Concrete Technology
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Lecture - 38
Special Concrete: Self Compacting Concrete

We introduced, we discussed on you know in the last lecture, we talked about self-compacting concrete. We will continue with that today. At the end, we will also introduce fiber concrete.

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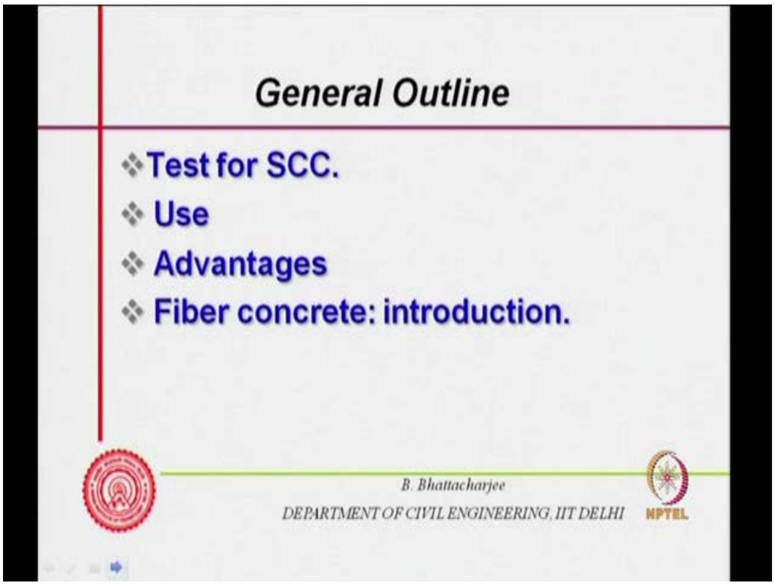

So, outline of to this lecture would be some test for self-compacting concrete, it use, and advantages, then we will have introduction to fiber concrete. Just to remember what we did in the last discussion last lecture, we said that water to powder ratio should be 0.8 to 1.1 by volume something of that order. Total powder content ranges from about 400 kg per meter cube to 600 kg per meter cube powder. Remember, powder means cement plus even fly ash or any other inert material. So, all that comes into powder; course aggregate content of 28 to 35 percent of the mix volume, and water content less than 200 kg per cubic meter. Fine aggregate content is generally higher in this one, 48 to 55 percent of total aggregate.

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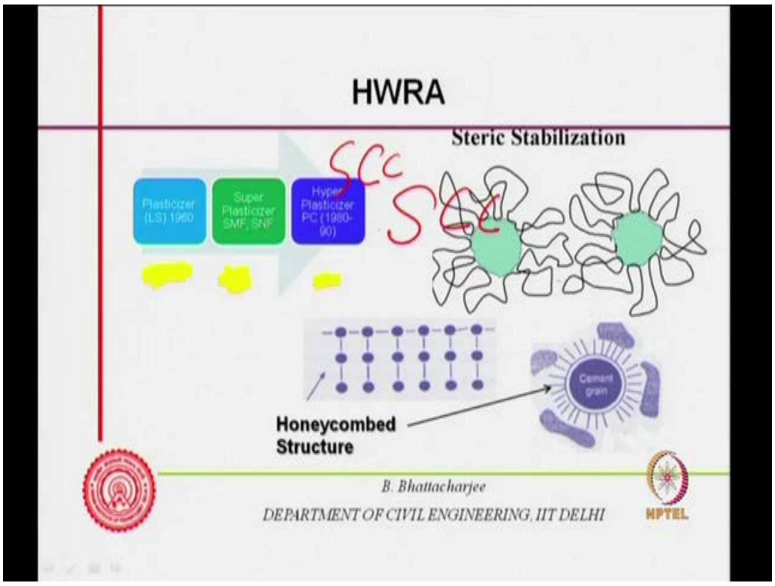

This was possible because of very high range or ultra-high range water reducing agent. And this is if you look at the plasticizers, 1960 super plasticizer. Basically sulphonated melamine formaldehyde and sulphonated naphthalene formaldehyde. They are actually 1970s. Then, poly carboxylate ether was 80s and 90s. Some modification of this one through polymer modification, in between, all that occurred. All this led to our honeycomb structure that could be form obtained from this poly carboxilate ether type. This is what led to actually SCC. This is what led to SCC. This arrow shows, this was led to SCC.

So, these are the honeycombed structures. We know that for this one, this because of this static stabilization, it would actually disperse the cement rain more. That is what resulted in this kind of concrete that is self compacting, concrete self compacting concrete. So, this is the, this is water scotch. This we discussed earlier. What is static stabilization and a kind of pc how do they work? These we have discussed when we talked of chemical add mixtures to concrete. We are just creating the same thing; a little bit more. Historically, this has lead to self compacting concrete. So, that is what we are saying. It will have to self concrete.

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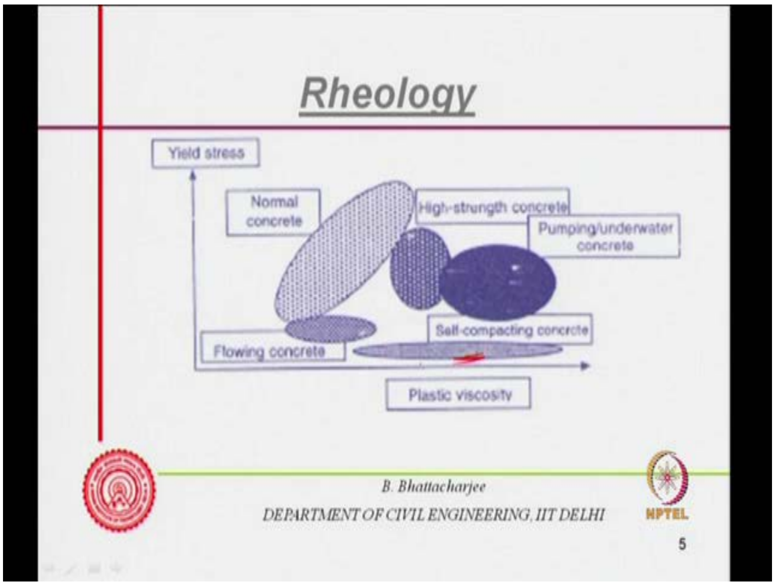

If you look at the rheology plastic viscosity along this direction, yield shear stress along this direction, the Newtonian fluid will go somewhere there. Newtonian fluid will go somewhere there. That will be a linear line with yield shear stress being 0.

So, flowing concrete should have; lot of, very low flowing concrete will have very low yield shear stress. Normal concrete lies somewhere there with some amount of yield shear stress and the viscosity being there somewhere. So, normal concrete will lie somewhere there. High strength concrete has more paste remember. Therefore, the change, like the yield shear stress might be somewhere there to yield some of this range depending upon of course, flow properties and viscosity ranges varying from this to this.

So, this is high strength concrete because paste content is more. Pumping concrete should have low viscosity; low yield shear stress and viscosity should be somewhere there. Now, why yield low? The yield shear stresses it can be send some amount of yield shear stress. How? This is because it can yield some amount of yield shear stress because you will be pumping them. So, there is a pumping pressure. Only thing it should remain cohesive and should not segregate internal pressure disturb relative motion between particle should not be there within it. It must form a plug; and then move so that is pumping able concrete.

Now, self compacting concrete is somewhere here flowing concrete. So, very little yield shear stress and viscosity ranges from here to there. So, viscosity ranges from here to there. So, that is where in the rheological scenario self-compacting concrete location is somewhere there should have very little yield shear stress. It should flow straight away. So, that is what self-compacting concrete is. So, it lies here somewhere. It lies here somewhere.

So, the test went for self-compacting concrete. So, we actually looked into all the principles of self-compacting concrete. What it is, why it becomes self-compacting etcetera in the last lecture. Then, we continued a little bit. Now, we can look into the test methods meant for self-compacting concrete obliviously. Since, it is flowing highly flowing, does not require any compaction, so we cannot use the conventional slum test or compaction factor test. compaction factor we nearly one practically no variation. This is because it will be it is, it will just fill in and obliviously we cannot use vv test, which is meant for stiff concrete.

So, this is actually a vv time will be 0 in all the cases. Therefore, you have to device new test for this one. Several tests have been devised. There are large numbers of them. Some of them have been codified in some codes, but still to be universally accepted single or two tests, which will be suitable for self-compacting concrete. Its property to at least define it as a self-compacting one, there is no single test. Currently there are large numbers of test. They are getting gradually codified.

You remember the requirement of self-compacting concrete. We said it should have filling ability, passing ability, flow ability; and remain cohesive and so on. So, forth segregation resistance several properties we talked about. Now, there cannot be any single, single single test by which I can determine all those requirements or all those properties. So, how do I measure? For example, resistance to segregation, its and quantification is of course, is still far. So, at the moment, there is no quantification, but some empirical tests are been devised. We will discuss some of them.

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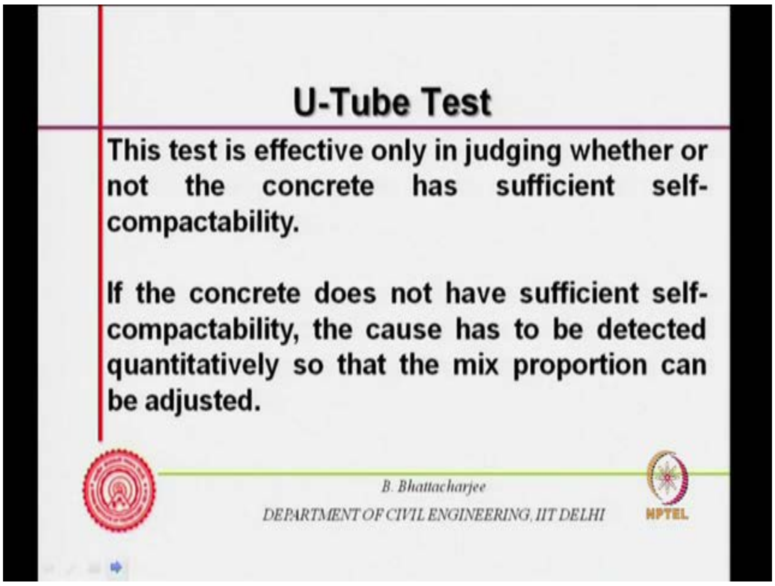

So, one of the test is U tube test. This test is effective only in judging whether or not the concrete has sufficient compact ability. Will it compact itself? It will not be, it will not be able to judge the flow ability to a great extent or other requirement segregation resistance. So, it will not be able to judge the segregation resistance and such thing. If the concrete does not have sufficient self compact ability here, the cause of course has to be detected and the mix proportion has to be adjusted. I mean there should be any void in the system. It should compact on its own. So, this looks for self-compact ability.

How does it will look? I have actually a U tube separated by a barrier, kind of a barrier separated by a barrier. So, this is the U tube. This is the U tube. Then, there is this, this is the partition. There is a barrier. Now, this is actually a gate, which I can open. So, I am filling the concrete here. First dimensions are of the order of around whatever is given 660 mm and so on 260 mm and that kind of thing. Dimensions are by enlarge given to 280 mm. Dimensions are given by enlarge. The dimensions have to fit in. so, this 280 mm, 680 mm and so on, so forth and there is a gate, which I can open.

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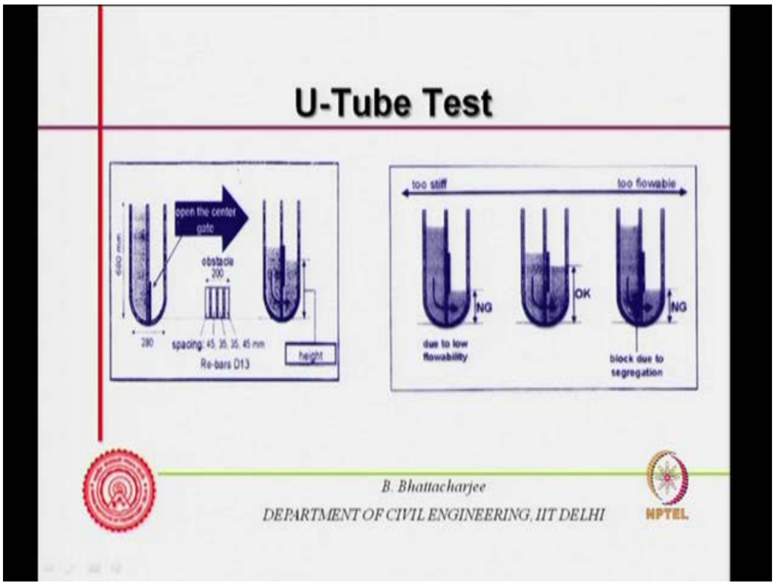

So, I fill in the concrete here. In this place, there is an obstacle. Also, there are bars. Reinforcement bars are there. The spacing between the reinforcements is there. They are actually 16 mm bars and obstacles are there. So, what you do is followed from this. I just leave this up and allow the concrete to move from here, allow the concrete to move from here.

Now, if it is self-compacting, then this height should be same. So, if this is not flowing due to low flow ability, if it is not flowing, it is because of the segregation. Then, it cannot be self-compacting. So, this is too stiff mix. It is a stiff mix. It does not move at all. It does not move at all. It is very stiff due to low flow ability. It is a stiff mix, not self-compacting.

So, the stiff mix does not move at all. Only little bit it moves. Actually, it is too flow able, that means might cause segregation. Water might have moved, but the solid might have got stuck here. Solid might have got got stuck here. Thereby, it results in higher density. It is the solid at this place and only water flowing down there. Solid remaining is sort of kind of accumulating here. Therefore, it is not self-compacting.

Therefore, it is not self-compacting. A self-compacting one will have water. Of course, if I put it, they will have it will adjust. It will just have equal height, but this is not water. So, it should be sufficiently close to each other, sufficiently close to each other. So, it is called U tube test.

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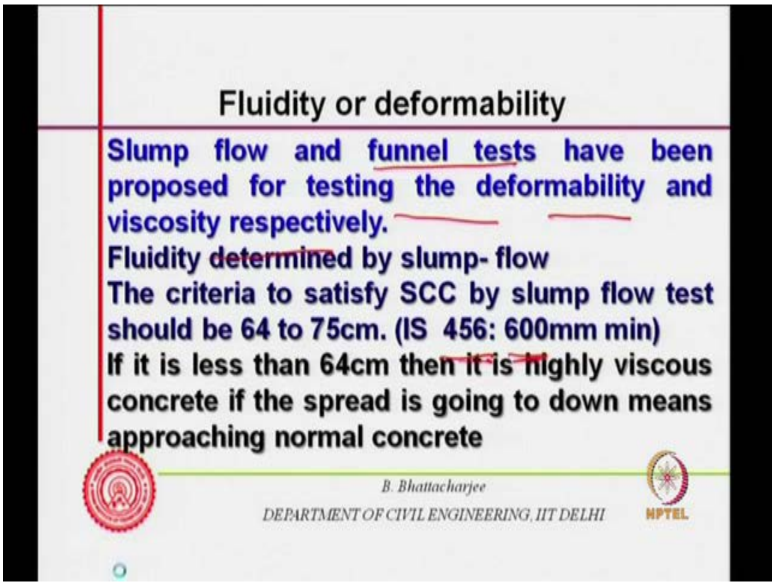

So, this test gives us self compact ability. Slump flow gives us fluidity and deformability. So, 2 other tests, one is a slump flow test and other is a funnel test have been proposed for testing deformability and viscosity respectively. Therefore, fluidity is determined by slump flow. The criteria to satisfy such self-compacting concrete by slump flow test should be 64 to 75 millimeter centimeter slump flow. IS 456 204 456 2000 of course, defines 600 mm minimum flow to satisfy. It has a self-compacting concrete. So, this is actually determines fluidity. Now, how does it do it? I will come to this. I will come to this.

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This is your slump cone and these are the markings. This is about 500 mm. Then, if you you fill it in the standard manner, as you fill it in lift it up; it should get spread like this. This is done to measure the spread, measure the spread. So, this spread is a slump flow. This flow minimum should be this flow minimum should be 64 to 75 centimeter from 30, 20, 20 centimeter to it should go to about 64 to 75 centimeter. IS 456 says minimum it should be 60 centimeter or 600 millimeter to define it as a self-compacting.

So, minimum for self-compacting concrete is given. If it is less than 64 centimeter, then it is highly viscous concrete. If the spread is less low down that means approaching normal concrete, so spread should be sufficiently large. Therefore, it is viscosity. It is higher viscosity has a tendency. If it is lot of resistance, then it will not flow. So, it is somewhat measurable. It is related to flow a fluidity of the system, fluidity of the system. So, that is what it is, what it is the slump flow test.

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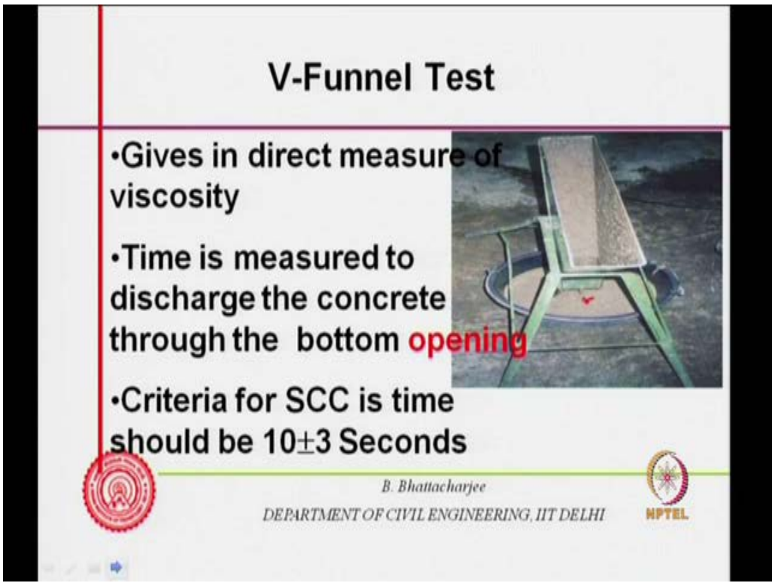

This is very popular because it is an easy test. V funnel test gives direct measure of viscosity. Sort of it gives some direct measure of viscosity. That is what is people felt. You have a funnel, which is closed at the bottom in the beginning and open the gate at the bottom. Fill it in a standard manner. Then, the time is measured to discharge the concrete through the bottom opening, which is in now initially closed, and then it comes down here. If this time is 10 seconds, 10 plus minus 3 seconds, then you can say it could be self-compacting.

So, basically, you determine the fluidity. This determines viscosity. So, this determines the measure of viscosity. This is a measure of viscosity. So, higher flow means what I mean if it takes longer time that means a stiff concrete does not have flow ability. It is not proper because it is flowing through that bottom opening. So, the kind of viscosities would dominate. So, if you have too much of friction or viscose resistance, then it will take longer time. If it takes too less time may be this, it give might have a segregation tendency. So, therefore, that is why that is why it is that. That is why, this is 10 plus minus 3seconds time. That is what V funnel test is.

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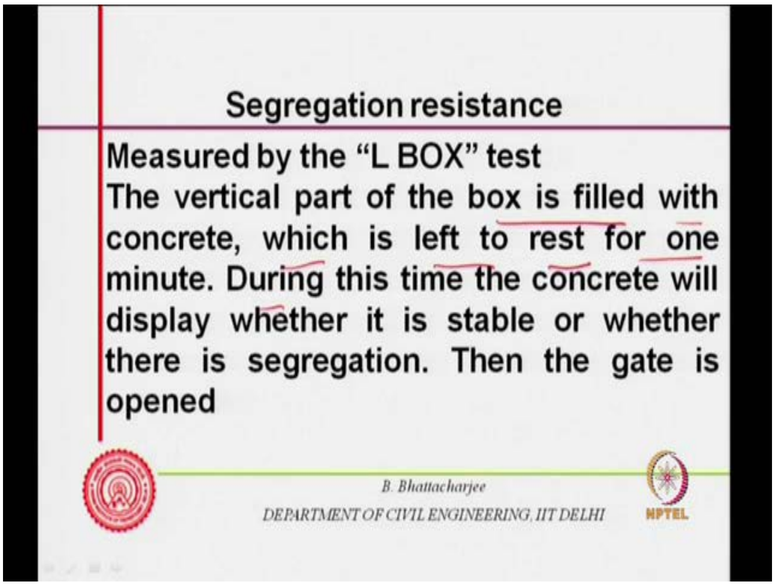

Now, segregation resistance is measured by L box test. This segregation resistance is measured by L box test. The vertical part of the box is filled with concrete, which is left to rest for 1 minute. During this time, the concrete will display whether it is stable or whether there is segregation. That means when you keep it 1 minute in a vertical part of the L box, which we will see just now, if it is, if we leave it for some time, if there is too much of water segregation, it will come up. So, if it is not segregating, then you open the gate. As we shall see that you open the gate.

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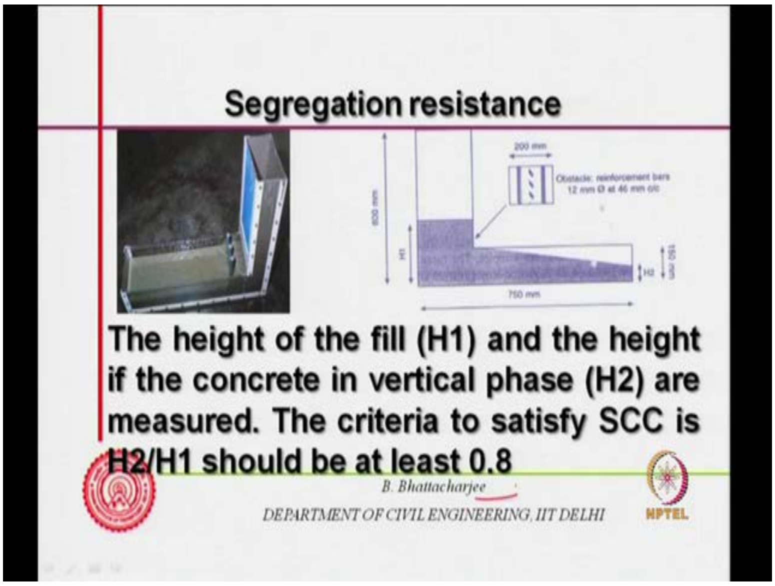

So, it will look like this. So, this is the L box. So, you fill it. This is there is a gate here. You close it. There are obstacles here. So, the gate remains close and fill in the concrete in a standard manner be there. Keep it there for 1 minute also. If there is no segregation, we allow it to past through. We can judge whether segregation was. Then, obtain the gate. It will past through this obstacle and fills in the concrete at this portion. It will fill in the concrete here.

So, it will look something like this through the obstacle. It will pass 200 mm is the width of this one. These obstacles are 12 mm bars at 46, 46 mm spacing as a rate of 46 mm center to center spacing. As it pass, the concrete here would be like this. This height we call it H2. This H1, this dimension is 750, 760 mm. This is 600 mm and so on so forth. This is 150 mm. So, it allows it to pass through it if this to H2. H2 by H1 is equals to 1, and then it is perfectly self-compacting. The water would actually make this to height same.

For self-compacting concrete, this should have a minimum ratio. That ratio is 0.8. So, that ratio is 0.8. That ratio is 0.8. So, it should be at least 0.8, at least 0.8. So, it should satisfy the criteria satisfies; SCC should be H2 by H1 should be at least 0.8. If it is 1, then that is very good. So, it should be 0.8. It should be 0.8. It should be 0.8. So, that is what it is. So, this is another test. So, you can see there are several tests so far we have looked into. There are more tests actually.

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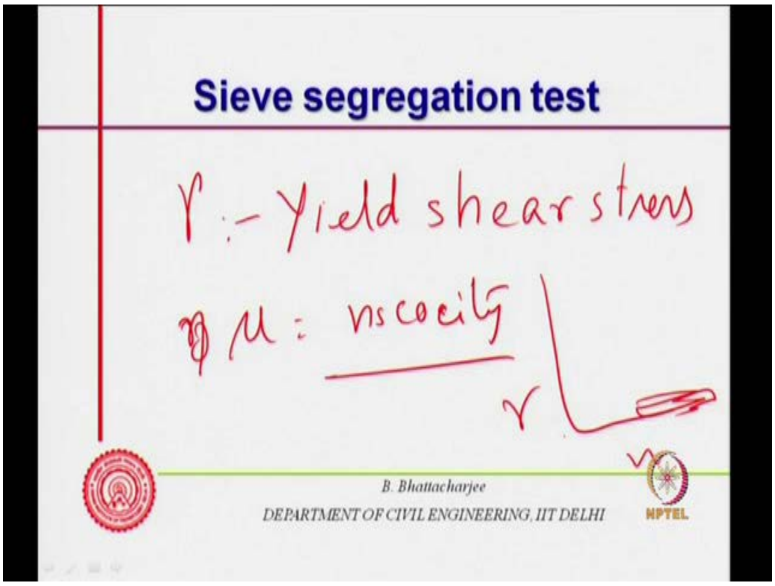

For example, there is sieve aggregation test. Now, the problem is we are yet to; actually we are yet to find out. First of all the criteria like you said filling ability, passing ability, compact ability, segregation resistance, fluidity, all these are several requirements. So, if we could is how do you quantify this requirement actually to quantify the requirements? Some sort test should be devised, but then they are not all independent. This is because if you have high fluidity may be that will help in compact ability. If you have for example, passing ability that might have again relative to flow ability.

So, there are there is there at the moment, there is kind of kind of no uniformity. You see when you are very confident about certain things, when understanding has grown very well; you need only 1 test or may be 1 parameter to define everything. You need 1 model at least to define everything. Here, the confidence is yet to build up on the understanding and a single test cannot. Now, there is no single test. So, there are several tests as I said suggested by different people. Finally, possibly over the yes, it will come into a kind. Now, let us, it will get reduce down somewhat.

If one wants to look for fundamentals like Bingham's model, then this should have Bingham's model. Then, this should have been the gamma yields shear stress and the viscosity you call it nu or mu or whatever it is you call it mu. So, this this could have viscosity should have been sufficient. But, at the moment, this is not really happening that way. For example, we said that gamma versus viscosity, we plot it. Somewhere here, it should lie. So, if there is no way to measure gamma, I mean there is no, I will say not really no way, there is no universally accepted method to measure gamma or mu the rheological properties.

But, supposing that I we could have done this, we would have said that for being it being self-compacting only 2 1 measurement. The rheological measurement determines gamma as well as mu. You say, if the gamma and mu ranges between these ranges, gamma should range from 0 to something. Mu should range from this to this. Then, I will call it compacting, but at the moment, we are not at that stage. The way to measure this self compact ability is still not really universally acceptable.

Neither the rheological properties are no universally acceptable accepted method for measuring rheological properties. I mean rotation viscose meters are there, which we talked about the tau versus rpm and etcetera etcetera. Remember, we showed some graph earlier when you are talking about rheological properties. So, the this viscose meter themselves are not really so far universally accepted. So, therefore, we have large number of tests.

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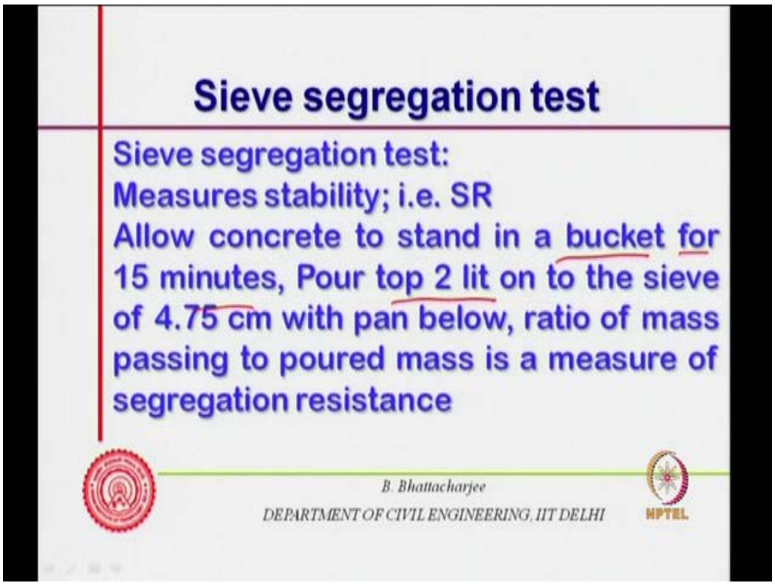

So, we have one more test that is sieve aggregation test. Now, this test measures segregation resistance. It measures segregation resistance. Now, what you do? You allow the concrete to stand in bucket for 15 minutes. Pour 2. The dimensions of this system will be fixed actually pour top 2 liter on the sieve of 4.75 centimeter. It can be centimeter

4.75 millimeters; 4.75 millimeter centimeter should be this. No, no, 4.75 millimeter stands size. It is a stand does a mistake. So, pour top 2 liter on the sieve of 4.75 centimeter with a pan below. Ratio of the mass passing to poured mass is a measure of segregation resistance.

So, what you do? You take the top 2 liter from a bucket, put in on to the sieve. The amount passing through it, amount passing through that sieve is it is actually is a measure of segregation resistance. This is because you have kept it for 15 minutes. Now, if there were segregation, for example, if the water is coming out and the solids so larger particles etcetera go down below. Then, actually quantity passing through this civil will be very large. So, if the solid, even the finer solid is separating out along with water. It is taking out the final material too much. Then, passing through 4.75 mm, most of it will pass through.

So, the quantity that is passing is a measure quantity. A proportion of the mass passing is the measure of segregation resistance. If it is less actually if it is less actually that means the reality proportions of the fines water to the total mass that is that is that is that is that that would be I mean that should be appropriate. So, you can actually relate this to the segregation resistance. So, one can relate this to the this segregation resistance.

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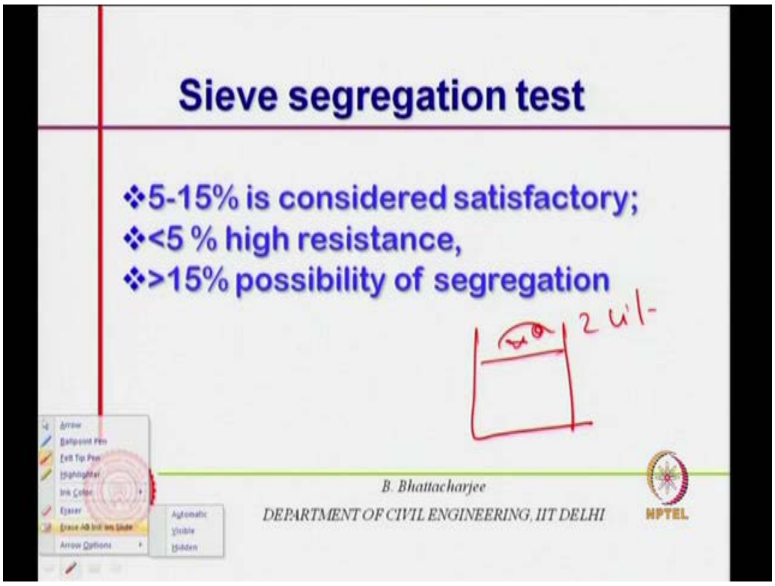

One can relate this to the segregation resistance. 5 to 15 percent is considered satisfactory, less than 5 percent is high resistance to segregation. This is because nothing is passing and more than 50 percent is possibility of segregation so less passes through it. First of all, you have separated out separated out taking only top 2 liters top 2 liters 2 liters from the top. So, if it contains a lot of fines, if it contains a lot of fines and not larger material. But, supposing it is not segregating larger material also will be here larger material also will be here.

So, if you take the top 2 liters larger, so it is not segregating it right resistance to segregation. So, high segregation resistance might reduce on the flow. That is why, less than 5 percent may not be desirable, but if more than 15 percent is passing, that means it contains mostly the fines. Therefore, majority is passing through it. Therefore, this is a measure of segregation resistance. This is a measure of segregation resistance. This is a measure of segregation resistance.

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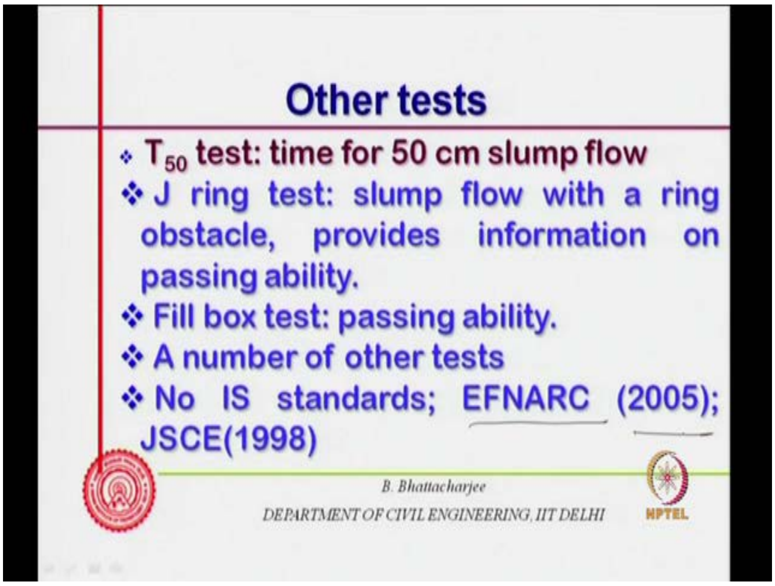

Then, this this is another test T 50 test. There is this I already talked about L box test, some more tests. We will talk about T 50 test is time for 50 centimeter slump flow. So, you find out measure that measure flow as against time measured flow against some flow against time with time how slump flow is changing? So, time at which 50 centimeter slump flow occurs that is T 50 test, so that gives you T 50, 50 test. So, that is again that is a measure of slump, any way slump retention. It will be slump retention or related to another another test.

Actually, J ring test is slump flow with a ring obstacle. So, you have the same slump flow. There is an obstacle. There is an obstacle. There is an obstacle. There is an obstacle. So, there will be obstacle obstacle here. So, it is a J ring test slump flow. Ring obstacle provides information of passing ability. So, whether while flowing, it is actually trying to combine the fluidity with passing ability. It is trying to combine the fluidity with passing ability. So, then you can find out the flow after putting the obstacle. What is a flow? So, that would be a kind of measure of fluidity plus passing ability.

Fill box test that is again a box, in which concrete is filled in first. Then, it is allowed to move through some, a number of obstacle reinforcement bar etcetera etcetera. In the J ring test, it also had reinforcement bar. So, bars making the obstacle through, which it has to flow. So, this has also talks about pass. It is a box through which concrete is again allowed to pass and passing ability. Since, obstructions are there in form of in form of bars, so this is also is a measure of passing ability.

There are a number of other tests as I said. Since, we are still not in a state to finalize only a few set of tests, may be 1, 2, 3 or 4 or may be 2 tests or 1 test. It can measure all the properties. It may be difficult at the moment to measure 1 test, but 1, 2 test empirical test. Therefore, there are number of other tests. So, a lot of people have developed lot of tests. This is where the state of is a status.

So, we discussed some of those tests. We do not have Indian standard. There is a European one. So, EFNARC is a European one guideline 2005, this was available. It includes some of those tests that I just talked about. Then, Japanese standard for civil engineering 1998 that developed some of those test at the moment Indian standard only talks of 600 mm slump flow. So, the tests, status of the tests are here only.

SCC for various applications, depending upon the application, you will require viscosity form lower to high slump flow from lower to higher and passing ability to segregation resistance, passing ability to segregation resistance. Segregation resistance some cases, you would require segregation resistance. It should not segregate somewhere. It should have passing ability. So, the kind of some guidelines is available. For example, ramps where concrete can slide down. You do not want very high viscosity. So, it should be lot of resistance to movement viscose should it should be kind of sticky.

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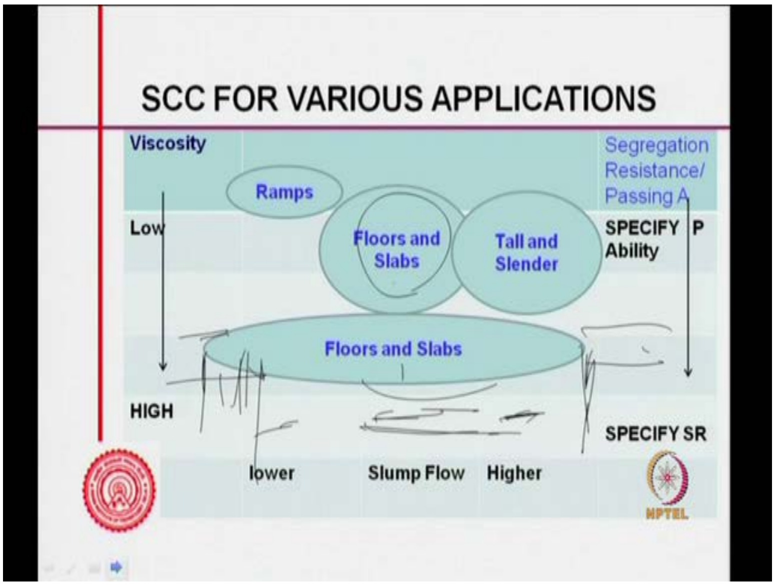

So, therefore, ramps you have low viscosity lower slump flow flow ability also you do not need very much. You need a lot of passing ability in this zone. You need passing ability, passing ability and floors and slabs tall and slender structures. You need low flow low viscosity, high flow tall slender structure and also passing ability. This is because you might have slender structure lot of reinforcement. So, this flow could be, you need lot of flow and therefore, should have passing ability also.

This will be part of floors. Slabs can be floors of slab, thin floors, thin slab, but larger floors and slabs, which are flat. You might require segregation resistance to be specified. Depending upon the situation, you might require higher slump flow or lower slump flow. They are more to this. I think I have just picked up some of them. In fact, this is just to explain. This is this diagram is little bit high up. It could be somewhat down as well.

So, for example, floors slab might it is, but it explains that I should have floor slabs, ordinary floor and slabs slightly thicker could have very low viscosity to high viscosity high slump flow. Of course, the viscosity is somewhere there and segregation resistance could be there. In some other thin structures, thin floor and slabs, it would be like this. So, this gives us some idea where for, what kind of application, what you take care. There are many more like this. So, this is just simple. A few of them are shown here.

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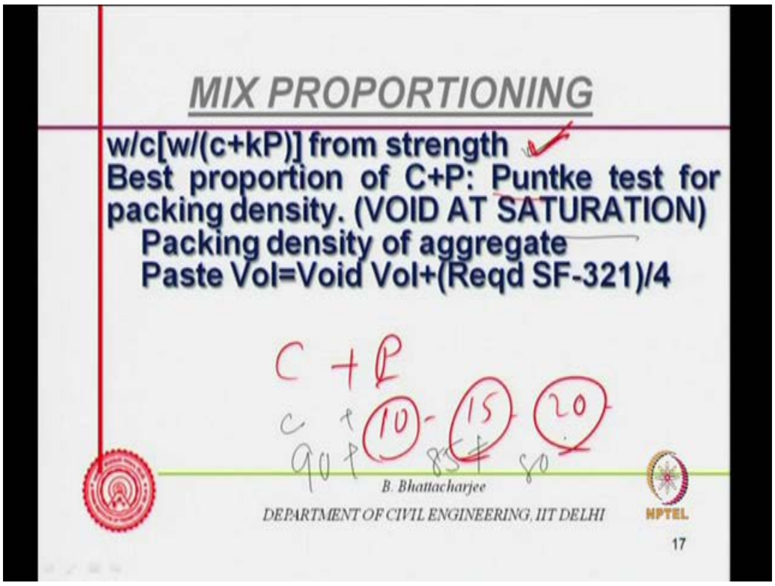

Mix proportioning water to cementations ratio from strength. First of all, you must determine water to cementations ratio for strength. So, this is from strength criteria because that would go on the strength best combination of c plus pozzolana or any other material that you are represented. You can use a test called puntke test use for cement fly ash because this uses, it find outs the best packing density that is avoided saturation situation.

So, what you do you mix? c and p, that is your cement plus other powder material in the proportion that you like, which will vary. May be it starts from 10; go to 15, 20 percent etcetera etcetera. You add them up together mix, mix 90 percent, 10 percent, 85 percent, 15 percent, 80 percent, 20 percent and so on so forth. So, different proportions you can take and then mix for a specific case of 90 90 cement, 90 cement 90 cement plus 10 p.

So, this is c and this is p plus this p 10 for specific combination. What you do? You put them in a container, measure their mass etcetera etcetera by various kinds. Several mass are empty container mass with cement mass with mass with powder other powder material and so on. So, you add right proportion, add them up in correct proportion, add water to the system and remove all to find out in the saturated state. What is a void content void content? What is a saturation state? What is a void content in the saturated state?

What is a void content? How much water has gone in actually by various mass measurements? There is a formula available. Then, next change it to 85 plus 15 and do this test. So, void content in each stage, you can find out. If the void content overall volume total because mass of the materials are known, their specific are known, total voids, total volume of the solids you can find out. So, volume of the solids and volume of the voids are known. Therefore, you can actually find out packing density. You can find out packing density.

So, this punkte test can be used, which is actually used for fly ash cement combinations. So, you can use this test for finding out the best packing density for cement and powder. That combination, you can use that combination, you can use for your self-compacting concrete. Packing density of aggregate you can measure, which we have talked about. So, paste volume would be void volume plus required slump flow. This is an empirical formula developed at IIT Madras actually.

IIT Madras, they have developed this. The equation may be different, but the idea is that paste volume is void volume plus how much paste, extra paste you need. It would depend upon required slump flow. It would depend upon required slump flow. Then, they found it out to be required slump flow in millimeter minus 321 divided by 4. They found it out to be like this.

So, for example, if this is about 640, you need so or 621. Let us say for simple case, so 300 divided by 4 void volumes 300 divided by 4 must be expressed in terms of volume in some c c or whatever it is. So, this will be 300 divided by 4 whatever. If this is a empirical formula, so the one all I can say for at the moment is that it will be required. Depending upon the slump flow higher the slump, flow required more will be the more is the phase volume required.

This we have understood from the fundamental because it is a paste on which the aggregate will have a kind of a piggy bag ride on to the system. Therefore, it is proportional to proportional to proportional to slump flow higher the slump flow required, you will require more paste. The equation of course, is empirical. So, the unit etcetera to be seemed, but this equation may not be universally valid. They found out in one case. Somebody else might find out somewhat different these values and so on. But, at least, qualitative understanding is very clear. What volume plus if you recall more slump flow fluid more fluidity, then you require more paste. This is understood. This is understandable from our discussion in different lectures. This is understandable.

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Super plasticizers, those are optimized by slump mini slump test, which we talked about. So, 170 spread and there is no bleeding. That is what gives us super plasticizer dosage. First, you find out the compactable super plasticizer. You can do mini slump test or mass count test or whatever you like. As we discussed earlier, this is a guide line given that SP dosage would be 170 spread. So, this 170 spread is what they are actually suggested, but it could be different. More spread with no bleeding from this actually mini slump test, you can determine what is the SP dose required.

Viscosity modifier, if required there is a test marble test, which is used for viscosity modification, whether you how much quantity of viscosity modifier, you need or do you need it at all. The viscosity modifier, which I did not mention much, actually is required to make it. If there is a need to reduce down the segregation, improve the segregation resistance, what will happen when you are adding too much of water and too much of adding the super plasticizer, high plasticizer whatever?

They do by tendency to actually cause excess dispersion. Therefore, the water might get out, may not remain, and may not be within the system. If you have sufficient finds very find the powder material, then it is still may be holding it particularly fly ash etcetera, which increases the cohesiveness can hold it on together. In internal separation, it will provide resistance against internal separation of the particle. That is particle to particle distance within the whole system of concrete, larger particle to larger particle, they will not relative motion would be minimal while flowing.

Supposing that this is not happening, then you can use v m a viscosity modifying viscosity modifying agent, which are nothing but we said that they would actually increase the stickiness kind of glue. They will try to increases the stickiness. That is what we have seen for under water concreting. Also, we use v m a sort of thing. When we talked of ad mixtures, we talked about this viscosity modifying agent or viscosity modifying agent. They are there. So, you might use them.

Now, how much quantity you want to use? What you want use whether you want to use at all or not. You can actually find out from a test called marble test, other test for self compact ability. Then, of course, you have to do trial. So, there are several tests. All those test, you tube test etcetera etcetera. You can also do in addition to doing this kind of test. Then, do the trials to see there it is self-compacting.

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So, laboratory to laboratory, they will actually select the test. This is a kind of a guide line one. One can use for mix proportioning as a simple way. This is from strength c plus P powder combination from punkte test packing density that you check for aggregate. Then, super plasticizer dosage maybe per mini slump test viscosity modifier application if required from marble test and other test if required. So, what are the advantages? The advantages obviously first is speed of casting. You would self-compact, you do not require vibration. The speed of casting will increase less labor.

That is of course, an advantage in h western countries. This is because as I told you, first it came from this for these 2 purposes, no noise and less labour cutting down on to the level cost of vibration. So, cost of vibration, use of vibration is actually cutting down on that, but then cost of the self-compacting concrete will be somewhat higher than normal concrete. But, if it is cheaper putting together the labor cost, which I have not, showed in Indian scenario how does it work. Even it must be working pretty well. This is because this is when self-compacting concrete has been actually readily taken up by the construction company. Several projects actually have been used actually this.

For example, what first one temple in Chennai, then the Delhi metro it was also used and there are several other places being used at the moment. So, the total cost must be there, must be cost saving, must be there in terms of labor saving. Although the self-compacting concrete itself may be slightly costly, there are compaction surely better compaction and of course, no noise.

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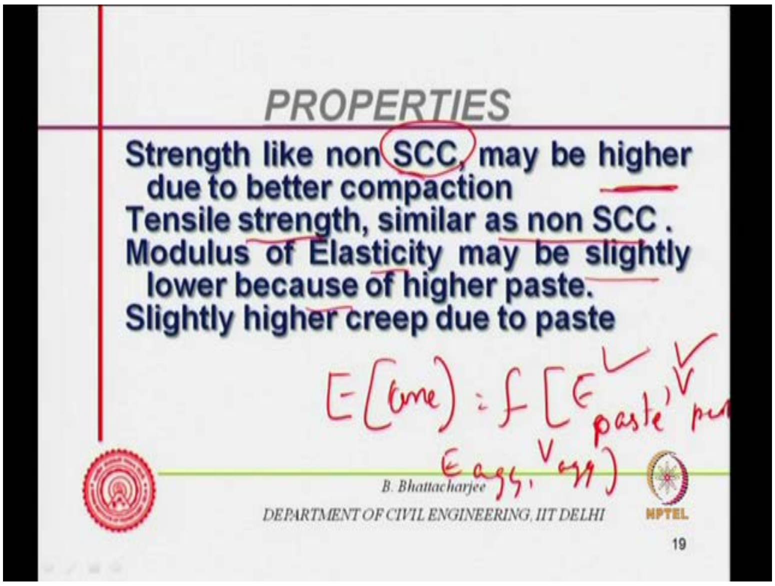

So, vibration noise would not be there. This advantage cost saving can come because this saving would be there. Saving on this would be there, a cost less labour and even saving on vibration machineries compaction machineries etcetera for a better surface. As I told you, it is used in India in many sites. Many sites have actually; I used this self compacting concrete. So, self compacting concrete has been used by in India by many sites.

Let us see the properties strength like normal concrete that is non self compacting concrete. There is no really impact on strength really significant, but may be higher. So, strength is like non self compact concrete. This is because finally, it is the water to cementations ratio, water to cement ratio, which we are using as a criteria that governs the strength. Therefore, self-compacting concrete will be as good or as bad or as you desire may be higher slightly higher. This is because for better compaction, there should be any question on tensile strength.

It will be similar as non-self-compacting concrete. After all, we have seen that empirically tensile strength is related to the composite strength. So, therefore, there is no question modulus of elasticity. It may be slightly lower because of higher phase content. Now, here is a modulus of elasticity. We talked about E of the concrete. Concrete is a function of E of paste E of paste E of paste volume paste volume and E of aggregate and V aggregate. So, since I am increasing V paste and E paste, it will depend upon E of the paste. So, it will depend upon the situation where E paste is high. That means in a high strength situation, if you have self-compacting, then modulus may not be lower.

So, it will depend upon what is E of the paste that you are using. So, it could be effected somewhat, slightly lower, higher paste content depending upon E of the paste, might have might have slightly higher crib due to paste. This is because paste is responsible for creep shrinkage etcetera etcetera. So, it could be slightly higher because of the paste requirement shrinkage may be non-same kind of situation might be valid here. Drying shrinkage if it dries out, then drying shrinkage chemical none autogenously and all those shrinkage, there may be similar as the non-self-compacting concrete. After all, here another of course, this is related to the permeability of the system.

Now, if there are something similar, water cement ratios, all these are similar. Then, it would be similar as non-self-compacting concrete. But, the paste volume is more. So, if the paste, whatever paste volume, whatever properties are affected by paste volume, this will also be affected by the paste volume itself.

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So, better bond strength, more paste could give you better bond strength of the steel. Fire resistance will be similar to non self compacting concrete. Durability may be some slightly better than better surface because of the better surface concrete. Since, surface may be better, it may lead to difference.

This is because we have seen the durability is related to surface concrete. Durability is related to surface concrete near surface concrete. Therefore, this may be slightly better. So, there is no significant, really no significant, no significant difference with the no significant difference with the non non-self-compacting concrete. In the properties concern, most of the properties will be similar. Most of the properties will be similar. It has been. That is why, it has been readily, it has been readily expectable by the by the construction industry unlike many other new special concrete, which are specific application oriented.

Self-compacting concrete has been actually readily acceptable. Example, I think the signature bridge in Delhi, which is been constructed now is also another example where self compacting concrete is being used. So, self compacting concrete has found its use in many places. The popularity, the cost, the cost effectiveness is very much there in this particular concrete. So, but it needs lot of understanding development of silk, lot of understanding is required in terms of its fundamental understanding.

So, that is what self-compacting concrete is. One can of course, discuss much more about it in terms of the test methods that has been devised because as I said if we, if it is all universally acceptable, then there will be less number of tests. At the moment, there are our understanding are easier to develop as far as behavior I mean self-compact ability etcetera are concerned.

Therefore, you have large number of tests. One could have covered more. Then, our time frame is limited. Therefore, this is what you can discuss. You can just conclude our discussion on self-compacting concrete. So, the next special concern that we look into is fiber concrete, fiber reinforced concrete, which I will introduce today. They again continue with the next lecture. Now, fiber enforcement has been used for much long time for many years together in materials.

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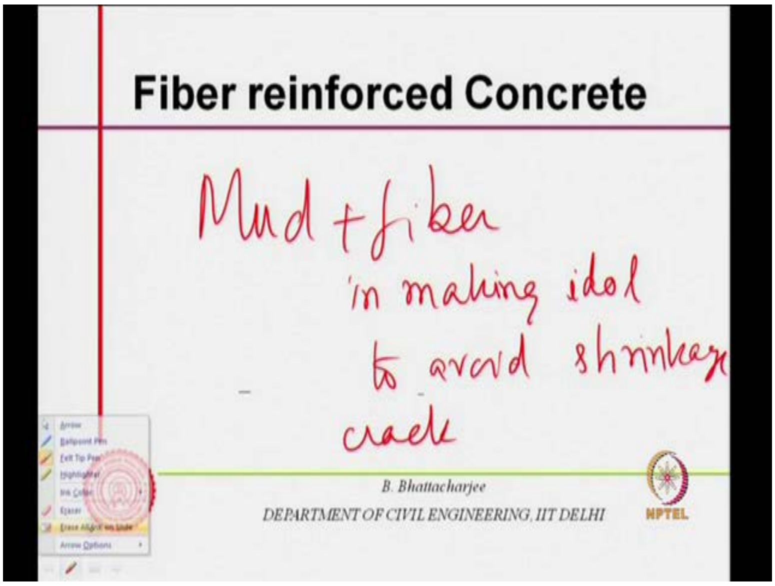

For example, you use with mud fiber reinforcement with mud plus fiber in making idol in making idol in making idol to avoid shrinkage to avoid shrinkage crack to avoid shrinkage cracks drying shrinkage cracks shrinkage cracks. Therefore, many years or similar other material, you put fiber too actually, which can erase the cracks. Therefore, fiber has been used for many many years and in concrete also. It is relatively older compared to other concrete. That is so far we have discussed. It is older, much older because it is been used extensively in tunnel lining and such place over the years. So, let us look at where it is used.

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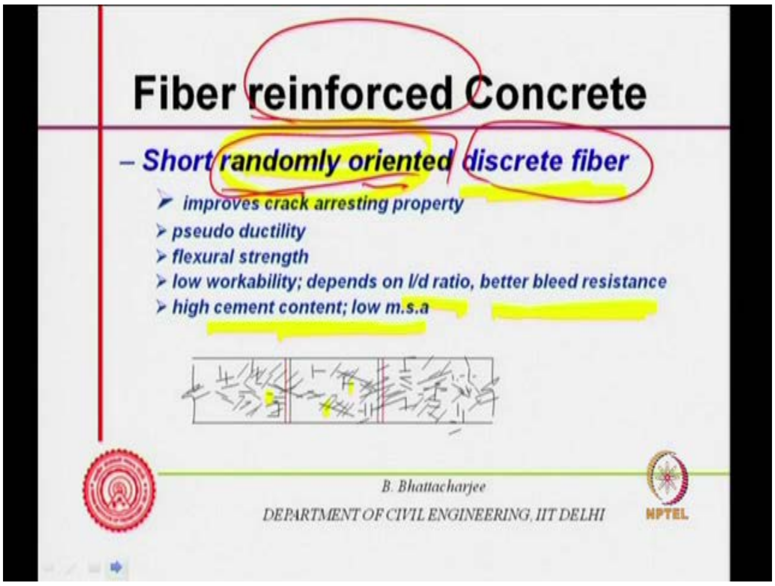

Where it is utility? Now, when we are talking of fiber or fiber reinforced concrete, we are essentially talking of short randomly oriented discrete fiber. These are randomly oriented fiber, just basically randomly oriented fiber. They are not aligned. I mean you can align them, align if you do, then it will be very good. For example, slurry infiltrated fiber reinforced concrete could be, you have can have fiber align or if it is long fibers, you can even align them and possibly make a mat out of it. That is a different one. But, it is quite commonly used. This short randomly oriented discrete fiber that is what we are talking of.

They are conventionally different than conventional reinforcement, which we normally understand in concrete. They essentially improved the crack aerostation property pseudo ductility. They would provide. How they will provide? You will look into them flexural strength enhancement is there. Obviously, they do not improve the workability. They are like elongated aggregates. Therefore, they lower the work ability. It will depend upon l by d ratio bleed resistance, but provide by the bleed resistance.

So, we will come to each one of them. Just to understand this material, let us look at it high. Obviously, they will have cement content m s a is low. Why this, all this we look into? So, that is the characteristics of fiber reinforced concrete. So, let us say this is your concrete. You have discrete fibers like this are the discrete fiber. So, when the crack comes, they will actually bridge the crack.

When the crack comes, they will actually bridge the crack. That is how they provide crack aerostation property. So, that is the understanding of where fiber, the utility of the fiber or how fiber, where fiber improves. So, you can now look into some details, but before that, we can quickly look into some theories, which we will discuss little bit today.

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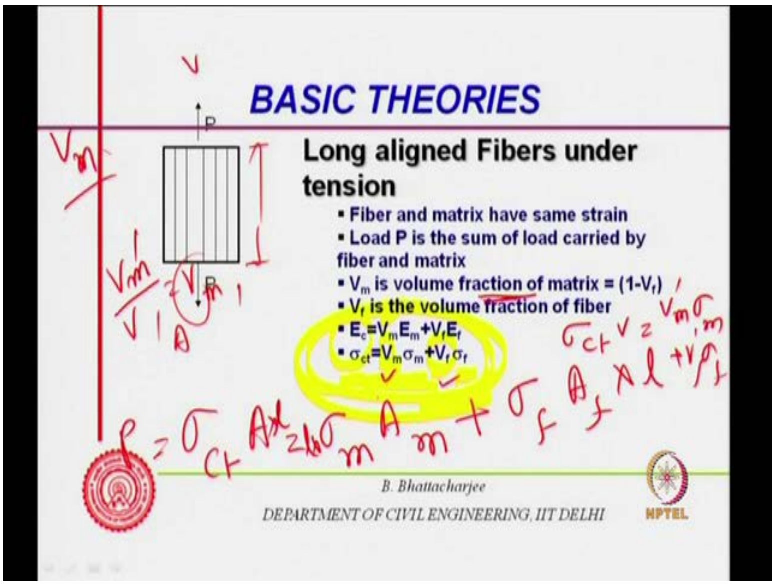

Supposing that this is your material, which is your matrix as we call it concrete matrix. I have put some aligned fiber there, put some aligned fiber there. Now, I apply a tensile load, apply tensile load on both this direction, apply tensile load on both this direction. Now, actually material is in parallels. Materials are in parallel P, P load. I have applied. So, part of the P will be shared by they will be strain will be same epsilon, will be same long aligned fiber under tension.

That is what we are looking at over a small element. You say small element, let us say fiber and matrix have same strain. This is because they are bonded together. So, we assume that there is no sleep aid they bond together. So, load P is the sum of the load carried by both fiber and matrix. If I say V m is the volume at the volume fraction of the matrix, then fiber volume will be V f. V m is equals to 1 minus V f. So, V m is equals to 1 minus V f. V f is the volume fraction of fiber.

Modulus of elasticity can be simply written as composite modulus of elasticity can be simply written as V m E m and V f E f. How it can be written simply? This is because strain is same. Strain is same. One can actually show that the tensile strength of the composite will be proportional to fiber strength of the stress in the fiber. Stress in the matrix, volume of the fiber, volume of the matrix, we will come to this actually in detail, but just for the understanding in the next class.

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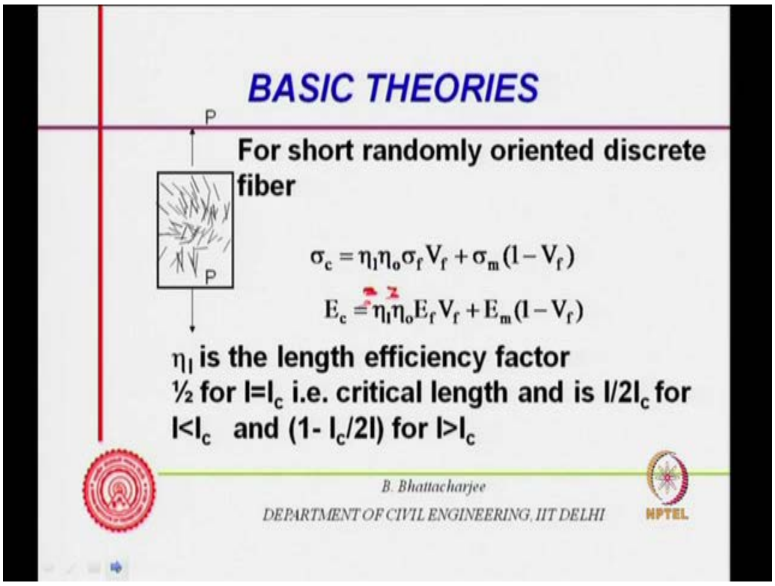

We will start from here, actually again, continue with the same for short randomly oriented discrete fiber. We will just come to the previous discussion in the next class. So, we can start with actually long align fiber in an element long align fiber in an element, derive their properties derive their properties long align fiber in an element under tension. First, we are starting with tension. This is because it is a crack registration property, which is very important. So, fiber actually bridges the crack. Therefore, under any pool, which causes cracking, it erases this to understand that it is better to first look at an element with a line fiber. The properties of align fiber are like this. I will, we will come to this in detail in the next class actually, but right now, just introduce it to you.

So, the modulus of elasticity of the composite, we can find out modulus of elasticity of the composite. We can find out which would be a function of the modulus of elasticity of the matrix? That is your concrete and the volume protection of the concrete and volume fraction of the fiber and modulus of elasticity of the fiber under this kind of loading situation.

Similarly, the tensile strength of the composite or tensile stress in the composite at any moment of time will be given by this. You can understand this of course, quickly can if we can look into sigma c t into a total area. If this is the total area a must be equals to that is the force is equals to p and that must be equals to sigma matrix stress multiplied by the area of the matrix plus sigma fiber into area of the fiber. Now, since the lengths are same, this align fiber lengths are same. So, multiply everything with l multiply everything with l multiply everything with l.

So, I can write sigma c t V is equals to V m, volume of the matrix V dash of the matrix and into sigma m plus V dash f of the matrix into sigma m. Now, V m dash divided by V m, I am saying V m dash divided by V is equals to V m. That is volume fraction. So, here volume fraction and similarly, so this is how this equation is obtained. This equation is obtained.

Now, since the strain is same, since the stress strain is same, since strain is same, stress by strain, so I can divide sigma c t by epsilon, which is same V m by sigma m by epsilon strain. All of them are same. So, epsilon m, I can write there is epsilon composite everything is same plus V f sigma f by epsilon f because epsilon m epsilon f is equals to epsilon c composite. Therefore, they are same. This is nothing but stress by strain is modulus of elasticity.

So, there is a simple equation one can easily derive it. One can easily derive it. One can easily derive it, easily derive it. Then, when it comes to random fiber, then what you do? You add, you add some factors because all the fibers will not be effective. They are not aligned. So, there will be kind of an orientation factor new o and length of all the fibers will not be full length. So, there is an equivalent efficiency factor, length efficiency factor. So, we call this as oriented efficiency factor, length efficiency factor and composite strength, composite stress. Then, you can determine in this manner similarly, modulus of elasticity also.

We can look in this manner. This is called length efficiency factor. This is called orientation efficiency factor. In next class, we will look into the same. So, this is the introduction. Therefore, what we looked into today? We looked into some aspect of SSC.

Now, what are the aspects of SSC? We looked into test today. The principle basic mechanism by which actually we form SSC, self-compacting concrete, we discussed in the previous lecture. Today, we discussed about little bit about the V m a. What you call the super plasticizer, which make it possible, little bit about little bit about little bit about the principles of self compacting concrete. Then, the test, their application, usage and advantages etcetera, we looked into today.

Then, we just introduced the fiber concrete basic. What it does actually? Where it is? Its advantages like cracker station, pseudo ductility, flexural strength, and then we just tried to introduce the theory of fiber reinforcement assuming a as element in which all fibers are aligned along the direction of load. We will come back to this in the next class and discuss the fiber concrete in the lecture 4 of this module 9.

Thank you.