Development and Applications of Special Concretes
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Lecture 19
Self Compacting Concrete II

Namaskar and welcome back; to another lecture in our series on development and applications of special concretes. Today we will continue our discussion on self-compacting concretes. So, today our discussion will focus on characteristics and testing of fresh self-compacting concrete.

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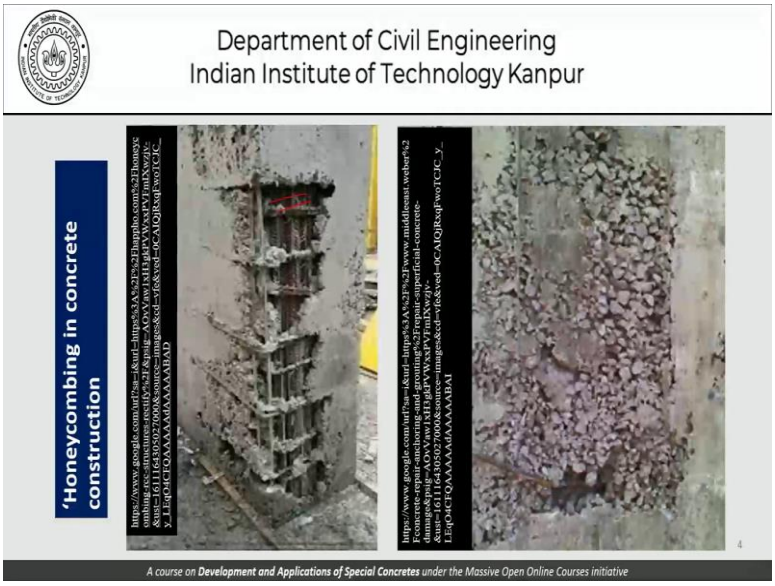

We have seen this picture before and we know that this honeycombing is a result of the inability of the concrete to flow around the reinforcement and that is the whole backdrop in which we are talking about self-compacting concrete. This is a similar picture for honeycombing and we have seen this before.

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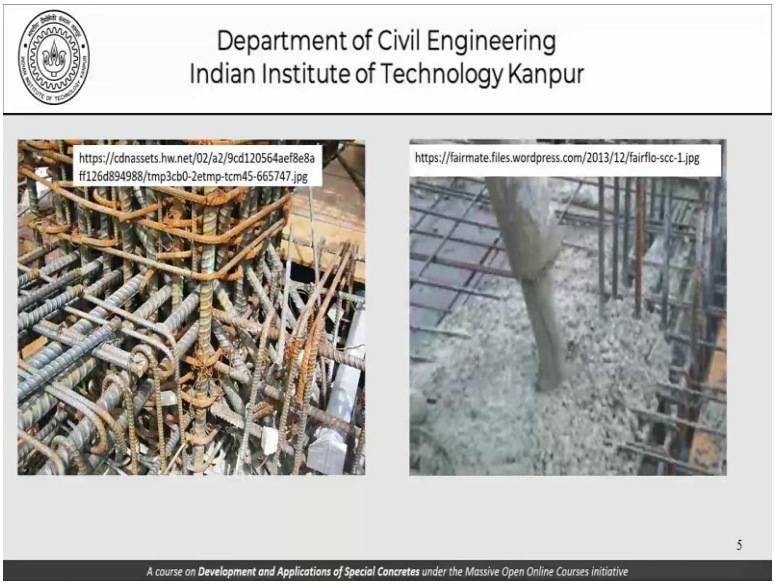

Now moving forward this is a real picture of a RC member and we can see that there is a huge amount of congested reinforcement. And concrete is expected to flow around this reinforcement and that is what has given rise to the need for the self-compacting concrete. That is impossible virtually to have a needle vibrator trying to get into the reinforcement that is shown here and try to compact the concrete.

So what we have tried to do is to get a situation something like this that of course here the reinforcement is not as congested but the concrete is simply poured into the formwork and it finds its way through the reinforcement to the different nooks and corners of the form work to give you the kind of RC member or the reinforced concrete member that the designer has thought of.

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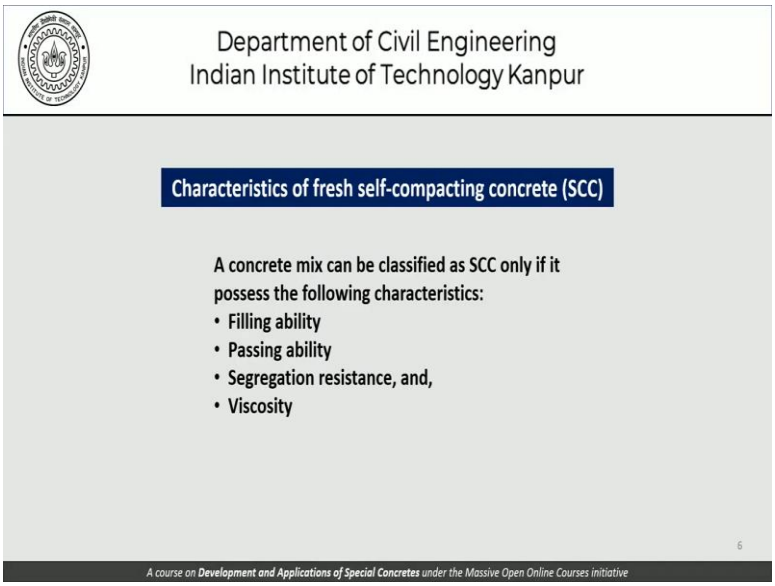

Now as far as the characteristics of the fresh self-compacting concrete are concerned a concrete mix can be classified as self-compacting only if it possesses the following characteristics. So these are some words filling ability, passing ability, segregation resistance and viscosity. So the self-compactability of a concrete is really a combination of all these characteristics and there are different tests that have been developed over a period of time through rigorous research in different parts of the world which have helped us determine or finalize these tests.

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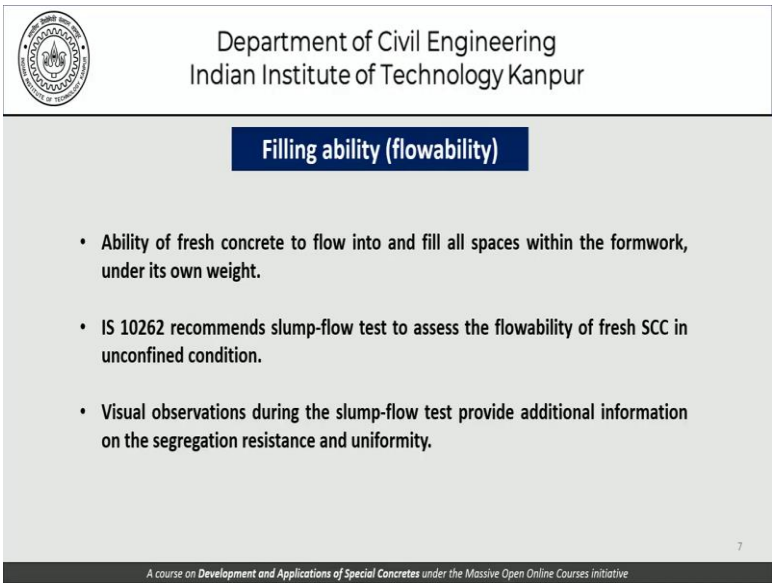

Now coming to the; first one which is the filling ability which is flow ability, the ability of fresh concrete to flow into and fill all spaces within the form work under its own weight this is what is the definition or this is what we can define fill ability or flow ability as. IS 10262 recommends the slump flow test to assess the flowability of fresh self-compacting concrete in unconfined condition.

So remember that the slump flow test we will just see it in a minute is carried out as the concrete deforms or flows without any hindrance without any encumbrance. So, visual observations during the slump flow test provide additional information on the segregation resistance and uniformity of the concrete.

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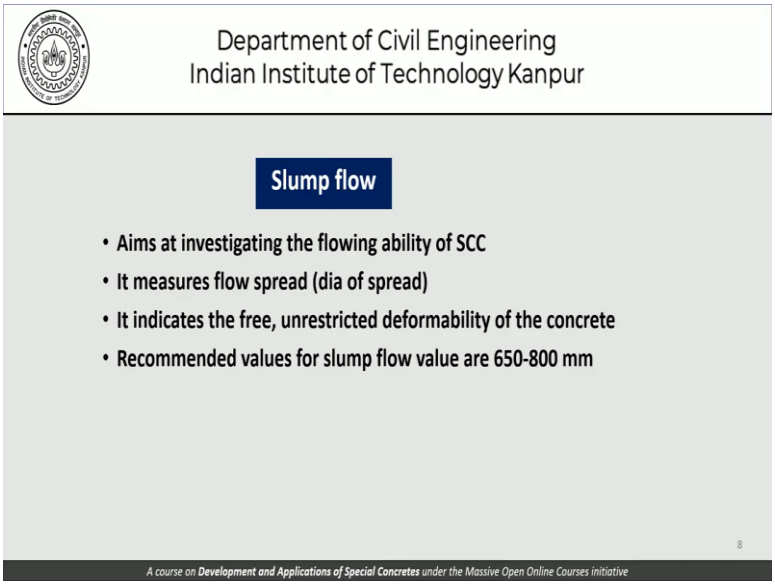

So as far as the slump flow is concerned that aims to investigate the flowing ability of the self-compacting concrete it measures the spread which is in terms of the diameter of the spread. Remember that the bottom of the slump cone is 200 mm that is the bottom diameter of the slump cone. So how much it spreads from there is really the slump flow that we are talking about as we should see also.

It indicates the free unrestricted deformability of the concrete and the recommended values for slump flow could be between 650 and 800 mm depends on the kind of congestion of the reinforcement and so on which we are talking about. So the pictures that we saw just now could be kept in mind as an image if that is the level of congestion then we need at least a slump flow of 700 mm as slump flow of 500 mm will not do and that is something which the engineer has to judge.

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This picture here shows the spread that has been achieved after the slump cone has been removed and this diameter is what we are talking about as the slum flow. As we shall see just now the procedures call for measurement of two diameters and try to take the average provided it is not highly skewed and so on and so forth. A corollary to the slump flow is the flow time called the T 500 test.

Now the T 500 test measures the time of flow to reach a certain level of course this 500 here is the 500 here. So it is a T 500 means the time that it takes for this spread to reach 500 mm. Remember that we start with initial diameter of 200 mm that was the diameter of the slump cone just before it is removed. So after that this concrete has slumped and goes to this spread. Recommended values for T 500 could be 2 to 5 seconds.

Now remember that we had some discussion about this when we were talking about underwater concrete also. Now in underwater concrete and I had told you to go back and try to look for these values you will realize if you have done your literature search that if the concrete is extremely viscous and that is why we have all these different terms fillability flow ability segregation resistance viscosity coming in.

And the self compacting concrete should have all those characteristics roll into one if the viscosity of the concrete is high. Then no matter what happens to the spread it is also important what time it takes to reach that spread. In the case of underwater concrete surely the spread will not reach 500 mm in 2 to 5 seconds it could be lot more because the concrete is a lot more viscous.

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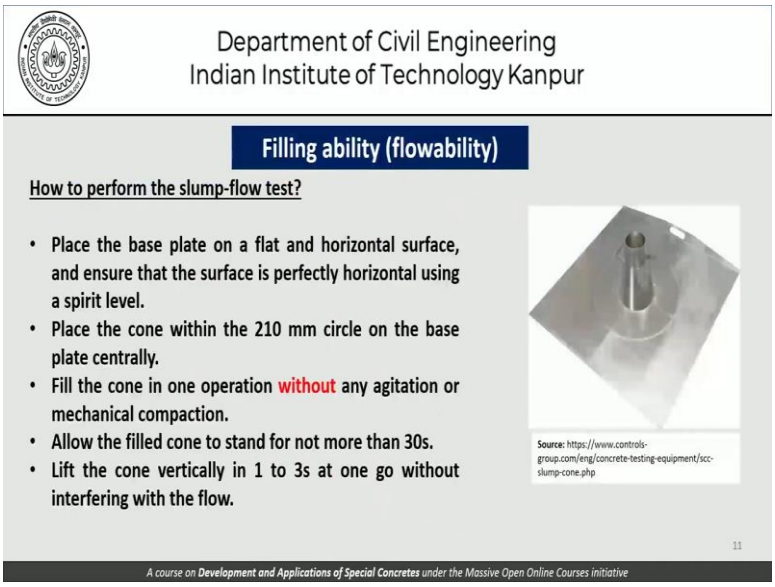

As far as the procedure to perform the slump flow test is concerned place the base plate on a flat and horizontal surface and ensure that the surface is perfectly horizontal using a spirit level. Place the cone within 210 millimeter circle range of the base plate centrally. So we have a circle which is already marked here and that a circle measures 210 because the slump cone itself is 200. Fill the cone in one operation without any agitation or mechanical compaction.

Remember that when this normal slump test is carried out it is supposed to be filled. The slump cone is supposed to be filled in a certain number of layers 1, 2, 3 or 1, 2, 3, 4 and each layer has to be tamped using a standard tamping rod for a certain number of times some 25 times or 35 times. And I am leaving it to you to study this procedure for normal concrete once again and try to see how it is different.

And of course that why it is different is very clear because as far as self compacting concrete is concerned. We are surely not going to be able to use any mechanical compaction and therefore it makes no sense try to fill this slump cone in layers. So here we are talking about filling the cone in one operation without any agitation or mechanical compaction allow the filled cone to stand for not more than 30 seconds.

Lift the cones vertically in one to three seconds at one go without interfering with the flow. Remember that as soon as we lift the slump cone from the bottom of the plate the concrete

will begin to flow out. And that is why this is stated here that do not interfere with the flow remove the slump cone by lifting it vertically within one to three seconds in a single go.

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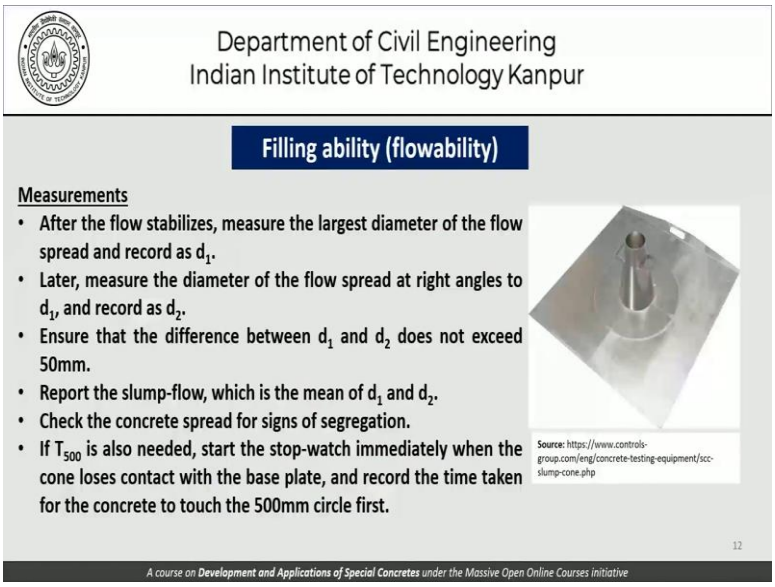

As far as the measurements are concerned after the flow stabilizes measure the largest diameters of the flow spread and record it as d_1 later measure the diameter of the flow spread at right angles to d_1 and record it as d_2. Ensure that the difference between d_1 and d_2 does not exceed 50 mm. And report the slump flow which is the mean of d_1 and d_2 which means it is $(d_1 + d_2)/2$. Check the concrete spread for the signs of segregation.

Now obviously what is going to happen is that if we are talking of a spread like this we should make sure that the concrete in the pockets which is very close to the periphery of the spread versus the concrete which is here in the central part which is the core this should not appear to be visibly different. Of course there are ways in means in which you want to extend this and try to take a sample from here and try to determine the course aggregate content and the course aggregate gradation.

Compare it with what you have got here you can try to do that as an extension but that is not part of the slump flow test. All that it asks you to check is check the concrete spread for signs of segregation. If T500 is also needed start the stopwatch immediately when the; cone loses contact with the base plate and record the time for the concrete to touch the 500 mm circle first. So basically on the base plate we have different circles which need to be marked out.

This is my 200 that is where I start the 400 circle the 500 circle the 600 circle and so on. So if we are looking at T500 just as the concrete touches this 500 line that is the time that it has taken to reach T500 that please remember does not mean that the flow has stopped deforming. In cases where there is a flow greater than 500 mm the T500 will still be the time it takes to get to 500 mm you will report that time separately as the time that it has taken to reach T500 that is the time it has taken to reach a diameter of 500 mm.

And you will report the spread separately as 600 mm or 620 mm or whatever it is. So that is how we try to do the measurements for the slump flow test.

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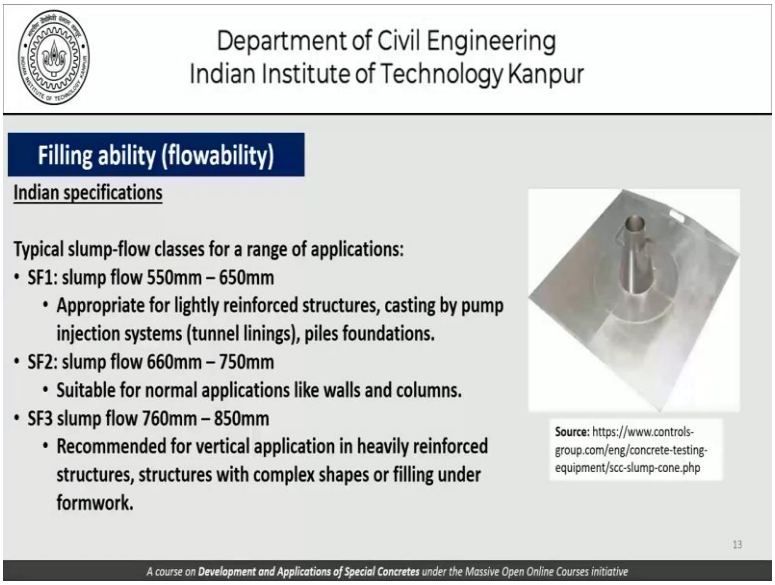

As far as Indian specifications on the slump flow test are concerned the typical ranges are given as follows. The slump flow between 550 to 650 mm this is appropriate for lightly reinforced structures casting by pump injection systems like tunnel linings pile foundations. And so on a slump flow between 660 and 750 mm is good for normal applications like walls and columns and a slump flow which is higher than that, that is you are looking at 760 to 850 kind of millimeters that is recommended for vertical applications in heavily reinforced structures.

Structures with complex shapes or filling under formwork. Now; this is something which we will try to discuss a little bit when we take up a case study in using self compacting concrete for actual construction.

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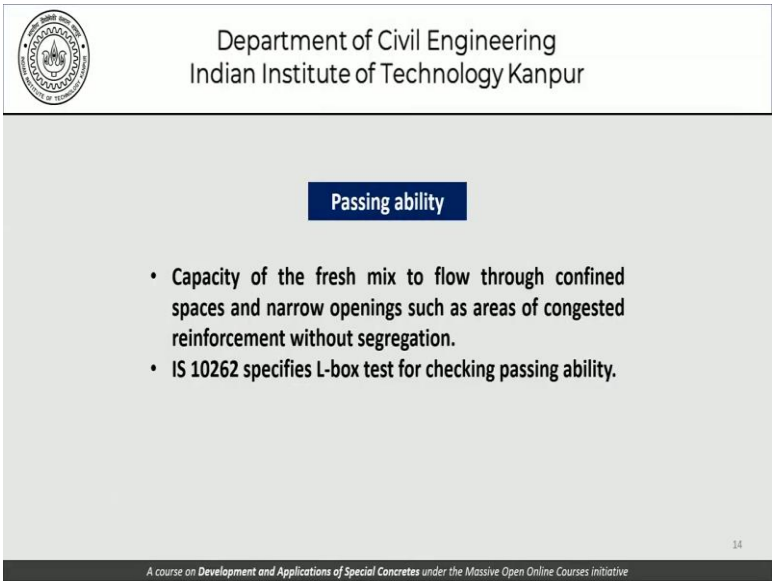

Now remember that the slump flow test is unrestricted flow of concrete that measures unrestricted flow of concrete without any obstructions. Compared to that the passing ability test is the capacity of the fresh concrete to flow through confined spaces and narrow openings such as the areas of congested reinforcement without segregation. Go back and try to look at the picture of congested reinforcement and that should always be at the back of your mind.

So that is what we really want to do. So, now in order to measure or in order to determine the ability of the concrete to flow through that reinforcement the IS10262 for example specifies the use of the L box test to check the passing ability of the concrete. Now what is this L box test?

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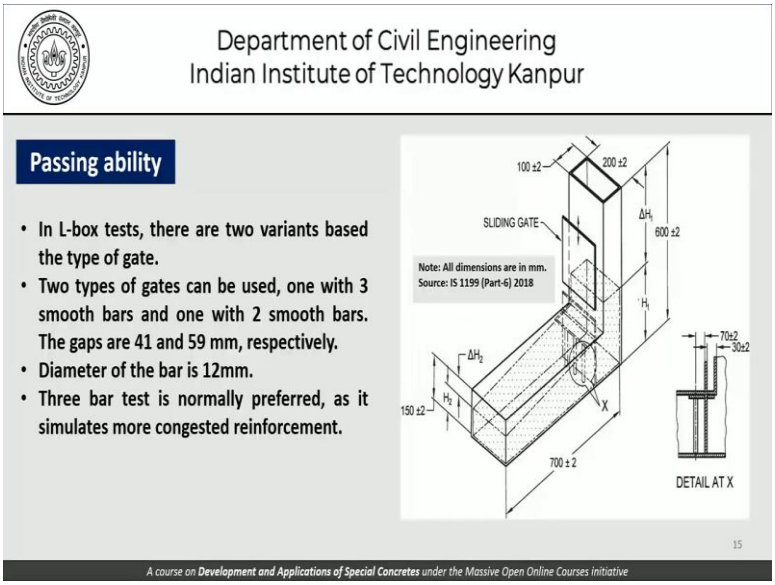

This is what the L box test means in the L box test there are two variants based on the type of gate now this is the gate that we are talking about between the vertical leg and the horizontal leg. So basically the L box comprises of two legs the horizontal leg here and the vertical leg here. So the two types of gates can be used here one with three smooth bars and one with two smooth bars the gaps are 41 mm and 59 mm respectively the diameter of the bar is 12 mm and the three bar test is normally preferred as it simulates more congested reinforcement.

So that is a detail of the gate that we use here. So basically the idea is that we fill this concrete here we close the gate or keep the gate closed fill the concrete here lift the gate and have the concrete flow into this horizontal portion. And as the concrete flows this gate here restricts the flow of concrete because we have either two bars or three bars. That is what we are talking about two bars or three bars through which the concrete has to flow.

So the spacing in the case of two bars is obviously more it is 59 mm and in the case of three bars it is less it is 41mm.

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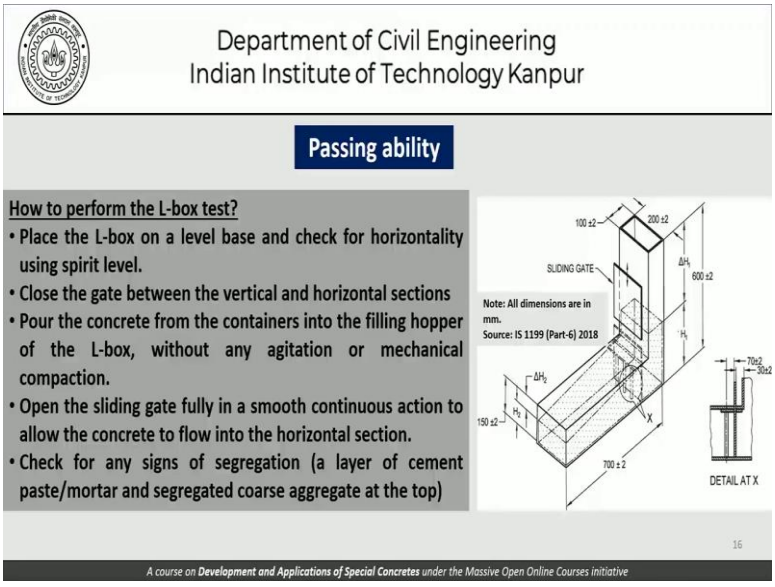

If you look at more details of this test let us try to see how the test is performed place the l box on a level base and check for horizontality using a spirit level. Close the gate between the vertical and the horizontal sections. Pour the concrete from the containers into the filling hopper of the L box without any agitation or mechanical compaction open the sliding gate smoothly and the gate should be opened fully in a smooth continuous action to allow the concrete to flow into the horizontal section.

Check for any signs of segregation a layer of cement paste or mortar and segregated coarse aggregated the top. So once the concrete flows into this part this is the observation that we make and we need to measure this H_2, ΔH_2 and there is an H_1 and ΔH_1 which is involved. What we have to remember is what is the size of this L box? We can see here that the vertical leg is 600 mm and the horizontal leg the wat it is shown here is 700 mm.

So as the concrete moves in here this delta H_2 is something which we have to be careful about. The total height of this horizontal leg is 150mm. And the size of this hopper or this vertical leg is 100 mm by 200 mm. So this 100 and 200mm kind of opening here that is what gets filled up with concrete completely and then we lift this gate allow the concrete to flow through this gate which has simulated reinforcement.

So as the concrete flows through after it has stabilized we try to measure what is delta H_2 and what is the height of concrete in the vertical leg. So what will happen if the concrete was a perfect fluid is something which I am leaving to you to imagine.

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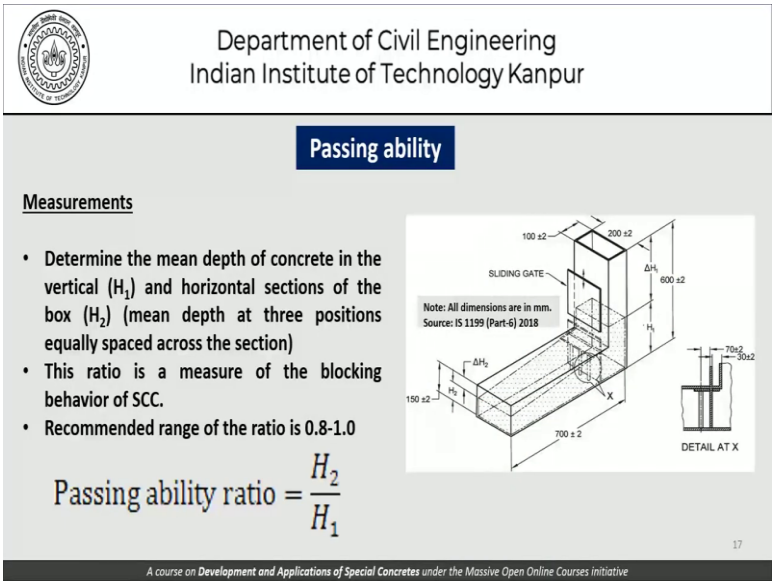

As far as the measurements are concerned determine the mean depth of the concrete in the vertical H_1 and horizontal sections H_2 the mean depth at three positions equally spaced across the section. That means across this section here we measure H_2 at three places because obviously this diagram here shows that the H_2 is the same value but it will not happen. So there may be a difference between these values here concrete may not flow as is shown so we measure three values here. Similarly we measure three values at different places as far as H_1 is concerned and we report this ratio. The passibility ratio is defined as H_2/H_1.

So this is the recommended range the recommended range for this ratio is 0.8 to 1 and the ratio is a measure of the blocking behaviour of the self-compacting concrete. So if the H_2 and H_1 is the same then we are pretty much in the self compacting range that is the concrete has more or less become horizontal. This is if it becomes horizontal then H_1 here and H_2 here will be almost the same. But if it is not horizontal which one is likely to be higher H_1 is likely to be higher H_2 is smaller.

So the concrete will take this kind of a shape. Now if it takes this shape then H_1 and H_2 so H_2/H_1 gives us the passibility ratio. So that is how we interpret the results from the L box test.

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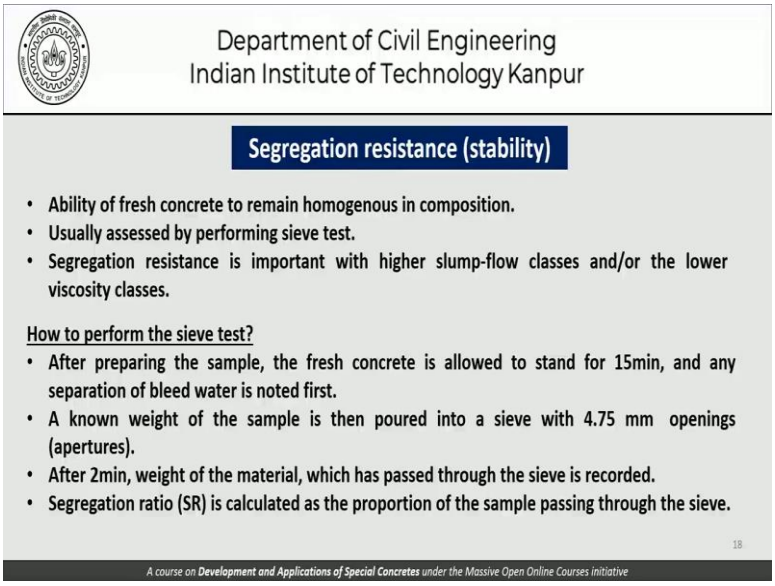

Moving forward let us try to talk about segregation resistance which is also a measure of the stability of the mix that can be defined as the ability of fresh concrete to remain homogeneous in composition and is usually assessed by performing sieve test. Segregation resistance is important in cases when concrete has a higher slump or lower viscosity and lower viscosity as well. So it is an and or here high slump flow lower viscosity. So higher slum flow shows high flow ability and lower viscosity means low segregation resistance.

So now this lower viscosity and higher slump flows are both reasons to have lower segregation resistance and that is what we are trying to measure through the sieve test. Now what is the sieve test and how it is performed after preparing the sample? The fresh concrete is allowed to stand for 15 minutes and any separation of bleeding water is noted first. A

known weight of the sample is then poured into a sieve of 4.75 millimeter openings which is apertures.

After two minutes the weight of the material which has passed through the sieve is recorded. The segregation ratio is calculated as the proportion of the sample passing through the sieve. So this is what is a measure of the segregation resistance of the; concrete? So, you can imagine that this 4.75 really is the limit for the fine aggregate. So material finer than 4.75 qualifies as fine aggregate or sand.

So if we are allowing this material to stand on that sieve, with that kind of a sieve size. So if we have this sieve here if concrete is allowed to stand here then if it is not segregation resistant then at least some bit of it would fall through. Now how much of it falls through is really the issue and that is how we calculate the segregation ratio and the time which is to be used for this test is two minutes.

So we try to see after two minutes what is the kind of material that has passed through the sieve?

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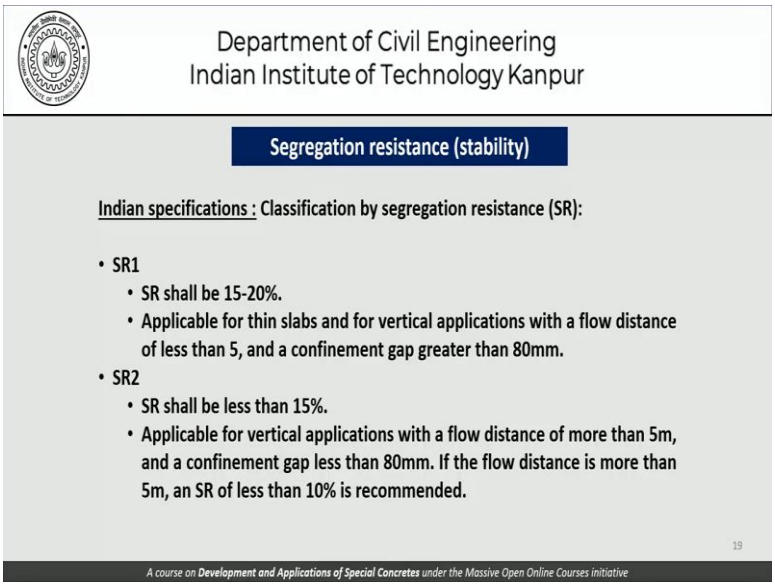

Continuing; with our discussion on segregation resistance. And the Indian specifications regarding it SR1 that is the first level of segregation resistance SR. The SR shall be between 15 to 20% applicable for thin slabs and for vertical applications with the flow distance of less than 5 meters and a confinement gap greater than 80 mm. SR2 which is the segregation resistance class 2 there we say that it should be less than 15% and is applicable for vertical

applications with a flow distance of more than 5 meters and a confinement gap of less than 80 mm.

If the flow distance is more than 5 meters a segregation resistance of less than 10% is recommended. So basically this is a test which is very easy to perform and I would recommend that you should try to do it those of you who have access to the laboratory please try to do a segregation resistance test for all the kinds of concrete that you use. And try to get for yourself know for yourself the kind of data or the kind of amount of concrete in terms of what flows through the 4.75 mm sieve.

So as far as the Indian specifications are concerned 10% 15% and 15 to 20% are the kinds of values that we are talking about as far as the different classes of segregation resistance are concerned.

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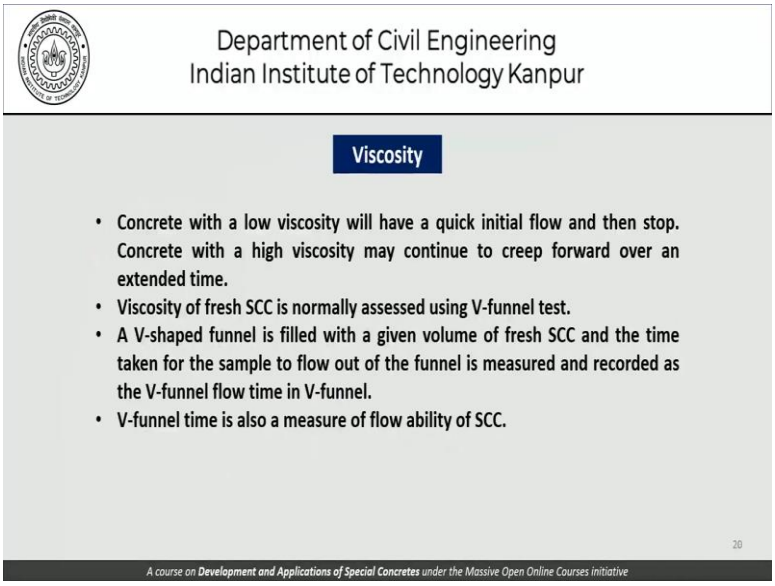

Now coming to viscosity concrete with a low viscosity will have a quick initial flow and then stop. Concrete with a high viscosity may continue to creep forward over an extended time that is what I said in one of the earlier slides when we are trying to discuss the slump flow. That if the concrete is viscous it will deform and then continue to deform slowly as time passes and it may continue for an extended period of time.

So viscosity of the self compacting concrete is normally assessed during a V funnel test. Now what is a V funnel test is what we will try to see just now. A V funneled or a V shaped funnel is filled with a given volume of fresh self compacting concrete and the time taken for the

sample to flow out of the funnel is measured and recorded as the V funnel flow time in the V funnel. The V funnel time is also a measure of the flow ability of the self compacting concrete. So the V funnel again is a measure of flowability as well as viscosity.

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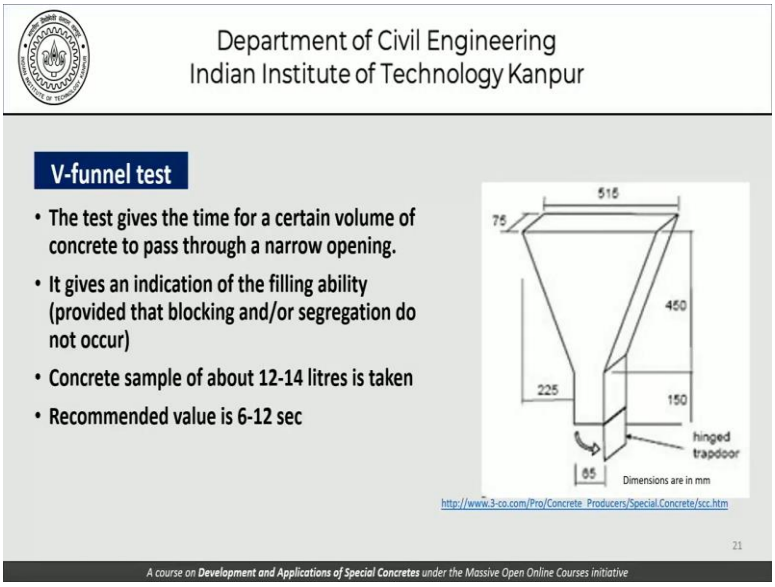

Here is the V funnel that we use 75 mm wide 515 mm at the top narrowing down to 65 at the bottom and then it has the straight vertical portion of 150. So at this point there is a bottleneck which has been specifically created at a depth of 450 mm. So the test gives the time for a certain volume of concrete to pass through a narrow opening it gives an indication of the filling ability provided the blocking and or segregation do not occur and concrete sample in this case is about 12 to 14 litres. And the recommended values are in the range of 6 to 12 seconds.

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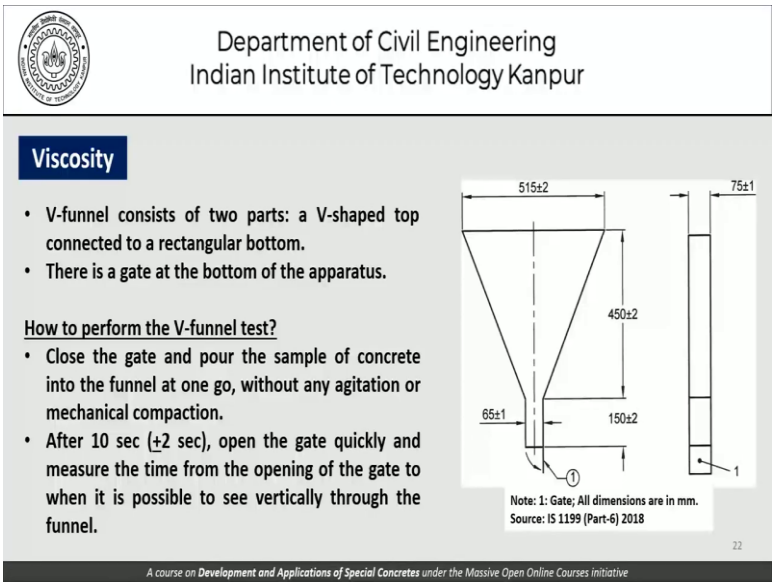

The v funnel consists of two parts a V shaped top connected to a rectangular bottom that is what we discussed just now 5 and 15 going down to 65 over 450 and then a rectangular part with 65 into 150 there is a gate at the bottom of the apparatus that this is the gate that we are talking about and as far as the performance of the test is concerned. We need to close the gate and pour the samples of concrete into the funnel at one go without agitation and mechanical compaction after 10 seconds plus minus 2 seconds.

Open the gate quickly and measure the time from the opening of the gate to when it is possible to see vertically through the funnel that means you should be trying to observe from the top and after the concrete has flown out what will happen is that this is how the opening is at the bottom. Now this opening initially because concrete is passing through this you will not be able to see through this. But after most of the concrete has gone through it may still continue to trickle because there will be some concrete sticking to the sides.

If you are able to see through the hole somewhere here and you can see light at the end of the V funnel that is the time that you need to record. So we have to start the stopwatch as soon as you open the gate keep an eye on what is happening from the top. And as soon as you are able to see through the bottom here that is the time you need to stop and report it as the V funnel test time. And this test is described in IS 1199 part 6 2018.

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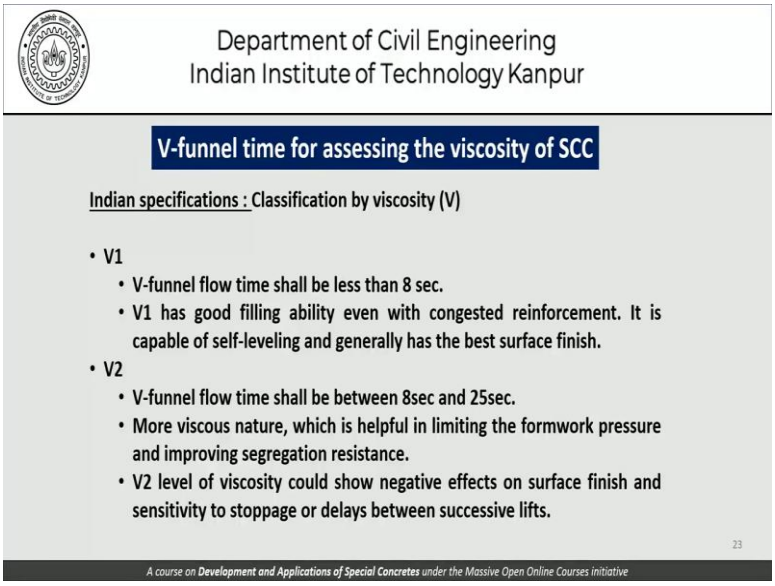

A little more discussion on the V funnel time for assessing the viscosity of the self-compacting concrete as far as Indian specifications are concerned the classification by way of viscosity is in terms of V1 and V2 where V1 means the v funnel flow time shall be less than 8

seconds or if it is less than 8 seconds it is classified as V funnel flow time is class V1. V1 has a good, filling ability even when the congested reinforcement is there it is capable of self levelling and generally has the best surface finish.

V2 is a V funnel flow time that elapses between 8 seconds and 25 seconds more viscous nature which is helpful in limiting the form work pressure and improving segregation resistance. V2 is the level of viscosity that could show negative effects on surface finish and sensitivity to stoppage or delays between successive lifts. So a new concept being invoked here is that of formwork pressure.

So remember that we are casting the concrete against formwork so this is my formwork. And if the concrete has a low flow time it will exert all the pressure on the formwork. It is more of hydrostatic pressure in that sense. Whereas if the concrete has a more viscous nature the kind of pressure that we have for viscous concrete will be lower than the pressure that we have for non viscous concretes.

So this another consideration that we need to keep in mind when we are trying to determine a specification or we are trying to specify what kind of concrete should be used in a particular application.

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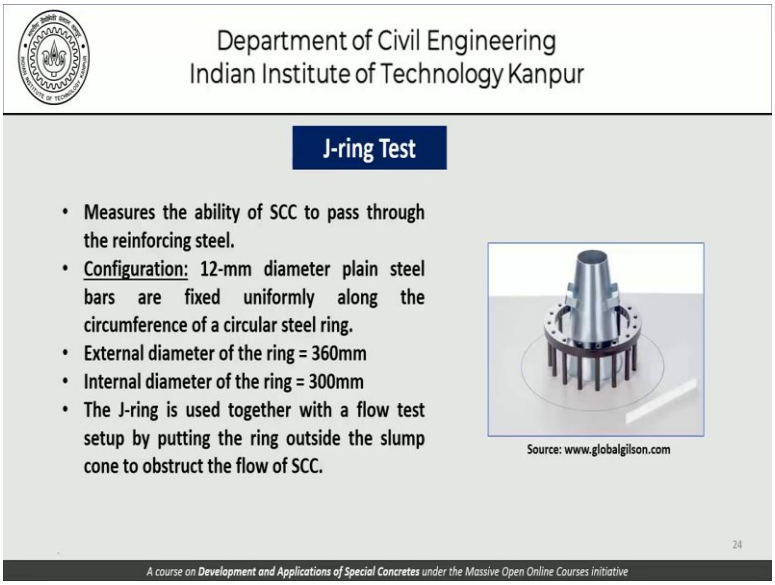

So we come to another test which is used to assess the deformability of self-compacting concretes that is the J-ring test. This measures the ability of the self-compacting concrete to pass through the reinforcing steel. Of course we have kept on talking about the self-

compacting concrete being used but all these tests are as such applicable to all concretes. Now whether they will pass or not pass what the values you will get whether they are acceptable to you or not that is a matter of judgment.

So when we say that this test measures the ability of SCC. It is not SCC alone it measures the ability of the concrete to pass through the reinforcement. Now if it meets a certain requirement then it qualifies to be an SCC or a self-compacting concrete. So that is something which we must keep in mind when we are talk of this discussion here. Now as far as the equipment description is concerned 12 millimeter diameter plane steel bars are fixed uniformly along the circumference of a circular steel ring.

So we are talking of these bars. Now these bars are fixed along this ring throughout along the periphery of this ring. The external diameter of which is 360 mm and the internal diameter is 300 mm. Remember that this 300 mm that we have here should be taken in view of the 200 mm that we need as far as the bottom of the slump cone is concerned. This test again is something that is coming out of a slump test.

The slump test or the slump flow test being carried out under certain modified conditions. What we have is the flow is now taking place through these simulated reinforcing parts that is we have reinforcing bars now here or something that simulates reinforcing bars at or through which the concrete is expected to flow. And these parts of this simulated reinforcement are placed at this distance here.

Now this distance you can find out because we know the internal diameter of the ring here and the external diameter of the ring here and given the fact that these bars are all 12 millimeter diameter the J-ring is used together with the flow test setup by putting a ring outside the slump cone to obstruct the flow of the self-compacting concrete or the concrete which you are testing.

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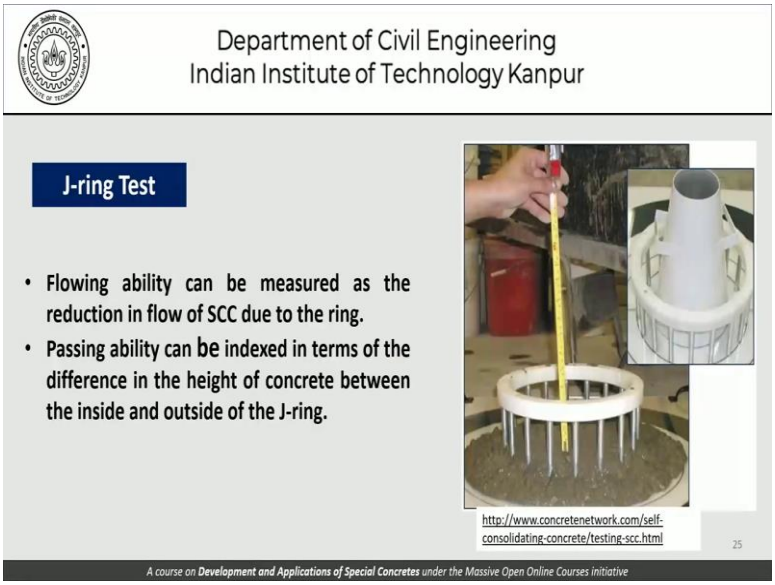

Now the flowing ability can be measured as the reduction in the flow of the concrete due to the ring and the passing ability can be indexed in terms of the difference in the height of concrete between the inside and the outside of the J-ring. So we can measure the height of concrete inside the ring and outside the ring and I am leaving it to you to read a little bit more about where exactly these measurements have to be carried out as far as the inside of concrete is concerned.

As far as outside of the concrete is concerned so please do that and then you will know what is the import of the J-ring test.

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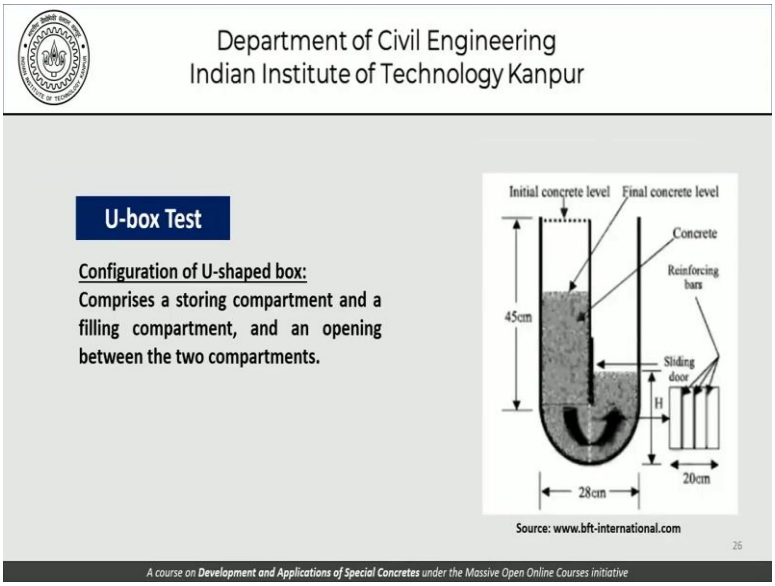

Moving forward we have the U-box test. So the configuration of the U-box test basically is it comprises a storing compartment and a filling compartment and an opening between these

two compartments. So this here is my storing compartment and this here is my filling compartment. The concrete is stored here and allowed to move through this gate into this filling chamber. The gate here is shown in this picture here and we can see that there is some kind of simulated reinforcing bars also.

So the size of this is known because we know the depth of the box and through that depth and this height the flow is taking place.

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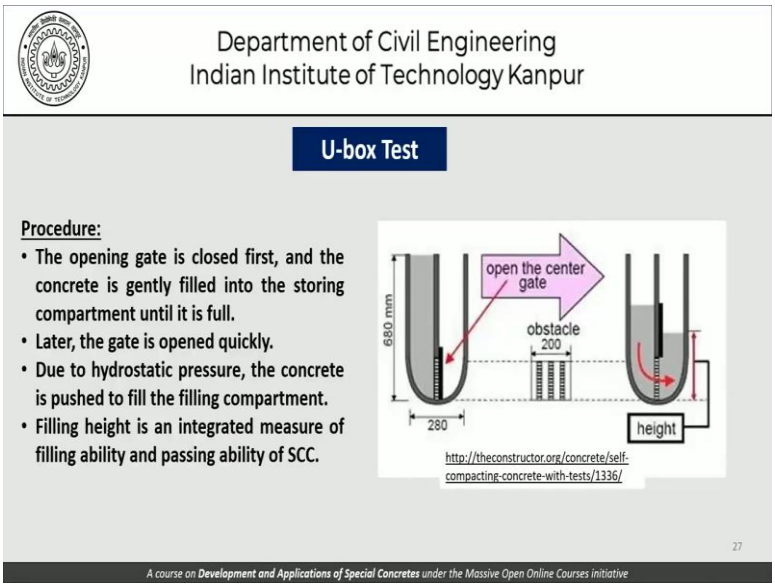

As far as the procedure is concerned the opening gate is closed first and the concrete is gently filled into the storing compartment until it is full. Later the gate is opened quickly due to the hydrostatic pressure the concrete is pushed to fill the filling compartment and the filling height is an integrated measure of the filling ability and the passing ability of concrete. So this concrete if it were a true fluid will come to this filling chamber in a manner that both these heights are the same.

But the way it is shown there is a delta H here and this delta H the higher it is the worse the concrete is as far as it is filling ability or as far as the U-box test values are concerned. So we can surely have different types of obstructions here but as far as standard U tests are concerned there is a given configuration of these reinforcing parts.

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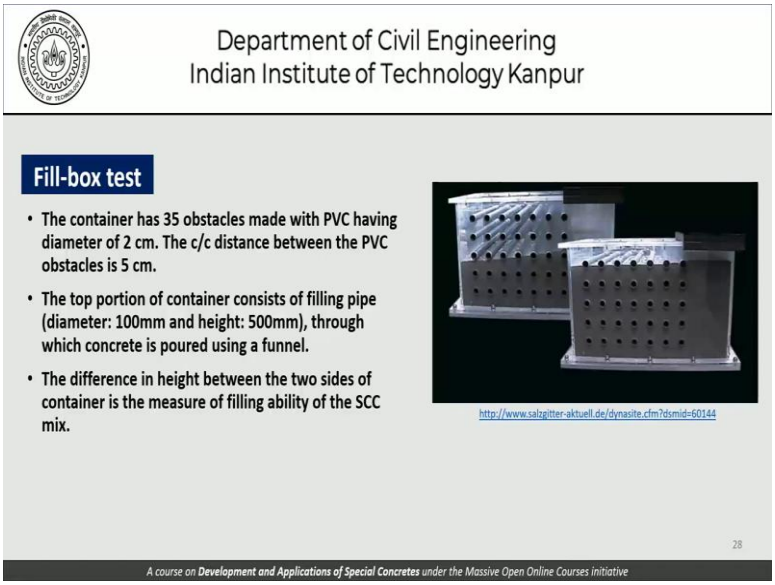

So moving forward we come to the last test that I have in my plan today that is the fill box test and this container has 35 obstacles. These 35 obstacles if you want to count them it is 1, 2, 3, 4, 5 and 6, 7 and arranged in 5 layers and we put the concrete here all over the place and then we try to see how it negotiates the space between simulated reinforcing parts. This test actually simulates the flow of concrete not through one layer only.

It shows or it is an indication of the ability of the concrete to flow through several layers of obstructions and come up to this place. Not only come up to this place but come up homogeneous that is the kind of concrete that we started with that should still be the kind of concrete that we have. Here in terms of the coarse aggregate content and so on and so forth. This kind of a configuration is very very susceptible to all kinds of problems including aggregate interlock.

So this kind of a configuration is very much susceptible to something like aggregate interlock and this is a very rigorous test that a concrete must pass. So the container as I have already said has 35 obstacles made with PVC having a diameter of 2 centimeters and the centered center distance between PVC obstacles is 5 centimeters the top portion of the container consists of a filling pipe of 100 mm diameter and a height of 500 mm through which the concrete is poured using a funnel.

And the difference in height between the two sides of the container is measured and that is taken to be a measure of the filling ability of the self-compacting concrete mix or the concrete mix that you are testing and you can have your own specifications as to when would you call

a mix as a self-compacting concrete. So you can obviously think that this 5 centimeter is the distance between the openings or the distance between the obstacles and this has to be somehow related to the maximum size of aggregate that we use.

So if this maximum size of aggregate is 20 mm then this is so depending on the maximum size of the aggregate that you use in the concrete you may like to adjust this. Now this kind of an adjustment is at the center of a lot of discussion that you may have for each project. Any of these tests whether it is the test which calls for 2 bars and 3 bars any of these tests can be modified to suit your own requirements except that then it does not remain a standard test anymore.

Now apart from Indian specifications or apart from referring to Indian specifications I have not referred to any other specification. In the discussion today it is an assignment to you to try to read the literature research literature to begin with and then you will find gradually some of these tests have been adopted by the different standardization bodies in the world and they have given certain numbers to the U-box test or the L-box test or this kind of a fill box test or the J-ring.

And please make a list of that and see if there are any fine differences between the Japanese code and the Indian code or the ACI or the European codes that is an assignment which you may like to do.

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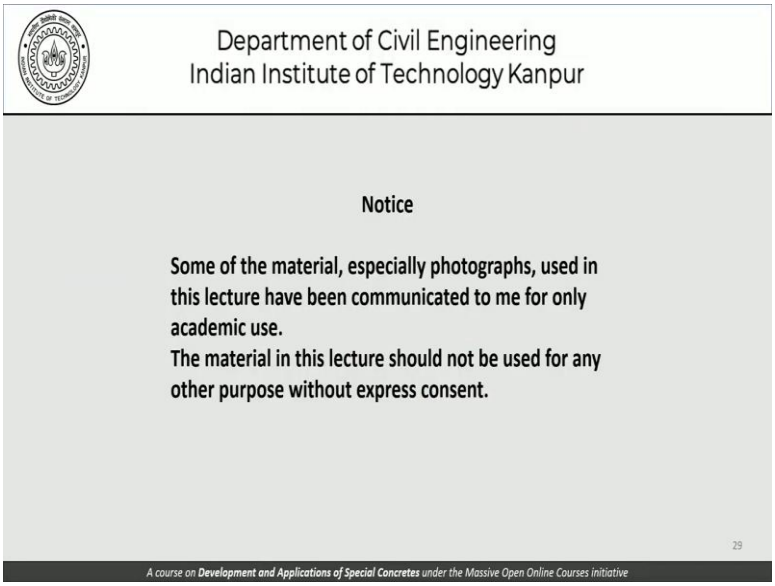

Moving forward I would not like you to use this material for any other purpose without express consent that is a part of a general agreement as far as NPTEL is concerned. We do not expect you to use this material on your own without express consent from us.

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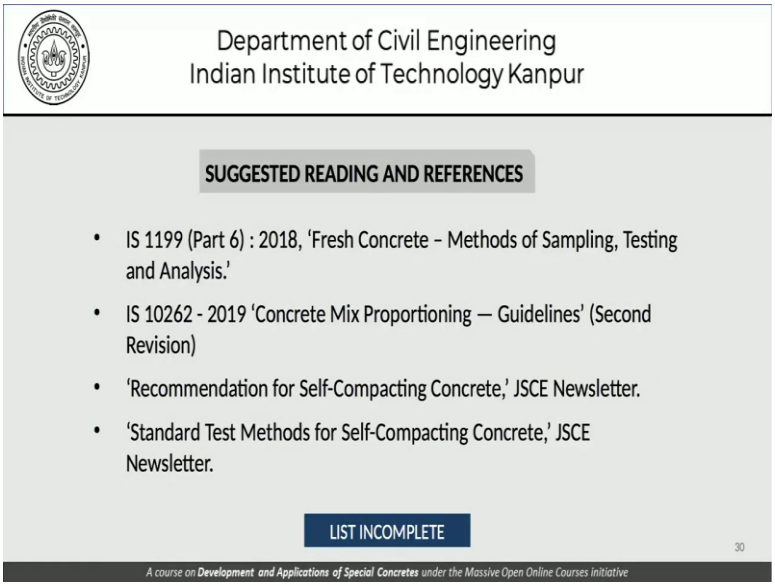

And this slide gives the suggested reading and references which you might find useful in following the material which has been presented today. However this list is by no means exhaustive and in fact it is for that reason that I have written as incomplete and you are requested and encouraged to look at the internet look for more relevant material and try to understand the subject matter better.

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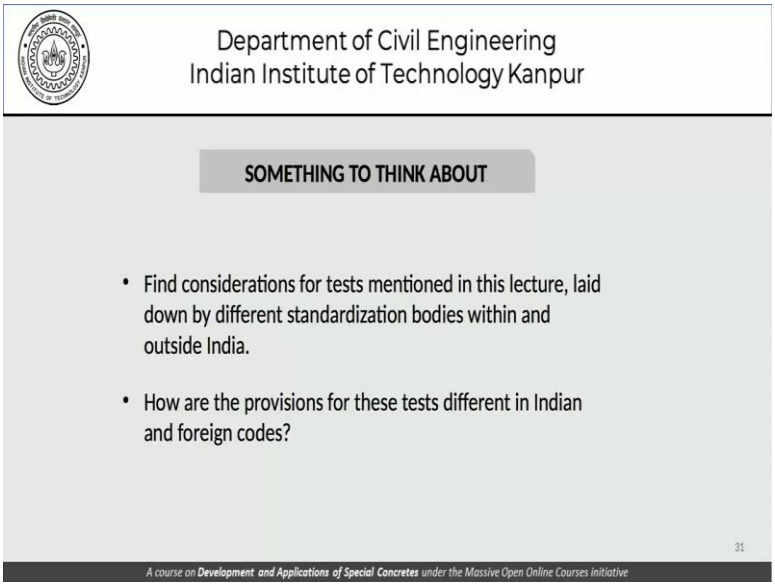

This tells you something to think about some of the assignments that I have given to you are listed here you are requested to go through these assignments. Try to enrich yourself through

this study and be better prepared to be able to test the concrete if you need to at any point in your career.

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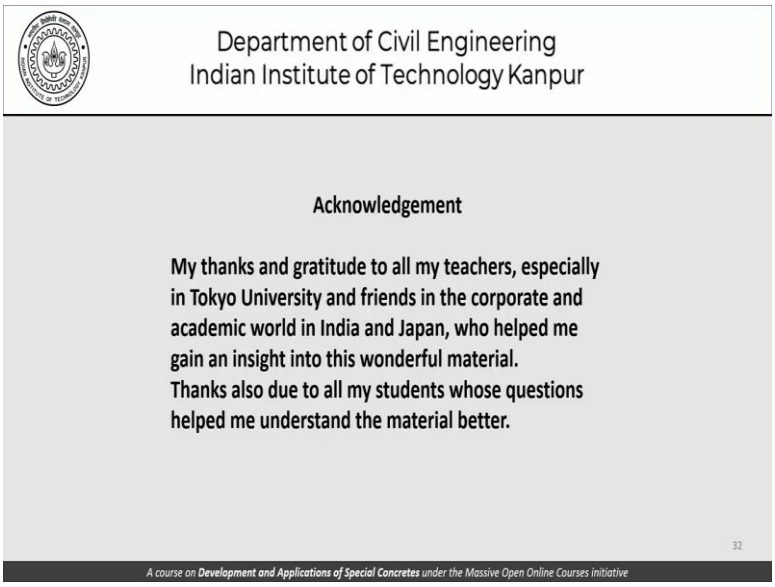

So with that let me thank my teachers once again my friends and colleagues and I look forward to seeing you at another lecture on self-compacting concrete. Thank you.