Admixtures And Special Concretes

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Lecture -61

Special concretes - Self-Compacting Concrete - Workability test methods, classifications, and issues

Workability Test Methods (Continuation)

So we have been talking about aspects of testing self-compacting concrete and we looked at certain test methods that are typically utilized to assess the flowability of SCC Then we also talked about how we can measure or quantify the ability of self-compacting concrete to pass between reinforcement that is typically done with the help of either the U-Tube test or the L-box test.

J- Ring with slump flow

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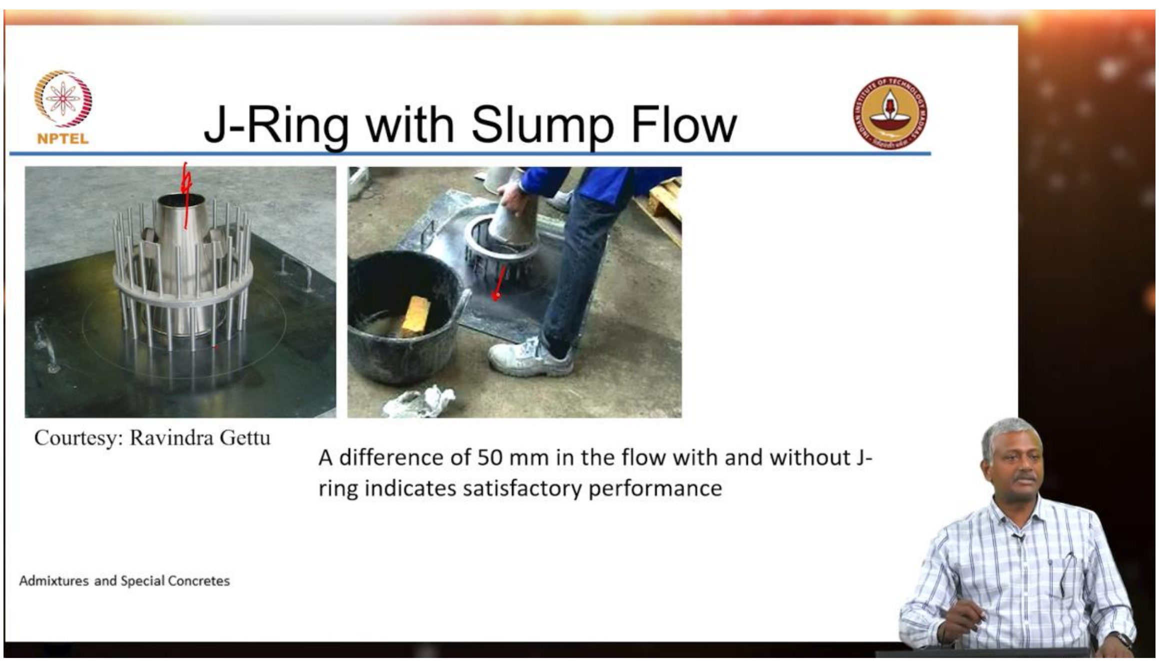

The J-ring is another test that we can do for passing ability. You must be wondering why J-ring? There's nothing like a J here. Essentially, I think it relates to a Japanese ring that was first formulated for this test. The idea is to have the slump cone in the center and have this reinforcement cage surrounding the slump cone. So, when you lift the slump cone, the concrete has to now flow out in a regular slump flow pattern but additionally, it is also flowing out through the gap between the reinforcement.

So, in normal circumstances let's say the slump flow is about 600 to 700 mm. So, in the presence of the J-ring, the slump flow has to be within 50 mm of that slump flow. So that's the way that the standards are written for J-ring with slump flow.

Box filling test:

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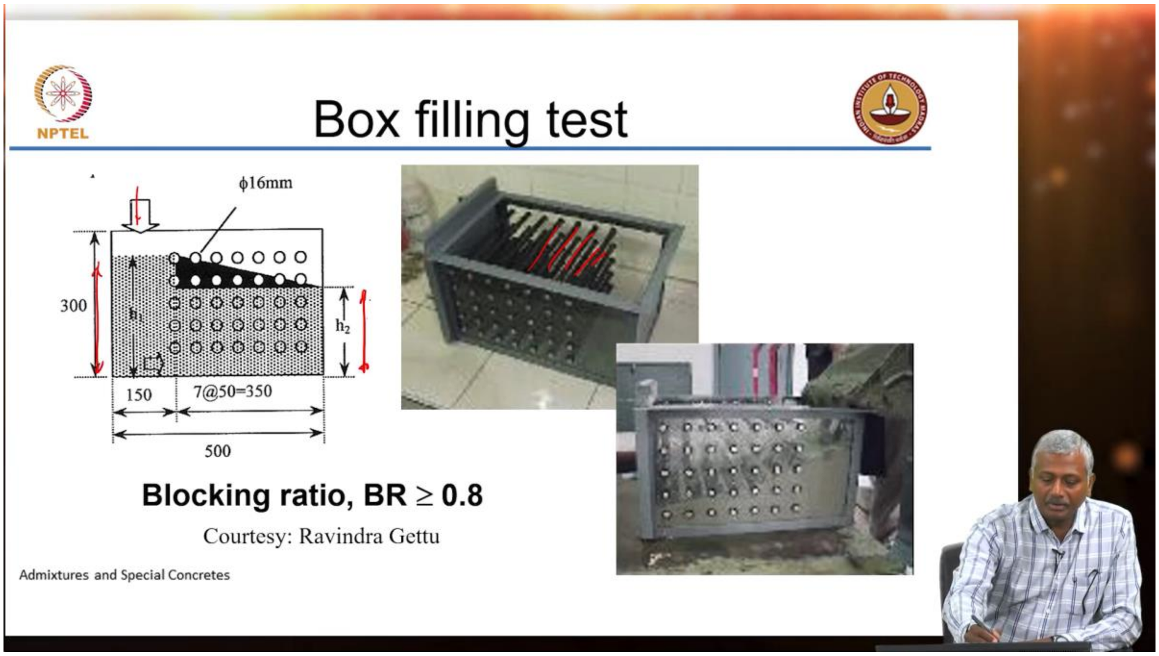

There are several other tests also that were initially being utilized for understanding SCC properties.

One is this box-filling test. Once again you have this box which has several reinforcements. The idea is to fill this box from one side and then look at the height of the filling on this side and on the opposite side. And once again similar to the L-box, here the height ratio should be greater than 0.8 for a suitable self-compactibility performance.

Testing for segregation

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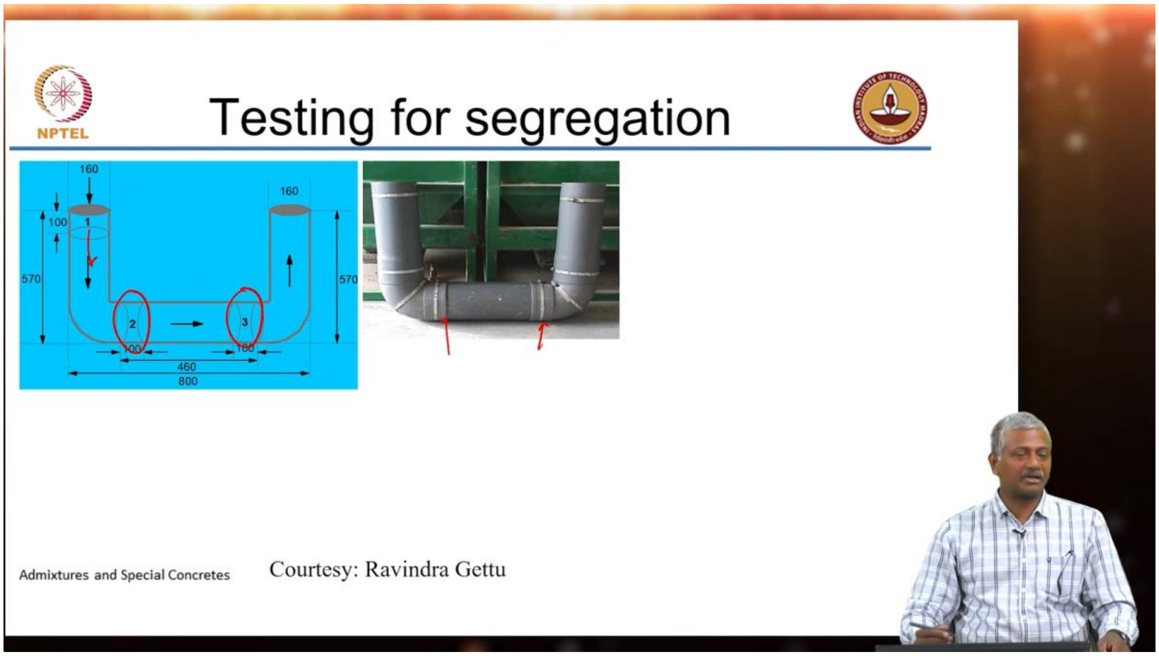

Now for segregation what we can do is look at the stability of concrete as it flows and see whether there is any distinction in the proportions of aggregate that are present in concrete at different segments. So this is essentially a pipe into which the concrete is made to flow. What is then done after you pour the concrete into this pipe is that you take two different samples of concrete, let's say here number 2 and number 3 which are extracted from these locations and then you assess the. Okay, you take the concrete from these different locations, then you assess the quantity of aggregate that is present in the concrete sample. How do you test the quantity of aggregate? How do you determine quantity of aggregate? You take fresh concrete, how can you determine how much of it is aggregate? You can sieve it, but what do you do? You put it on a sieve, what size sieve do you put it on? What should be the size? You want all aggregate, coarse and fine aggregate. Primarily coarse aggregate, because fine aggregate will not really have segregation problems, coarse aggregate is what will have segregation issues.

4.75, you sieve it, but what do you do? How do you wash off? I have said the answer, you wash off basically the cement paste, you can just take a jet of water and wash off the cement paste and sieve it to 4.75, you get the material which is coarse aggregate and then look at the proportions of coarse aggregate in the different samples of concrete.

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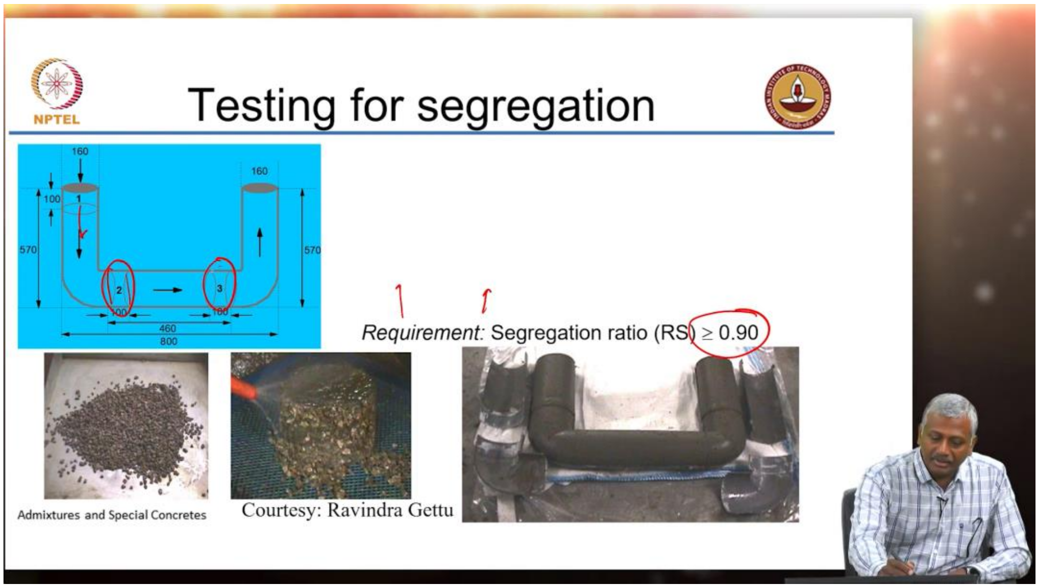

Alternatively, you can wait for the concrete to become hard and then look at the, just sieving it after spraying it with water. Not hard that means you can remove the external formwork and then extract these samples which are still fairly fresh and then you can remove it also. Either way, you can either do it in the fresh state, but the problem is if it is too fresh then you will not be able to extract this concrete out on its own.

That is why you wait for it to set, but not achieve final set, it should still be having initial set so that the water jet spraying can remove the cement paste quite easily. And then you get the aggregate proportion for a good self-compactibility, the segregation ratio should be greater than 0.9. What does that mean? That means the amount of coarse aggregate in section 3 should not be more than 90% different from what is there in section 2. So the mix has to maintain its consistency without segregating.

So, if there is segregation where will the aggregate be more at section number 2 or section number 3? If there is segregation, where will it be more? 2, 3 all answers are coming, what is the correct answer? Segregation should happen in the beginning, so 2 will have a greater amount of aggregate, the paste will tend to flow out without the aggregate because it is separating out from the aggregate and 3 will have a lesser amount of aggregate. So that should be within 90% is what is defined.

General remarks regarding tests:

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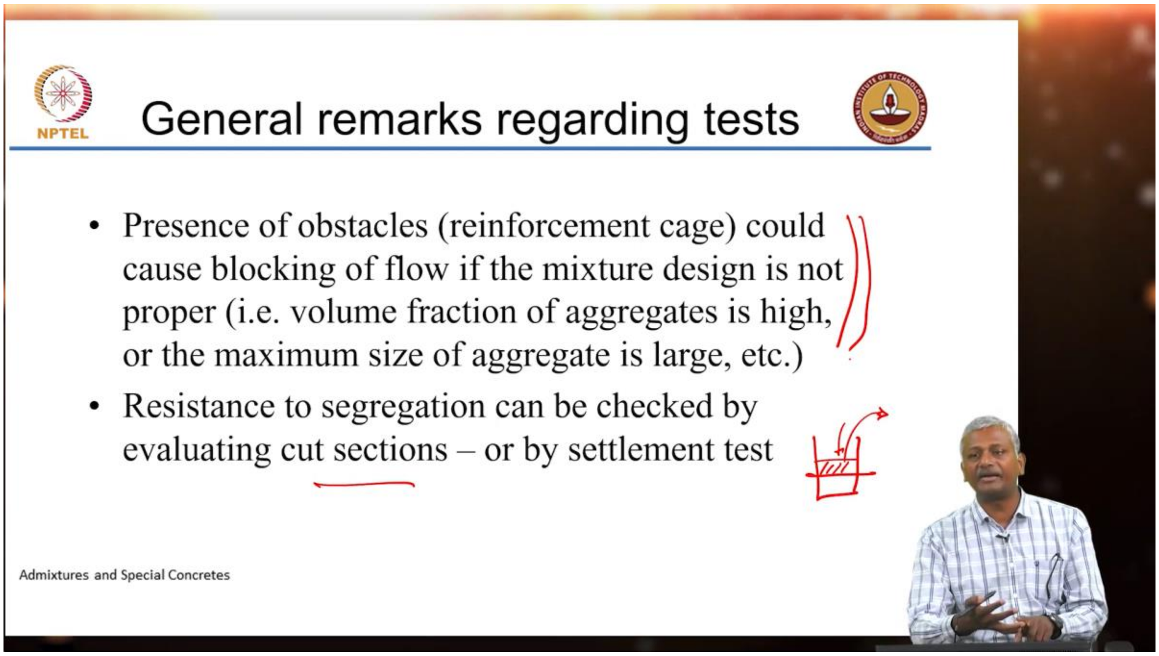

The other test for segregation is also just evaluating a cut section. After completing a concrete pouring take a section of the concrete or take a core and then just evaluate the core surface with respect to distribution of aggregates that is also easy to do. But you do not want to wait till that long till concrete is hard so you can also do it in a very simple way.

If you take a bucket you fill it up with concrete, allow the concrete to stay there in the bucket for some time and then take the top half of the concrete and do the same thing, measure the amount of aggregate in the top half and the bottom half and then you can also calculate the segregation ratio based on that. So all you need to do is ascertain that your mix is uniform at the top and the bottom that is all. Because of segregation the top half is going to have less aggregate because it is all going to settle to the bottom so it is a very easy method of doing it. Now in terms of your test that involve obstacles like the reinforcement cage, if your mix design is not proper your concrete will start getting blocked, if you have too large coarse aggregate present in your system or if you have more proportion of aggregate than the system can handle. Because it is not just about flowability, see your concrete is more economical with larger size of aggregate, the larger the size of aggregate the more economical your concrete is.

But the larger size implies that passing between reinforcement is not all that easy anymore. So, it is not just flowability you also need to look at passing ability and the resistance to segregation. Larger size of aggregate will also have a greater tendency to segregate as compared to smaller size aggregate. So, you need to design your concrete considering all of these aspects in place, flowability, passing ability, segregation resistance, and finally economy. That is also important obviously from a project perspective. You need to maximize aggregate; you need to maximize the maximum size of aggregate and so on.

On-site all acceptance test- Japan:

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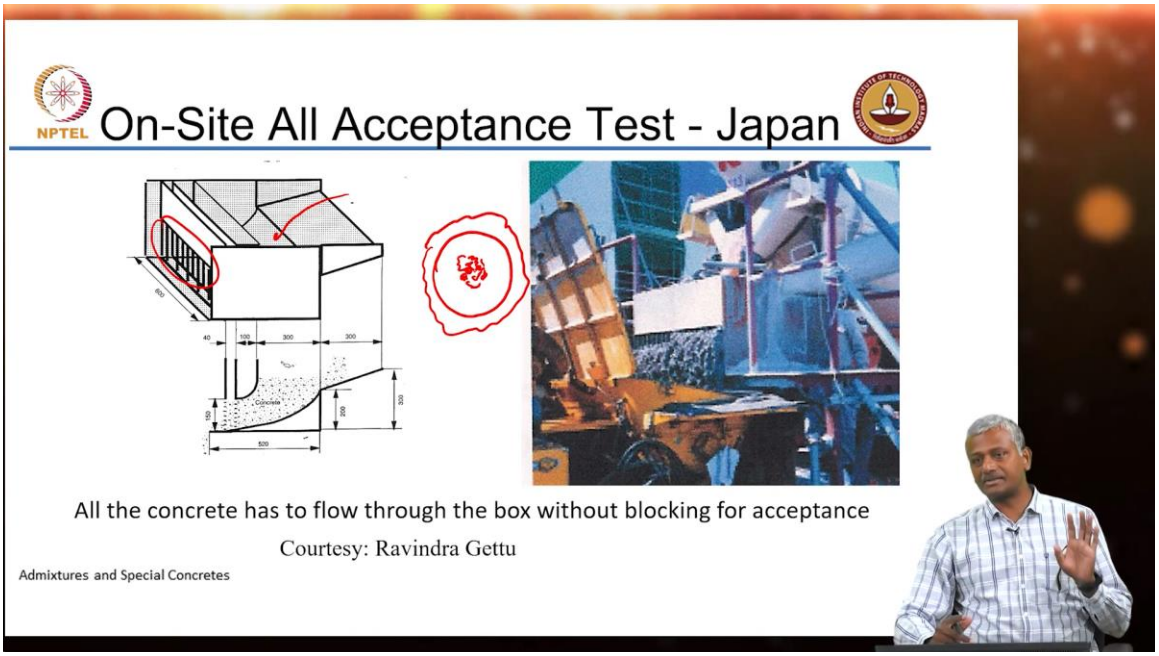

Now in Japan, they also developed this thing called an onsite all-acceptance test. So, they had done so much work with SCC at that stage that they realized that if they did this one test of the concrete passes which had been sent by truck to the site then it can be simply adopted immediately. So, this is again it has got flowability because concrete has to flow through this into the gap here and then flow out to the obstacles. So, all concrete has to flow through the box without blocking for acceptance.

So, here the concrete truck has already gone to the site with the SCC. To be able to be used in the structure it has to satisfy this test. It is a little complicated, it is not that easy. It is quite easy to satisfy a slump flow test, not much requirement there. But onsite if you start putting tests where concrete has to flow through obstacles lot of things can actually go wrong.

So, in most construction sites, you will see that it is just a slump flow test that is specified as an onsite quality control measure. In most of the cases, all the other tests would be done at the QC lab before the truck actually goes to the site. So, you have to be clear about what you want to use as a conformity criterion onsite when the truck actually reaches site. So, all these tests that involve obstacles they are very tricky and your sampling of the concrete can also make a difference. So, if you sample from the first material that comes out of the truck the characteristic will be quite different as oppose to if you waste some of that material and wait for the next material to come out of the truck.

So, sampling very essential to pay particular attention. I am not saying that the objective is to pass the test all the time if the concrete is bad it should fail. Your test should also detect the failure and one way to do that even with the slump flow test is that when you actually do the slump flow the concrete spreads out into the nice circular shape and you measure the diameter and everything. But if you wait for just a couple of minutes what will happen is if the concrete is having a problem of segregation there will be a periphery of water that will sort of leak out of the concrete. Alternatively, if there is segregation potential of this concrete you will see a large bunching of aggregates in the center and only the paste will be flowing out.

So, even with the slump flow test if you are careful enough you can actually pick up these problems. In most sites, slump flow is the only test that is done. But if you think about this all acceptance tests many concretes would tend to fail. So, you have to apply with some care what test you choose on the site.

EFNARC Classes for SCC:

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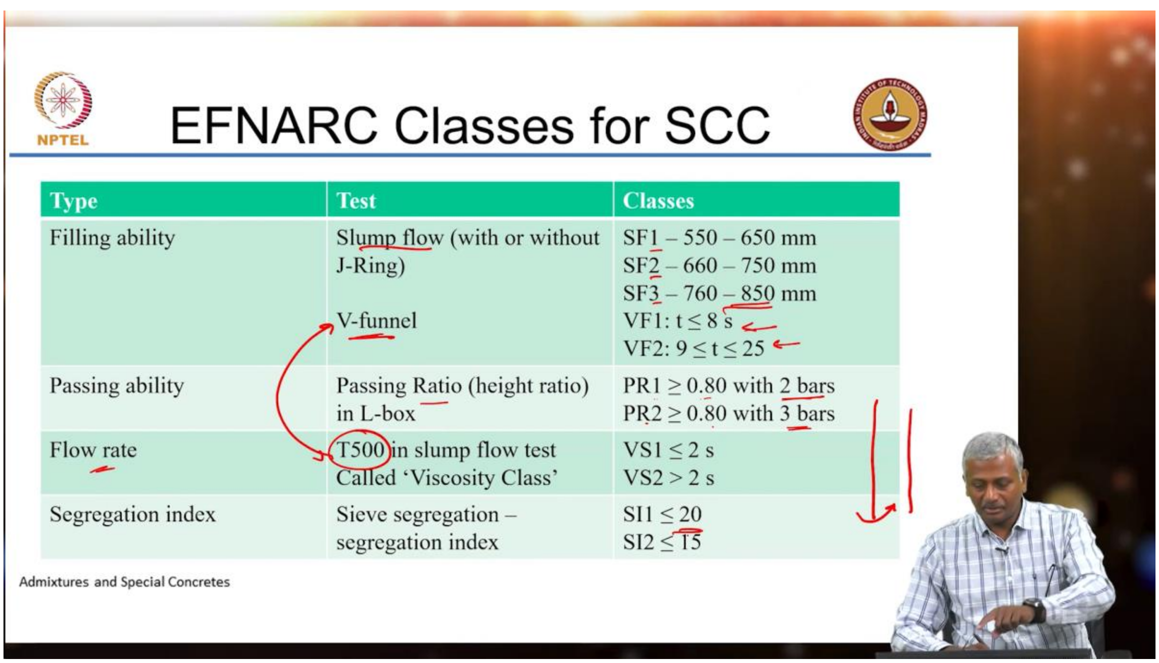

Now, EFNARC which I talked about had European committee which prescribed the early guidelines for SCC because in the absence of any standard it is trying to prescribe the methodology with which you can design SCC, you can control the properties of SCC and make SCC work on a job site.

So, they define these classes for SCC and then they relate these classes to specific applications. We will talk about that in just a minute. So, here they have filling ability. Filling ability is related essentially to the flow ability of the concrete. So, the flow ability is measured here in terms of slump flow and V-funnel.

So here the classes SF1, 2 and 3 are defined without the J-ring. But you can also define classes with J-ring. What will happen? Everything, all the numbers will be 50 mm lesser. The flow through J-ring has to be within 50 mm of your flow without the J-ring. So here there are 3 classes slump flow of 550 to 650 mm, 660 to 750, 760 to 850.

So that is the range of classes. Now can you think about what applications these could be used for from the discussions that we had previously. A slump flow class of, a low slump flow class 550 to 650, what kind of application would that be suitable for? We discussed this problem right? about plastic settlement cracking. Where does that happen? What kind of structural elements? Slabs. So, when you are doing slabs you have to go towards the lower slump flow classes.

When would you need a very high flow ability like 760 to 850? When the reinforcement is extremely congested like a beam-column intersection for instance. Where else? Can you think of a very tall column where we do not want to pour the concrete from top for obvious reasons? Is there any other way of filling it? Is there any other effective way of filling a tall column? You can send a shoot down with a tremie, so for that very high flow ability can be good. The other thing which people have experimented is to fill it up from the bottom. So fill up the column from the bottom. It is not easy to set up but that is ideal because what will happen is the concrete is simply going all the way up displacing any air in the process and you do not have any air pockets or honeycombs as a result.

So, in such instances, you will need the extremely high slump flow category. Now what you can also do is prescribe along with it a V-funnel test which is the time taken for the concrete to flow out completely out of the V-funnel. So here you have 2 classes VF1 and 2. In the first case time taken is only less than 8 seconds that means the material is coming out very fast. What does that say about the viscosity? It is a low-viscosity mix.

When the V-funnel time is more it talks about a higher viscosity mix. So, once again the application will describe what you want to use. For bottom pumping in a column, you would obviously go with a low viscosity. For a slab you would rather choose a higher viscosity system because in slab you can move the chute around and deposit concrete wherever you want. You do not want to dump concrete and allow it to flow.

You do not need to do that. The passing ability is the passing ratio or height ratio in L-box. Remember we talked about the fact that it has to be greater than 0.8.

Now PR1 category is 0.8 with 2 bars. So that obstacle if you have only 2 bars in that entire system the overall width is about 150 mm. So you are only keeping 2 bars inside. That means it is not very stringent. It is not a very stringent class.

But PR2 is greater than 0.8 with 3 bars. So in that 150, you keep those 3 bars of I think if I am not mistaken 20 mm diameter. So, what happens is the spacing between bars is now less. So, your concrete has to flow between the bars. You may think that the concrete has an aggregate size of 20 mm having a 30 mm spacing between the bars would be sufficient.

But please remember when concrete is flowing as a whole there is a lot of aggregates going and whenever they come across an obstacle like that they start arching and prevent the easy flow of concrete. So, your aggregate size that you have should actually be even one more order lesser than the gap between the rebars and that is how you will actually achieve self-compactibility in case of congested reinforcement. In the flow rate T500 or the time taken to flow 500 mm in the slump flow test. That is again related more or less to the V-funnel test where we are essentially determining the viscosity while flow is happening. So here there are 2 categories VS1 is less than 2 seconds VS2 is greater than 2 seconds.

So, imagine you need to measure this T500 and all it takes is just about 2 seconds. Mostly it is very fast as soon as you lift that cone it starts subsiding. So, within 2 seconds, it is VS1 more than 2 seconds is VS2. The aggregation index seeps aggregation just like what we talked about previously. Wash off the concrete and determine the proportion of aggregate it should be less than or equal to 20 which means the difference should be within 80% of each other.

That should be within 80%. SI2 class is less than 15%. So, it is more stringent as compared to SI1.

Issues with SCC:

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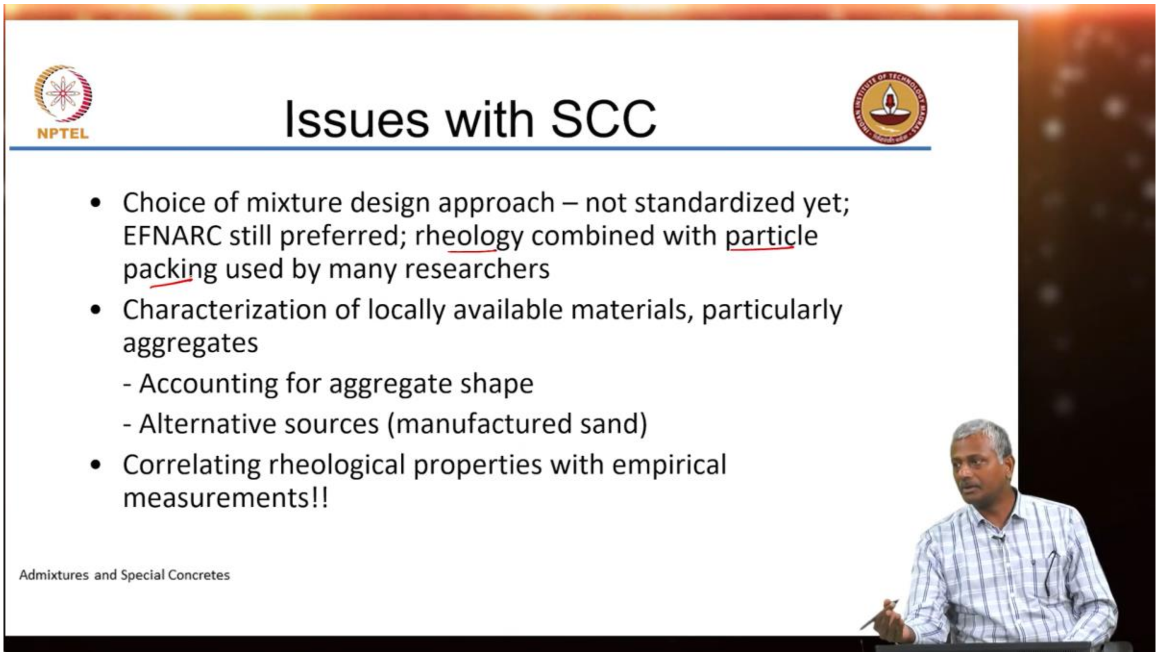

So, again EFNAR is still being utilized there is really no preferred mix design approach yet or no clear-cut standard guideline. So, it is more or less by trial and error but the EFNAR guidelines are actually quite good. Many researchers and many practitioners use concepts of rheology combined with particle packing and that is what we will look at in the example that I show you from our IITM work.

Now it is also important when you design self-compacting concrete to have aggregate that is not too angular because increasing angular aggregate leads more to blocking issues. We have more angularity in the aggregate blocking becomes a common phenomenon. And of course, we also need to look at it today since reverse sand is not available which was preferred previously for making self-compacting concrete. Today we have to look at either crushed stone sand or manufactured sand to make concrete. So that will affect the workability and rheology significantly.

The other challenge of course rheology gives you fundamental characteristics, plastic viscosity and shear yield stress, and of course the shear thinning or shear thickening coefficients and so on. How do you relate that to all these tests that we talked about? That is one challenge always because we want to use tests that can be utilized on-site. How can we get the maximum information from those and utilize that for an efficient design of SCC?

Possible effect of flaky and elongated aggregate:

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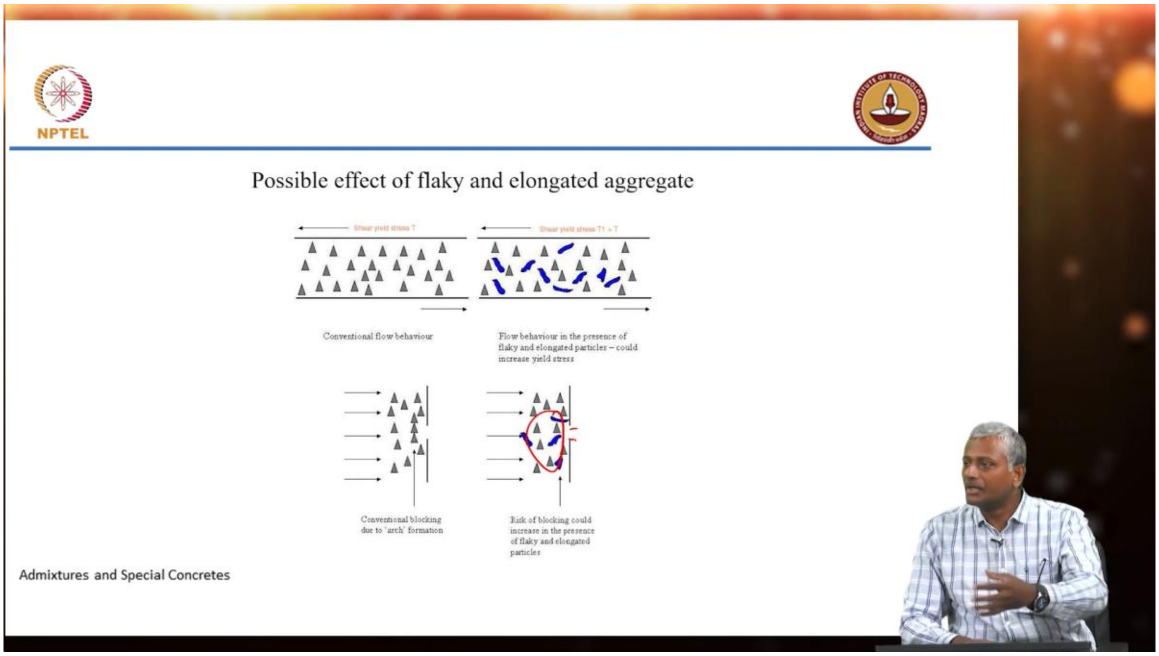

So, again just as I was saying about flaky and elongated aggregate the flowability gets restricted because flakiness comes in the way of easy flow of the concrete and as I was saying if you have more flaky material when there is small gaps to pass through the arching action can prevent concrete from moving easily through these gaps. So you need to design carefully, pay attention to flakiness and elongation. Is there a limit for flakiness and elongation for normal concrete? In the standards, if you look at it the aggregate limitations and flakiness and elongation are more for pavement concrete not as much for normal building concrete.

But then again specifications can be created for concrete to have the right level of flakiness and elongation. What is the difference between flakiness and elongation? What is the flaky particle? What is the elongated particle? Which one? No, no, not from the perspective of weak and unsound particles that is different. With an aggregate let us say a granite piece what piece of granite would you call flaky and what would you call as elongated? So, the idea is that the single dimension is different. So, for instance the flaky aggregate the thickness so if you think of a plate-like aggregate which has more area but very less thickness. Elongated aggregate you have a small area but high length.

So those kinds of aggregates need to be avoided. Flaky aggregates and elongated aggregates in normal concrete also can cause loss in strength increase in bleeding because if a flaky aggregate is there water will go and trap under the aggregate and not have a free path to flow up. So, all of these obviously have effect on the properties of concrete and

SCC they can have a severe effect. So you need to be carefully weeding out sources of aggregate that are creating a lot of flakiness and elongation and what is actually causing this? What is causing aggregates to become flaky and elongated? Why do aggregates become flaky and elongated? They are all achieved from rocks. What are the reasons why flaky and elongated aggregates come? How do you get aggregate from rock? Crushing so the type of crusher has an effect on the flakiness and elongation. So in most cases when crushing is in two stages jaw crusher and cone crusher you get lot more flakiness and elongation.

If it is in three stages the third stage being a vertical shaft impact crusher. A VSI crusher is something that is able to make the aggregate more equidimensional, more equidimensional. The second aspect that affects flaky and elongation is the actual source of the rock itself. If you are working with metamorphic rocks which have foliation those will become very flaky easily. But if you have igneous rock mostly it will be strong when you crush it, it will produce a good well-rounded, or equidimensional sort of aggregate.

Not round you cannot make aggregate round unless it is weathered naturally like by river. But in this case, when you are crushing you can avoid a lot of the problems by choosing the right source of aggregate. But then source you do not have too much control on because for economy purposes you need to be using whatever is locally available.

Other issues:

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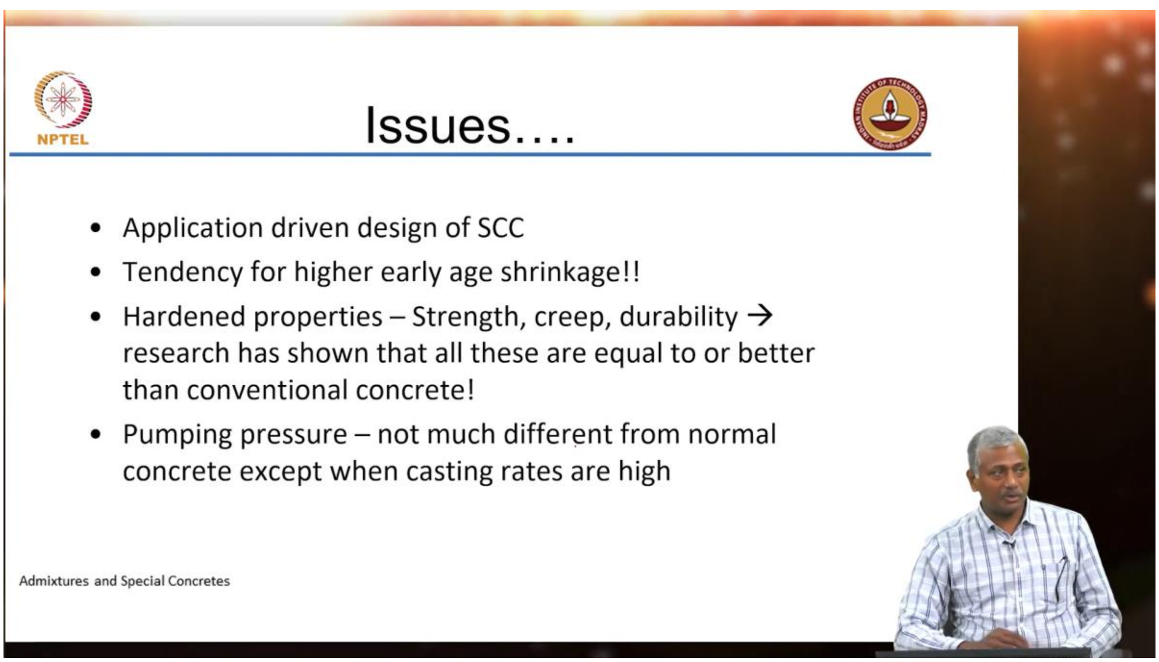

One thing you need to work application-driven design we already talked about that depending on the scenario whether you are putting a column or a slab or a beam, congestion of reinforcement and so on you need to choose specific sets of criteria for defining the characteristics of your concrete. You also have to be aware of the fact that the tendency for higher early-age shrinkage will be there.

We discussed this earlier, I showed I give you the example of the metro rail deck where silica fume concrete was used and it led to plastic shrinkage cracking. Hardened properties in terms of strength, creep and durability are generally equal to or better than conventional concrete because we assume that if no segregation happens if concrete quality is uniform the compactibility of the concrete is going to be better when it is self-compacting. So, generally, you will have at least equal properties and sometimes better properties than conventional concrete. Pumping pressure is generally not much different from normal concrete except when casting rates are high. So, when you are pouring a lot of concrete into the system the amount of pressure that you apply while pumping can be significant.

Secondly, the pressure on the formwork can be also large when you are casting at very high rates. So, if you are trying to fill up a large volume very quickly you are building up the hydrostatic pressure that is on the formwork. So, you need to design your formwork to take the hydrostatic pressure.

Application-based design:

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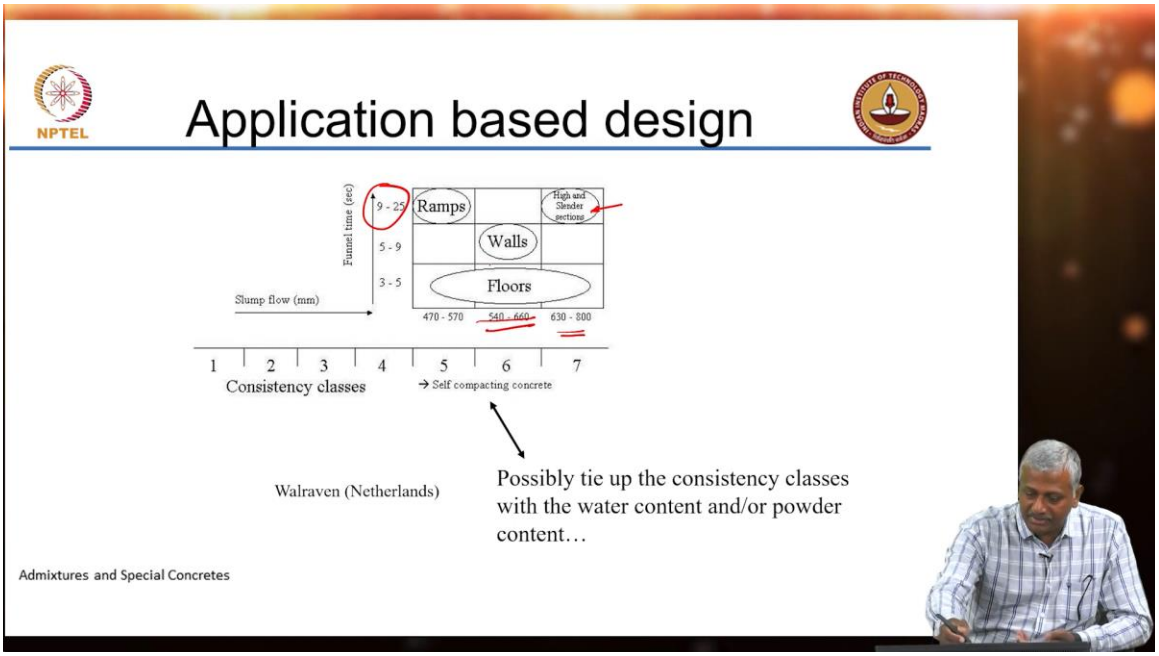

So, application-based design just some recommendations again on the work that was followed up from the EFNARC series. So when you are designing high and slender sections like columns you choose a high slump flow.

Funnel time you can decide based upon the type of application. Some cases you may want a high viscosity but in most cases when you want the flow to happen fast you can choose a lower viscosity. In the case of floors all 3 slump flow classes are defined here but what experience has shown is to avoid plastic shrinkage cracking you want to be at this level perhaps even push up your viscosity to some extent to ensure that you do not get segregation after the concrete comes to rest. So, again this is just a recommendation by one of the researchers who worked on the EFNARC guidelines but again all of these have to be looked at in the specific scenario that we are doing the construction.