Admixtures And Special Concretes

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Lecture -60

Special concretes: Self-compacting concrete - Segregation and laboratory tests

Segregating Category Concrete:

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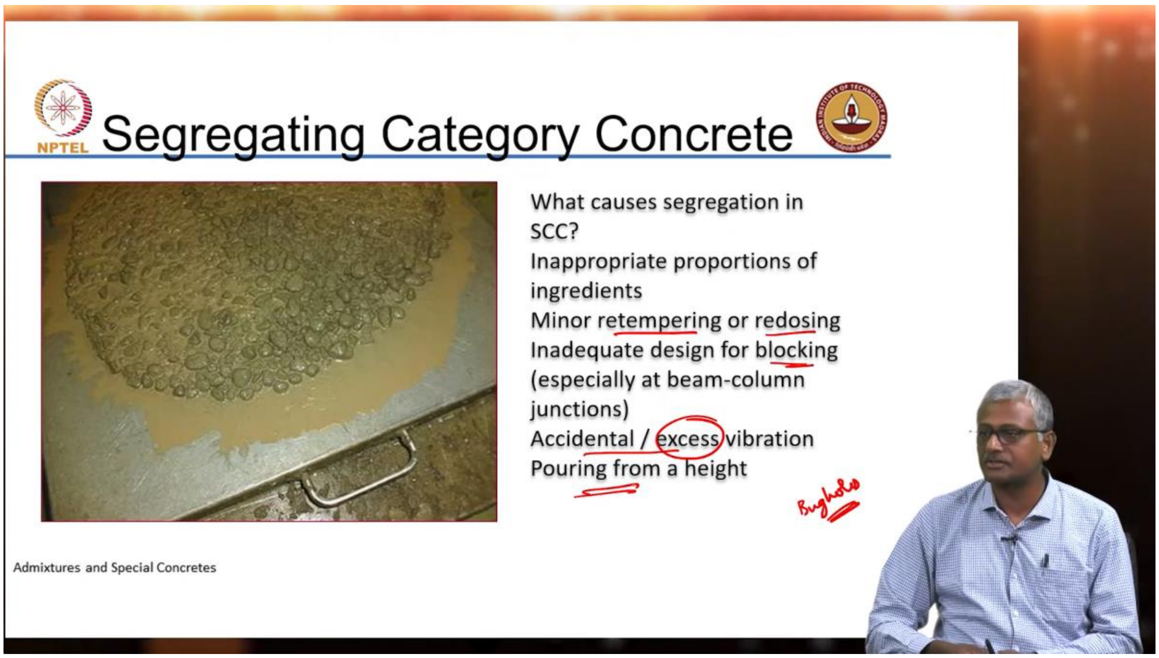

I am sorry I did not get the proper description of another acronym with SCC, so I just put segregating category concrete of course segregation is a realistic possibility with SCC if you do not design well, inappropriate proportions of ingredients can cause segregation in your attempt to provide very high flow ability if you increase water content too much it can lead to segregation. If you do minor re-tempering or re-dosing which is a common at site in our construction projects when concrete arrives at the job site it is not ready to be delivered it remains for a long time slump gets reduced you add water to improve the slump or you add another dose of admixture to improve the slump it can cause segregation potential to increase. Inadequate design for blocking especially when you have reinforcement congestion and beam-column intersections and those locations if you are not designing your SCC to actually actively pass around the reinforcement by adopting suitable test strategies, I will come back to that later when we describe the test. If you do not do that you can have blocking in those locations and accidental or excess vibration in some instances even when self-compacting concrete is used people tend to use a little bit of formwork vibration to ensure that the surface finish is free of any minor defects such as bug holes very often you see bug holes on the surface. Those are not really defects in terms of problems to strength or durability but aesthetically bug holes are not sort, desired on the surface finish of the concrete. In such instances, it may be beneficial to do actually a vibration of the formwork.

This is something that we did when I, after my masters I worked for a company called SICA in the US. SICA is a leading construction chemicals manufacturer and that was one of the first applications of self-compacting concrete in the US that we attempted. Here we went to a precast factory that was making jail cells, prison cells and these entire prison cells were single units which were getting completely prefabricated. So, if you put a person in there is no way, you cannot crack the concrete to come out because it is single unit.

So, anyway this single unit the concrete is poured all at once. The pre-SCC usage of conventional concrete, it used to take them nearly 3 to 4 hours to fill up concrete vibrate it and complete the entire prison cell. Here with SCC, they did the entire process in 10 minutes but they were seeing that when they use the SCC with the admixtures that we had developed at that particular point of time which were not really the best in terms of their polycarboxylate type characteristics because that was in 1997, I think that when we did this trial. At that time the admixture technology for SCC was still not as well developed as it is today of course. So, in those days when they actually did the concrete without any vibration, they found that the surface had lot of these bug holes. But when they added some surface vibrators to the formwork and about 10 to 15 seconds of vibration after the entire concrete was poured that was good enough to get completely rid of the bug holes that are on the surface.

So again, that is something that you need to look at but if you do an excess vibration, it is a flowing concrete if you do an excess vibration, it will start settling aggregates will start settling. Pouring from a height can be a problem can be a significant problem. So, we were involved in the project when they were constructing the new capital of Andhra Pradesh that is Amaravati I do not know which is the new capital now but nevertheless at that point of time when the new capital was Amaravati, they had these 5 tall towers that were to be constructed and these were supposed to be high rise buildings of 40 to 50 stories. Five towers of 40 to 50 stories were to be constructed and these were resting on raft foundations and the raft foundations are nearly 4 meters thick and 50 by 50 meters in size. So, you can imagine the quantity of concrete there 50 by 50 by 4 that is 10,000 cubic meters.

So, if you do reinforcement placement, conventional concreting, vibration imagine the amount of time it will take. They wanted to fill up the concrete in one stretch and it could not have been possible without the use of self-compacting concrete. So, here they used SCC to completely fill up and they took about 65 to 70 hours to fill up the entire volume of 10,000 cubic meters with multiple boom placers that were operating on site. But in this case, it is a raft, so in a raft you will have a lot of reinforcement at the bottom, a lot of reinforcement at the top, of course lot of vertical reinforcement also but in the central location you may not have so much reinforcement. But how do you now pour this concrete? The gap between reinforcement may not be sufficiently large to really get a chute right through and the reinforcement is all really large, large-diameter reinforcing bars.

So, you cannot really push things down this, you cannot really pull apart the reinforcing bars to push a shoot down. So, in this case the pouring was done from the top. So 4-meter height pouring was actually done in this case. But we designed the concrete appropriately so that the segregation could be avoided despite the placement from 4 meter height. However, this is not always the case, if you do not pay attention to the design, pouring from a height is bound to lead to a problem.

Rheological control of SCC:

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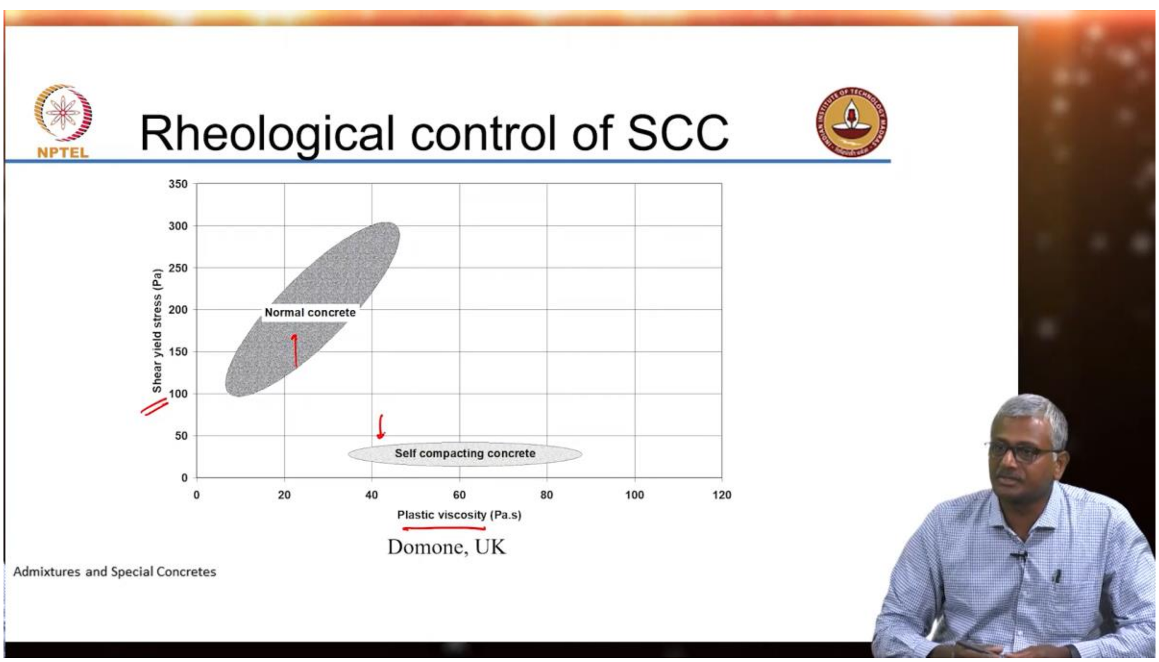

So, how do you control the rheology of SCC? If you talk about in terms of the normal rheological parameters that we talked about in rheology chapter, you have the shear yield stress that is the minimum stress needed to start the flow, initiate the flow and then plastic viscosity which deals with the resistance to flow once flow is initiated. So, in this case, normal concrete generally has a high yield stress and a low viscosity because you know that when you put the vibrator needle into the concrete it starts immediately moving. In self-compacting concrete, you need the yield stress to be as low as possible because it needs to be compacted under its own self-weight. There is no other external force that you are giving to compact it but it needs to possess a viscosity that is high enough to restrict segregation. So, you need to have a rheology defined by yield stress in plastic viscosity in a range which is generally to the right bottom of normal concrete implying you have low yield stress, close to zero yield stress and a higher plastic viscosity.

Naturally, when you have more powder in your system you will have more plastic viscosity. When you have less aggregate in your system you have lesser yield stress. So that automatically figures out the location that you have SCC with respect to your normal concrete.

Modified laboratory tests:

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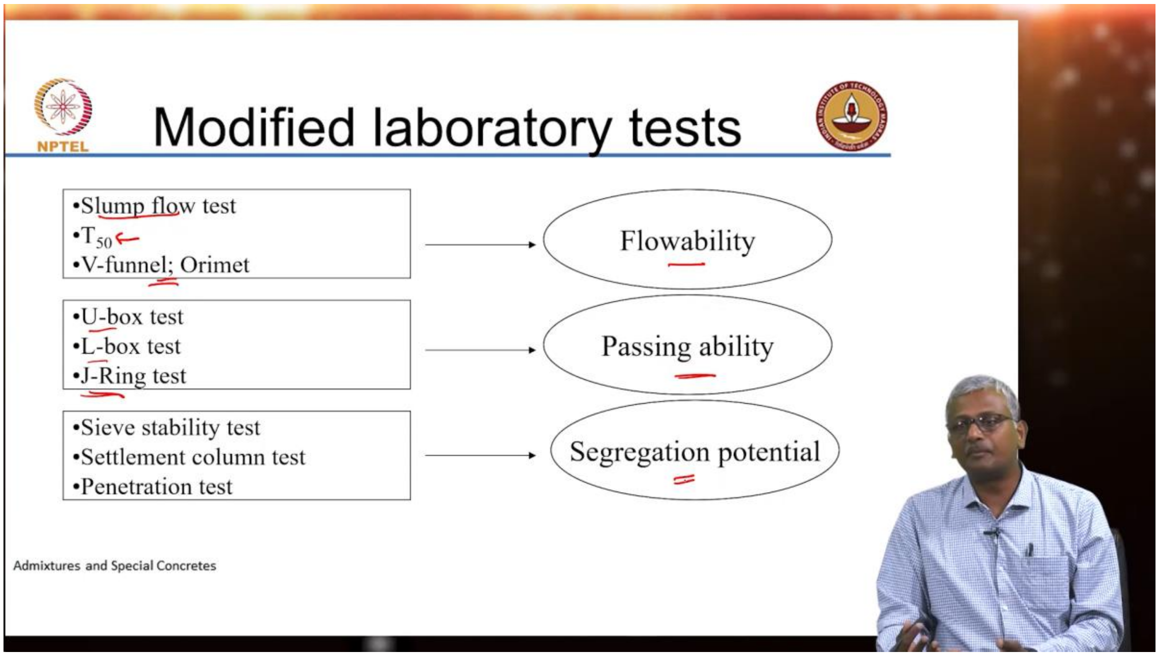

So, this has to be assessed with the help of either rheology measurements which we already discussed in the rheology chapter quite complicated for concrete, not easy to perform, specialized rheometers are needed which cannot always be available at the job site. So for this, we adopt modified laboratory tests for assessing the characteristics of self-compacting concrete.

So, one is to use a slump flow instead of a slump measurement, measurement of time it takes for attaining a diameter of 50 cm slump or slump flow or alternatively you can have other flowability tests like a V-funnel test or an Orimet test, I will talk about these subsequently. You also need to measure apart from flowability, the passing ability, how easily this concrete can pass between reinforcement that also needs to be measured and that is done with the help of different types of arrangements with reinforcement. U box and the L box as the name implies, the box is shaped like a U or an L and there is an obstacle in the form of reinforcements placed in the way of SCC that is moving or you have the J-ring test, J-ring is basically a reinforcement case that you place around the slump cone so that when the concrete starts slumping out or flowing out of the slump cone it has to then go between the reinforcements in the J-ring. Again, we will see how this works. The other thing to measure is the segregation potential.

What is the likelihood that the concrete mix that you are selecting is going to segregate? So, sieve stability test, settlement column test or penetration test can be done. Idea is simply that you pour your concrete into a bucket, if segregation is there lot of the aggregates will start settling. If you take the top half or top one-thirds of the concrete and pass it through a sieve that separates out the aggregate content, you can then understand how much of the aggregate is actually there as compared to what should have been there based on the mix design. It is an easy test to perform, it is not really very complicated.

Slump-based tests:

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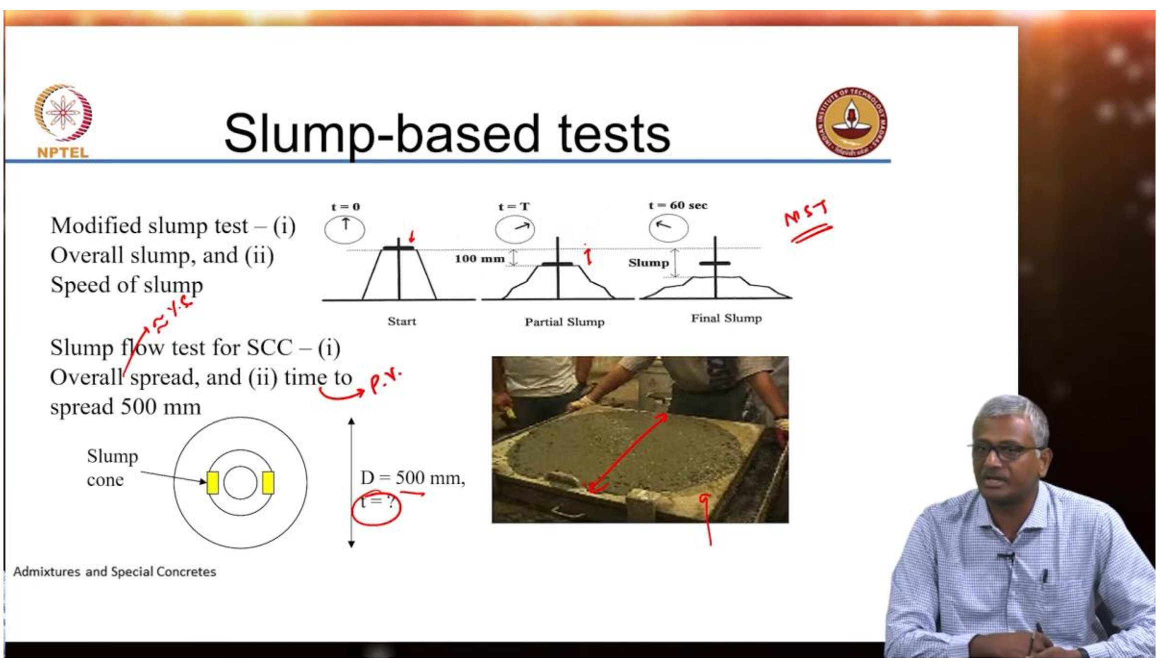

Let us look at some of these tests. You have slump-based test which can be done for self-compacting concrete like the slump flow test. Here the slump cone is the same or sometimes in Europe for instance they also adopt a modified slump cone, a truncated slump cone, instead of a 30 cm height it can have a truncation at 15 cm, a smaller slump cone also sometimes is used for flow test. But nevertheless, it is almost the same in terms of the entire volume of the concrete basically subsiding and flowing out. So you can measure the total diameter of the flow.

You can also measure the time taken for a flow of 500 mm. In what way are these two going to provide information about rheology? In what way? What do you think these are linked to? The overall spread is linked to what? What rheological parameter do you think it is linked to? Why do you think it is linked to viscosity? Because if you measure the time it is indicating the speed at which the concrete is moving and that is basically governed by the viscosity of the concrete. The overall spread is the general measure of the workability of the concrete and that will be more linked to the yield stress of the concrete. Just like slump in regular concrete is linked to the yield stress of the concrete. So, overall spread is linked to the yield stress and the time is linked to the plastic viscosity.

Similarly, even for regular flowable concrete or workable concrete which is not self-compacting you can modify the slump test to provide information not just on the overall slump but also the speed of slumping. Here what you do is at the start you put a disc on top of the concrete, a lightweight disc and then you start your timer, you remove your slump cone, let the concrete subside, you measure the time that the disc takes to move a distance of 100 mm and then you measure the total slump, final slump. So, you not only get the estimate of the slump you also get an estimate of how fast the concrete is slumping. So, this way you are able to get two results from the same test and you can correlate this in one way or the other with your rheological parameters that is yield stress and plastic viscosity. One of the references I gave you for this course that is from the National Institute of Standards and Technology NIST, they have actually done fundamental studies on such concretes which have been measured using modified slump and correlated the slump value to the yield stress and the time for 100 mm slump to the plastic viscosity.

U-Tube and V-funnel test:

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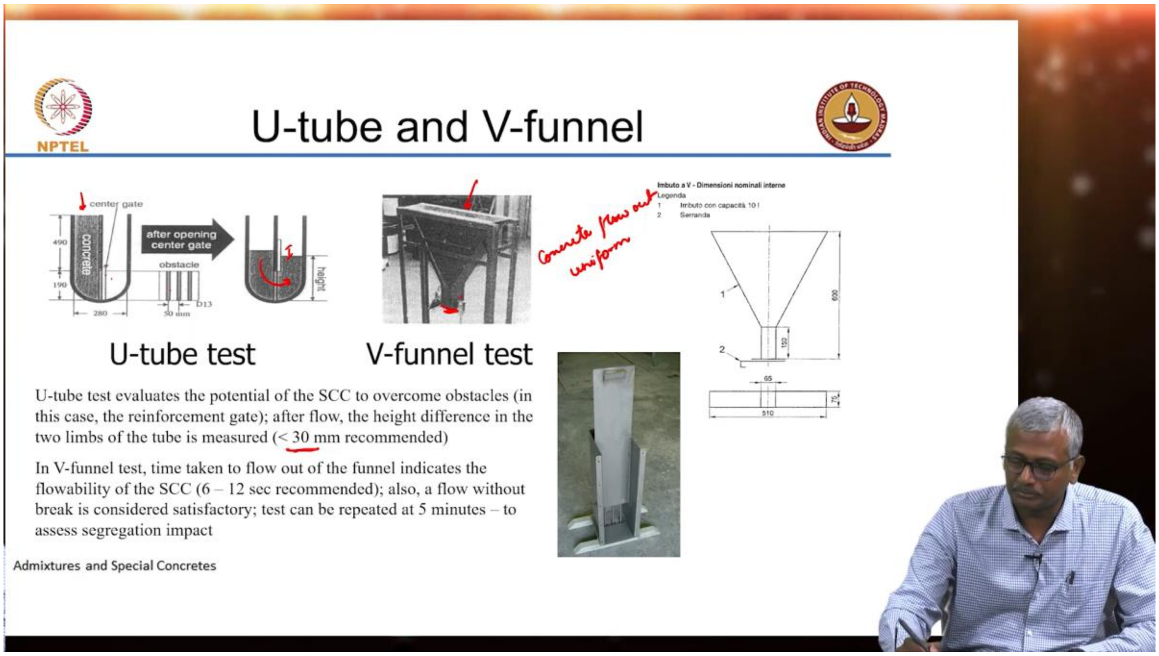

We actually have done this experiment and you can actually read about it on their monograph which I have referred to in the original chapter or the introductory segment of this course. The U-Tube, not the YouTube but just the U-Tube. U-Tube and V-funnel as I said are primarily looking at not just flow ability but also addressing some level of segregation sorry, passing ability. In the U-Tube you have a tube shaped like a U, you fill up concrete on one limb of the tube, you have your obstacle in form of reinforcements placed in the center and you have a center gate which is preventing concrete from moving. Then what you do is you lift the gate and the concrete will start moving, it has to move through the obstacle and concrete is deemed to be self-compacting or compactable if the height difference between the two columns is less than 30 mm. Most very good self-compacting concretes will not have any height difference at all because I mean it has to come to the same height because the pressure is the same. So, because of this, because of blocking and because of the potential for not being self-compacting you can have height differences but you should maintain the concrete height difference to less than 30 mm for self-compactibility.

The V-funnel is a test of flow ability and not really of the passing ability. Here you fill up your concrete into this V-shaped funnel, there is a gate at the bottom which is kept closed while the filling happens, then the gate is removed so that the concrete is able to flow out. So, concrete should flow out in a uniform fashion, it should not drop in chunks that means it is not cohesive, it is not having the flow ability. So it has to flow out uniformly and then you measure the time it takes for the concrete to get completely out of this V-funnel. So, that basically can be the measure of the flow ability of the system.

What you can also do is pour the concrete and simply wait for 5 minutes. What is that going to cause? What will happen in 5 minutes? Either loss and slump may happen, alternatively segregation may happen if the concrete is prone to segregation. So, keep the concrete in the V-funnel for 5 minutes and then open the bottom trap and then let the concrete flow out. The time that you measure there has to be within a few seconds of the time that you measured initially. There are SCC categories that I will define later on which looks at the time difference between the 5-minute reading and the initial reading in the V-funnel.

Of course, this is showing you the section through the U-tube, this is the reinforcement cage and this is the gate which has to be opened to ensure that the concrete starts flowing to the other side.

L-Box test:

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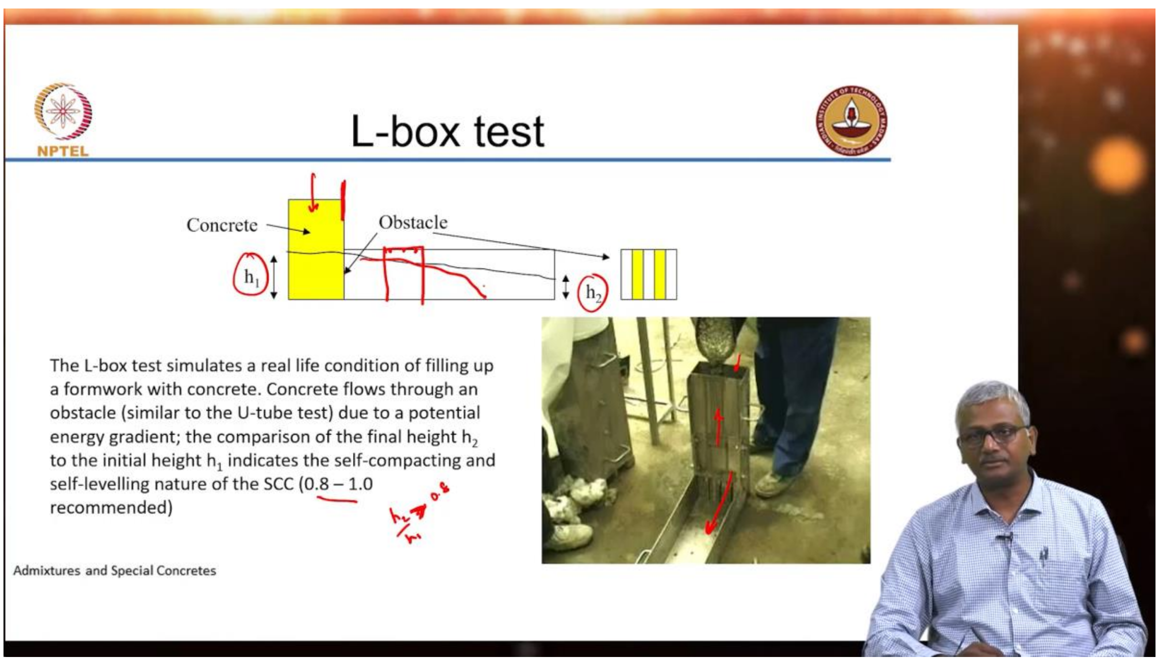

The L-box again the concept is similar to the U-tube, so here the vertical limb of the L-box is filled up with the concrete. There is an obstacle and a gate that is placed here. The gate is removed to allow the concrete to flow between the obstacles. See here the concrete is getting filled up into the vertical limb, there is a gate here, this gate is lifted and the concrete starts flowing between the reinforcement.

After the end of flow when the concrete reached the other end, you compare the heights of concrete at both the ends. For perfectly self-compacting concrete, there should be no height difference. But for an acceptable concrete that is H2 by H1 ratio should be 0.8 to 1.

So H2 by H1 should be 0.8 or greater than 0.8. That means you should achieve at least 80% of the height on the other side. Now what if the concrete does not flow to the other end at all? It is definitely not self-compacting. In this equipment, the Japanese also developed another sensor which they placed on top here and they actually measure the speed with which, so they have these points on the sensor which can detect the point at which the concrete is crossing like laser basically looking at when the concrete crosses that point and then they can establish the speed also.

So, you can then get another parameter, the speed at which the concrete flows basically relate to the viscosity of the concrete. So that is something you can also get from this experiment. So little bit tough, this result, this L-box test is quite tough to actually get the concrete to satisfy. It is not that easy. This stopping of flow somewhere before it reaches the end happens quite often with the L-box.

So, it is actually quite a stringent test. If you can get your concrete to pass the L-box test in most cases, it will work with all the other tests also.