are getting 0.43, it is Ok.

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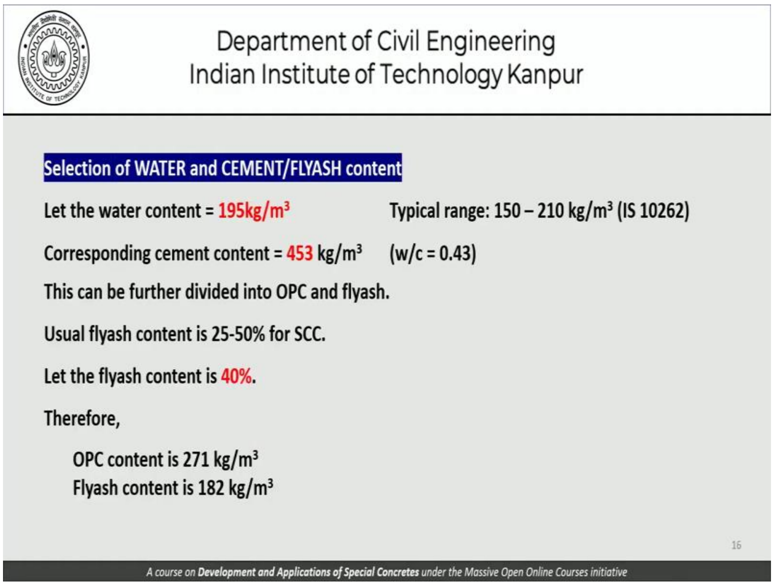

We assume the water to be 195 kgs in a cubic metre, typical range that is given for us as for as IS 10262 is concerned, 150 – 210. We begin with 195 based on past experience. Now, you will realise that a lot of mix proportioning exercise has past experience and given values. Now that is something which is typical of concrete mixers where a lot of discussion is largely empirical. So, we cannot just help it we have to start with something then modify very quickly and will converge that becomes part of our experience that becomes part of our past knowledge.

Now once we use 195 we get 453 as the corresponding not to cement content really, but the cementitious material content using this water Cementitious material of water binder ratio to be 0.43. Now this is what we would like to determine or bifurcate to ordinary Portland cement or fly ash. The usual fly ash content is about 25 to 50% for self compacting concrete. So in this case let us take fly ash to be 40%.

Now of this 40% means that 0.4 of this which is 182 kgs will go to fly ash and the remaining 60% that is 271 kgs will become OPC. Now once we are doing this, we are not using the concept of efficiency of fly ash. We are assuming that all of it will contribute to the Hydration process and strength for that something a matter of convention that something which we just keep at the back of our mind and we need to carry out experiments to determine what kind of strength values you get. So I am not getting into the discussion here once again, but just Flag for you to be careful.

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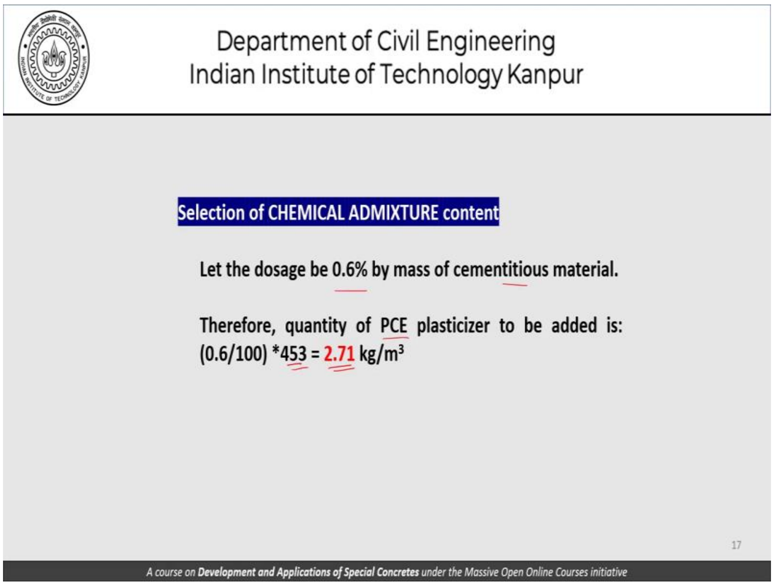

Now, coming to the selection of chemical admixture content, let the dosage be 0.6% by mass of cementitious materials that is something which has to be prescribed and told to us by the manufacturer and we need to verify at site using the material that we are actually going to use as far as the construction is concerned. Therefore the quantity of the PCE plasticizer will be 0.6% of 453 which is 271, 2.71 kg cubic metre.

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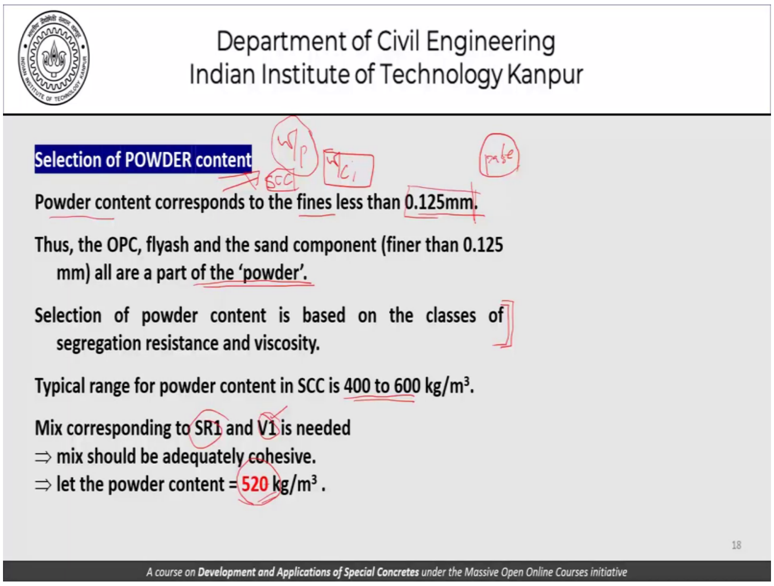

Once we have this value, we go to powder content. This is something which is a very unique step as far as the proportioning of self compacting concrete is concerned because water to powder ratio is an important player in the whole game other than simply the water cement ratio, the water cementitious material ratio that we always talked about from the strength perspective. Now the powder content here corresponds to all fines less than 0.125 mm.

This is a matter of convention and we say that so long as the Powder that is being used is less than 0.125. It will all contribute towards the paste content as far as that concrete is concerned. So now OPC, fly ash and the sand component finer than 0.125 will all be a part of powder. Now selection of powder content is based on the class of the segregation resistance and viscosity, which is required.

So, how much powder do we need in a particular self compacting concrete is determined by how much of segregation resistance or what is the V funnel time that we want from the concrete. And since in this case it is given to us to be SR1 and V1, the mix should be adequately cohesive, we take the Powder content to be 520 Kgs per cubic metre which is almost the middle of this typical range of 400 to 600 kgs a cubic metre.

So we fix the Powder content to be 520 or take powder content to be 520, we try to find out how do we achieve this 520 out of the 520.

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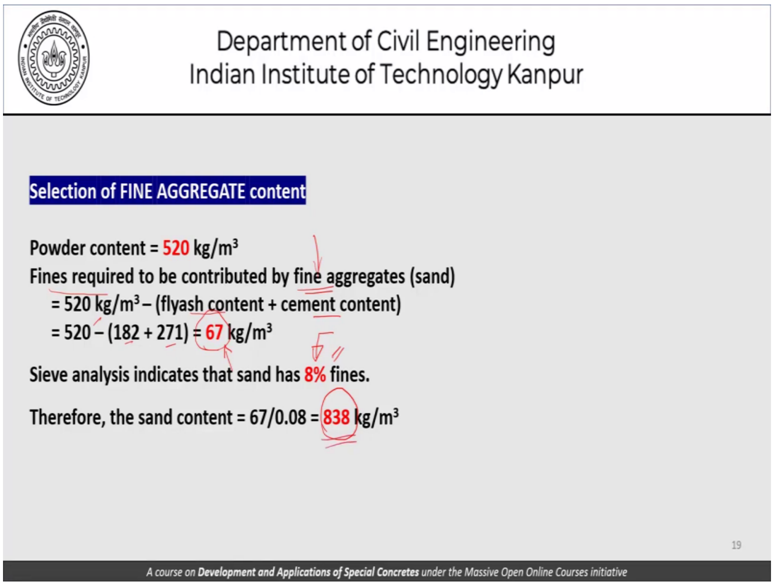

Out of the 520, we know that the fines that is required be contributed by the fine aggregate will be 520 - the fines that are already there. All the fly ash which is there is fine, all the cement which is there is fine, therefore, it is 182 + 271 which we have already done gives us 67 kgs of fines have to be contributed by fine aggregate that is sand. Now Sieve analysis, information that we have of the sieve analysis tells us that the sand has only 8% fine.

Now in order to get 67 kgs of Fines from a material which has 8% of fines, we need the sand content to be 838 kgs. Now just look at this number and try to compare it mentally with the kind of sand content that we normally encounter as far as concrete is concerned. You will realise that this value is much larger.

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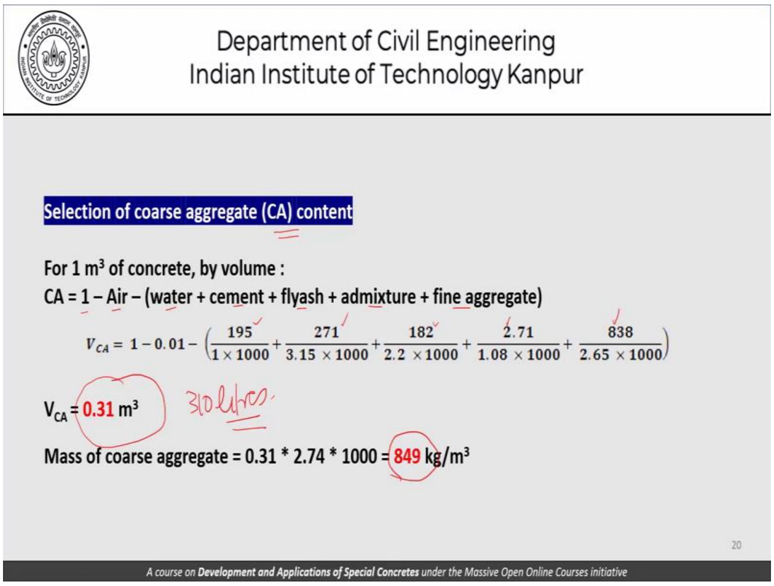

Having said that, the coarse aggregate content is now getting fixed? Because this is nothing but one Unity - air content - the content of water, cement, fly ash, admixture and fine aggregate. If we subtract all these from here, 195 that is water, 271 is cement, 182 is fly ash. 271 is my admixture and 838 is my fine aggregate that is sand. We find that the volume of coarse aggregate is 0.31 cubic metre that is 310 litres.

Now, this 310 litres translates to 849 kgs as far as the mass is concerned. So we are looking at a self compacting concrete with about 30% or 31% of coarse aggregate.

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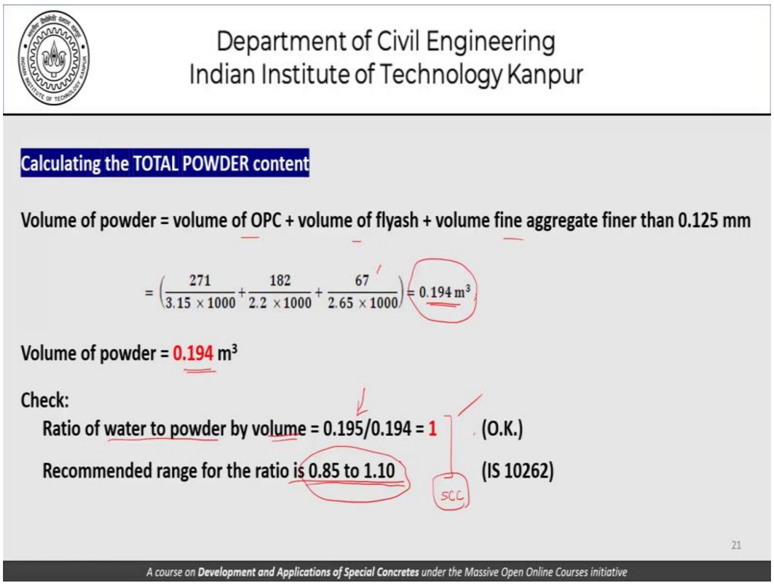

Now let us move to check the total powder content in the mix. The volume of OPC + volume of fly ash + volume of fine aggregate finer than 0.125 mm and that something is known to us. And we find that this number is nothing but 0.194 cubic metres. The 67 is contributed to this 194 and the volume of powder is 19% as far as the volumetric ratio is concerned. So, now, the ratio of water to powder by volume is 0.195/.194 .195 is 195kgs per cubic metre of water that we started with and 194 is what we got here.

And that is how we can calculate the water powder volume ratio, and it is acceptable to us, because the normal range for recommended as far as a water powder ratio is concerned is 0.85 to 1.1. Basically, we are targeting equal volumes of Water and the total fines. The mean value is 1 it could vary by water to 15% either way. And this is a very specific check once again as far as self compacting concrete is concerned.

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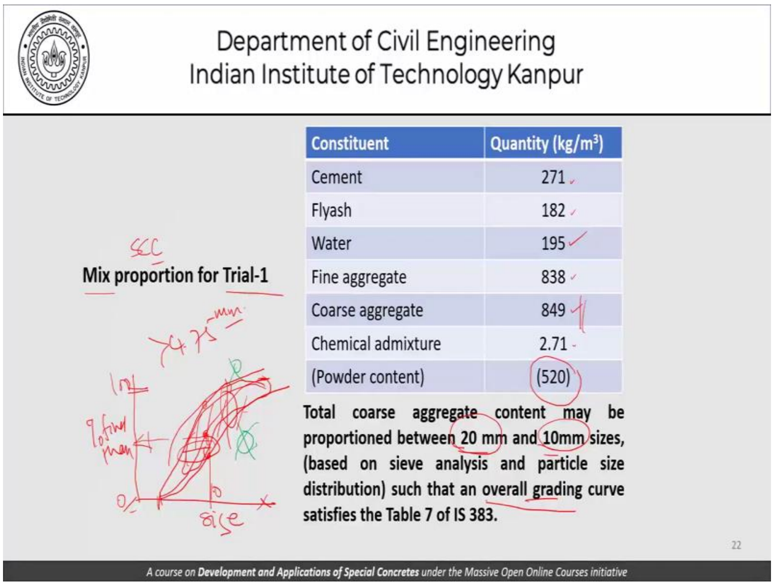

So now we will move onto determination of the coarse aggregate. in the next step. Having done this exercise, this is our final trial for the mixed proportion for this SCC, self compacting concrete. 195 kg of water 271 kg of cement and 182 of fly ash 838 of fine aggregate and 849 of coarse aggregate 2.71 kgs of chemical admixture. And the Powder content is 520.

So, the total aggregate content may be the proportion between 20 and 10mm aggregate because when we talk of coarse aggregates, we are talking of materials greater than 4.75 mm and in India most of the time we get coarse aggregate in two classes. One is the 10mm class and the other is the 20mm class. So how much of 10mm how much of 20 mm should be used to give me a value of this 849 that has to be determined again.

Based on Sieve analysis and particle size distribution that is there for these two aggregates that we get and make sure that the overall grading curve satisfies the table 7 of IS 383. So what these tables tell you really as far as the grading curve is concerned that if you have the size of aggregates here, and it is a percentage finer than somewhere here, how will it look like? Finally there will be a size here which will correspond to a value 100% is finer than this value.

Also, there will be a size here where we will find nothing is finer than this value. So whatever happens here, there is a particular for every size, we need to have a certain value for percentage finer than. These values are often given to us in a code by way of a distribution. It is known that after all when we are buying or when we are getting aggregates to site, it is not possible every time to come to a particular value for a particular finer than value.

Therefore, we are given a certain range here or a certain way if you want to look at it. That is ok so long as particle is finer than 10 mm is concerned, they should be at least 50% or 60% in the range of 40 to 60% or the range of 45 to 55%. So that is how we try to specify this you can try to go back and read the literature about it with the codes as to how this overall rating curve is given.

So, you cannot have an aggregate grading curve of yours which is outside. Which gives you values which are here or here that is not allowed. So, you need to proportion or mix your 10mm and 20mm aggregates to make sure your overall it fits into this range that has been given in IS 383 or any such similar document.

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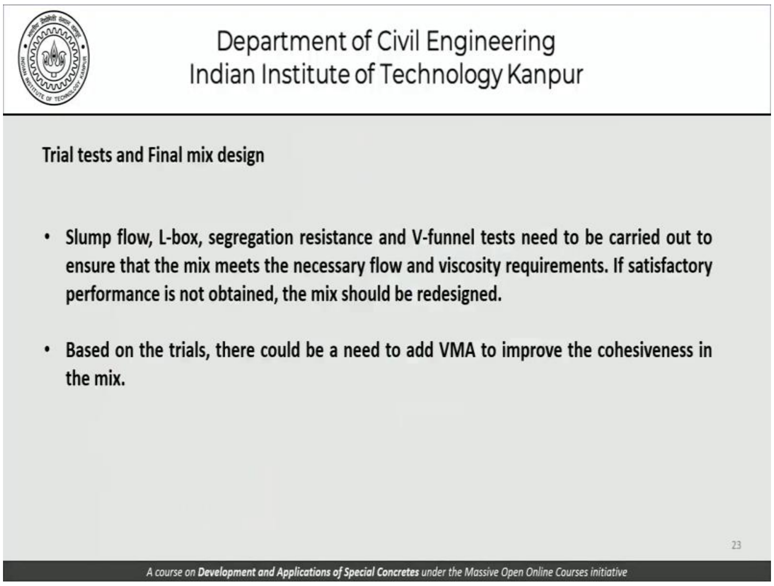

Of course, then we need to go to trial test, trial batches and final mix design based on the slump flow, L box segregation resistance V-funnel tests need to be carried out to ensure that the mix meets the necessary flow and viscosity requirements. If satisfactory performance is not obtained the mix, of course, should be redesigned and based on these trials that could be a need to add VMA to improve the cohesiveness of the mix.

What we have shown here is the Powder type approach to self compacting concrete, where we said that the minimum powder content should be such and such and we did not use VMA. If we need to use VMA, of course, VMA is an admixture which can be used and that will modify the properties of your paste phase. And therefore the mortar phase and therefore the concrete.

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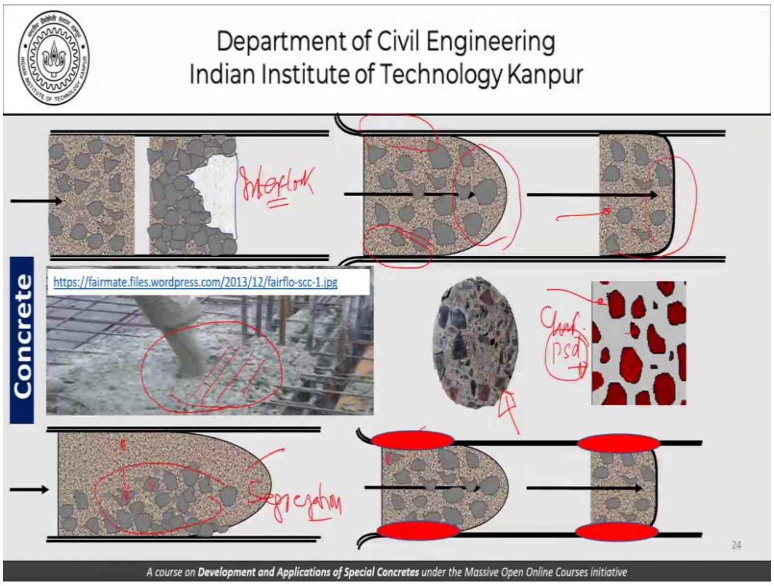

With that we come to a close more less of the proportioning part so I am sure you realise that if a lot of information is given to you, then proportioning is more or less an algebraic exercise which is reasonably straightforward, but what goes on behind that is something which we must also never lose sight of. So, these pictures are all known to you and have taken them from the previous slides that I that have already used.

This is Concrete being pushed through pipes and here we have what we had discussed as Aggregate interlock, we do not want this to happen. We want the concrete to move smoothly. Now whether this kind of a profile develops, on this kind of a profile develops depends on what happens if the interfaces that's what is shown here. This shows segregation of aggregate. That is the mortar component of this concrete could not support these coarse aggregates here, which are settled down.

And all this discussion here relates to a concrete which is something like this which has been modelled something like this here. So what we are talking about really is this coarse aggregate, its characteristics and its particle size distribution. Its individual characteristics in terms of Shape et cetera and Particle size distribution, how many of these particles are smaller, how many of much smaller and what is the maximum size of this aggregates and so on.

This understanding we need to have to, kind of understand try to keep at the back of our mind. That this whole thing really represents this concrete. In other words, this concrete is being represented through these kind of pictures. And when we are trying to proportion a mix, we are trying to determine the properties of the mortar phase that is shown here in different ways and the coarse aggregate phase which is shown here and make sure that the concrete does not segregate.

It has the right kind of viscosity for that. The mortar has to have the right kind of viscosity and finally, the paste has to have the right kind of viscosity and they should have the right kind of carrying capacity as far as the coarse aggregate is concerned. The mortar should have a certain type of characteristics and that is what we see in few slides.

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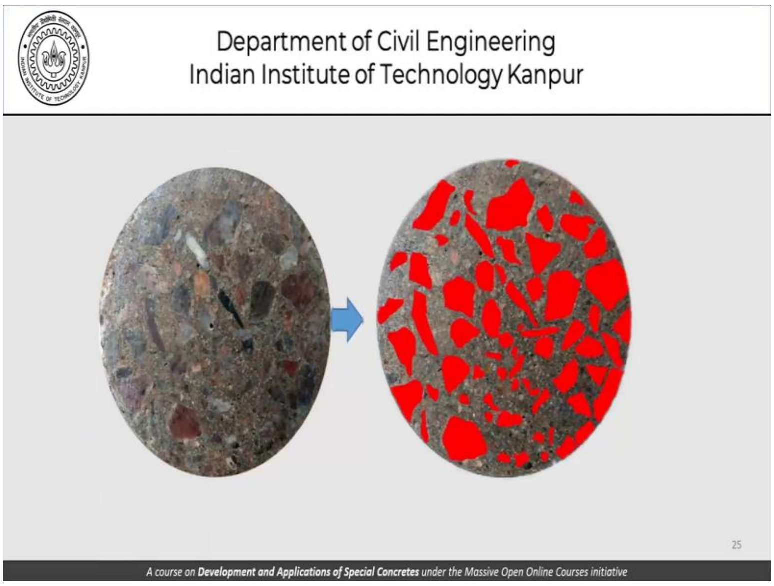

Before we close our discussion today, this picture, we have already seen this shows you how much of coarse aggregate we have in the system of course, all the coarse aggregates are not really marked in this. But that is more of a image that you must keep in mind.

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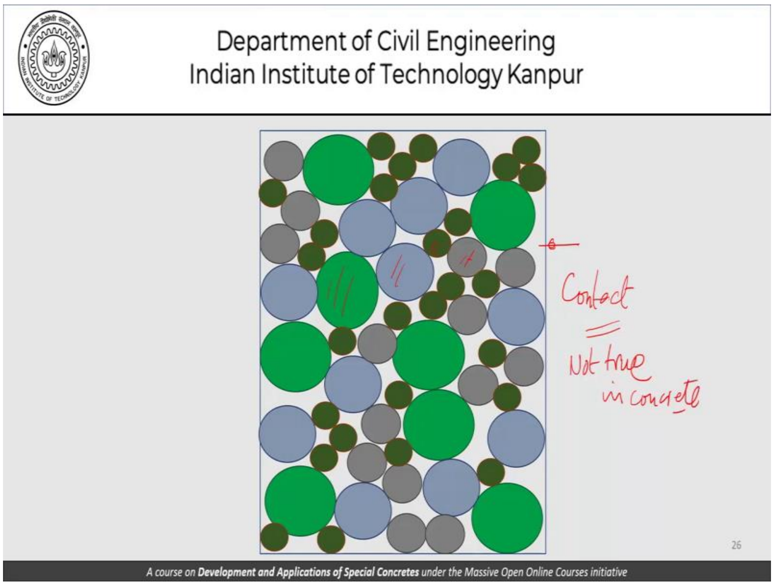

And this is what the particle size distribution of coarse aggregates let us say looks like. So we have some very large aggregates, we have smaller than that, smaller than that, may be smaller than that. This is something in between these two. And what we have here is this is my void volume. And the way I have shown it here, these aggregates are all in contact with each other.

This is something which is a reiteration from what are very early discussion in this course has been these aggregates are in contact with each other which is not really true in concrete. In concrete, the aggregates are not in contact with each other as we have seen in the previous discussion or the previous slide.

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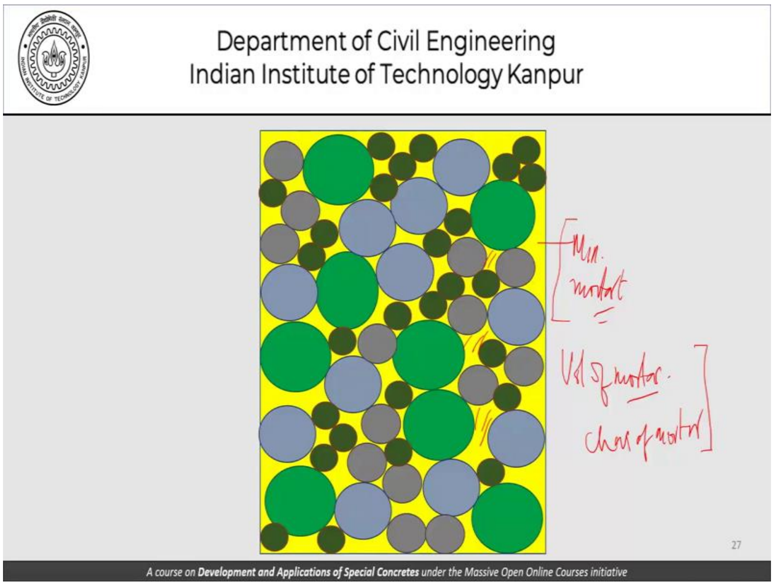

So, this yellow part, now this yellow part is the minimum amount of mortar, That is needed to make this mass into a concrete. Minimum amount of mortar means that amount of mortar which just fills the gap between the aggregates. So, the inter-particle voids, inter aggregate voids are now being filled with mortar. So this approach or these kinds of concepts are being repeated several times because they are very important as far as designing or understanding of self compacting concrete is concerned.

Because that is the volume of mortar that we have and then we have to have that characteristic of mortar, or the properties of that mortar. And the volume and properties they have to be judiciously chosen as a combination in order that our concrete mix the right kind of requirements or has kind of requirements which are acceptable to us.

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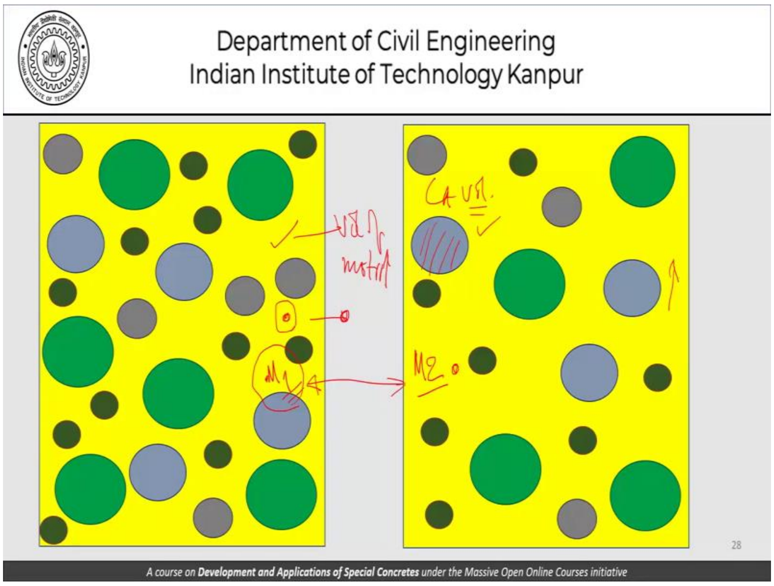

If we move forward. Here is a situation where I have removed the aggregates from the previous picture, to one level and other level. So, obviously the volume of mortar has gone up and has gone up even further in this case. What it means is that as far as the concrete is concerned, for example in this case, this mortar should have the capability of carrying with it all these aggregates which are shown here.

This mortar here should have the properties or ability to carry these many aggregates together with it, as it moves through pipes and is trying to be placed as a concrete. So don't you think that the properties of this mortar here, let us call it M1 and the properties of this one here let us call it M2, they need to be different. As far as the viscosity is concerned, which of them should have a higher viscosity mortar M1, needs to have higher carrying capacity because it is carrying a lot many more aggregates compared to mortar 2 which is carrying fewer aggregates.

This is basically the crux of our discussion what should be the properties. If we control the coarse aggregate volume and of course, the particle size distribution involved there from the packing perspective, then, we can also control or we can also get a pointer on what kind of material properties we expect as far as the mortar is concerned. That is what we get involved with when we are talking about the different ratios in terms of the water powder ratio or the total fines content or the total mortar content and so on.

Recall that, we have provisions relating to the maximum coarse aggregate content depending on the three different types of concrete that we want. Normal structures more congested structures and so on. So the maximum aggregate content does not exceed 35% if I remember correctly, please go back and check this number and that is what is being illustrated here. So I am not calculating the numbers or not calculated how much is a coarse aggregate content here, how much is the coarse aggregate content here.

You can always assume that they are spherical particles and can carry out this analysis and you will have those numbers.

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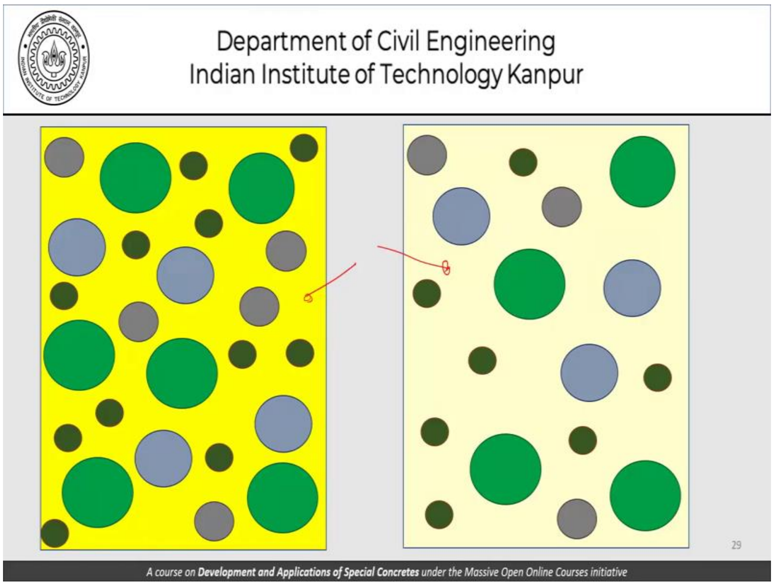

Now, this picture here is a representation of the previous one, where the properties of this mortar and this mortar have been shown to be different. That is why I tried to colour the mortar differently. So, if we have a lesser carrying load, we will have more mortar with the lesser demand on its carrying capacity. If we have a situation something like this, then we are looking at mortar which is lower in volume, but has to have a certain high demand on the carrying capacity.

More or less come to an end of the discussion today and I will reiterate that proposing itself is a reasonably straightforward exercise provided, we have all the information and the Arithmetic algorithm given to us. If it is not, then, it becomes a issue of science. It becomes an issue of carrying out some very simple experiments which are fundamental to the understanding of rheological behaviour of concrete and that is not something which we will do as part of concrete engineering. We will do it as part of a special topic discussion possibly sometime next week. And for this week, we close the discussion with only the self compacting concrete.

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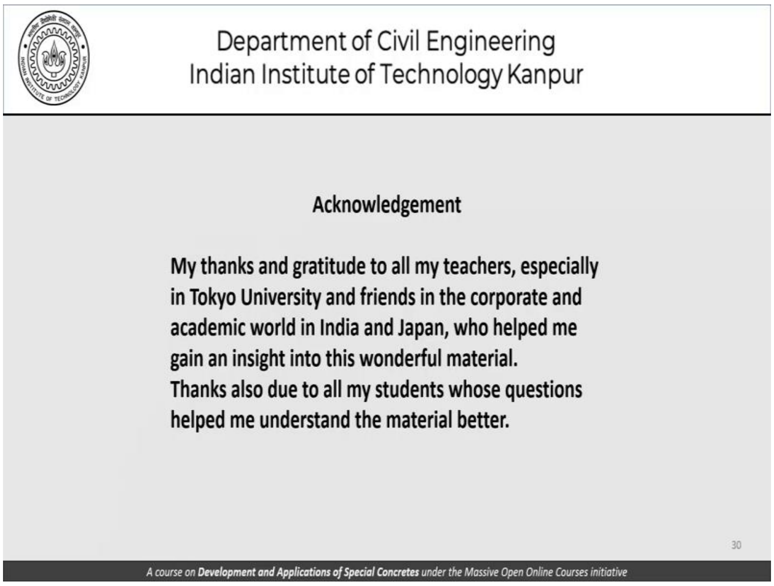

And I must as usual, Thank all my colleagues teachers and friends who have helped me understand the Simple concepts of special concrete.

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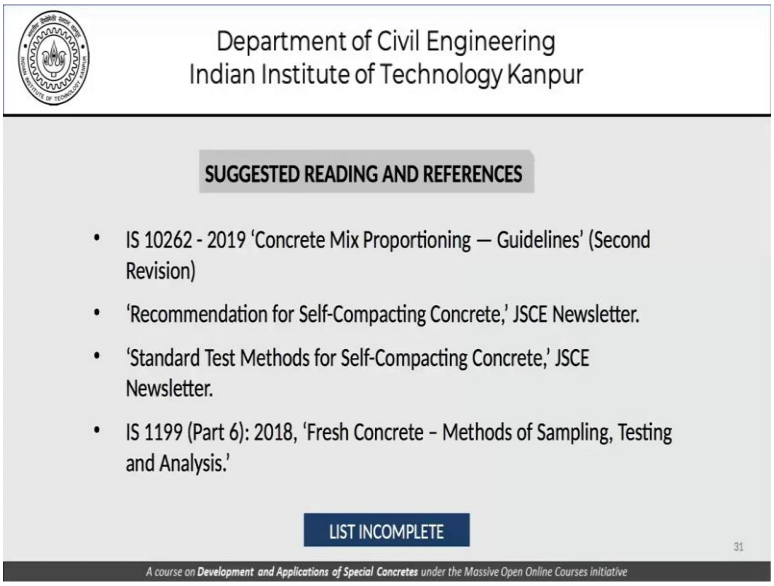

This slide gives the suggestive reading and reference which you might find useful in following the material that is represented today. However, this is list is my no means exhaustive and in fact for that reason, written as incomplete and you are requested and encouraged to look at the internet, look for more relevant material and try to understand the subject matter better.

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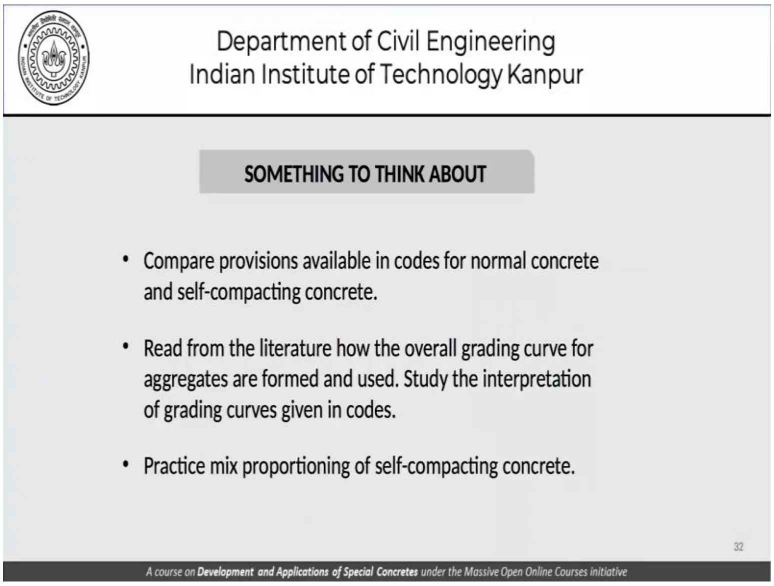

This slide gives you some ideas as to what you can do. Some of these things we have already mentioned in the discussion while we were talking with the different slides. But, these kinds of things will probably help you understand the concepts better. And with that I come to an end of the discussion today. Thank you so much for being with us.

And I look forward to talking to you once again next week, in the next module, when we will talk of some science related to self compacting concrete, the proportions, the properties and then we will take up a discussion on fibre reinforced concrete. Thank you.