Concrete Engineering and Technology
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Lecture - 22
Testing self-compacting concrete

(( )) and welcome to this lecture in our series of concrete engineering and technology. Continuing our discussion on special concretes, where we were talking about high workability concretes in the last class, we had developed the following ideas.

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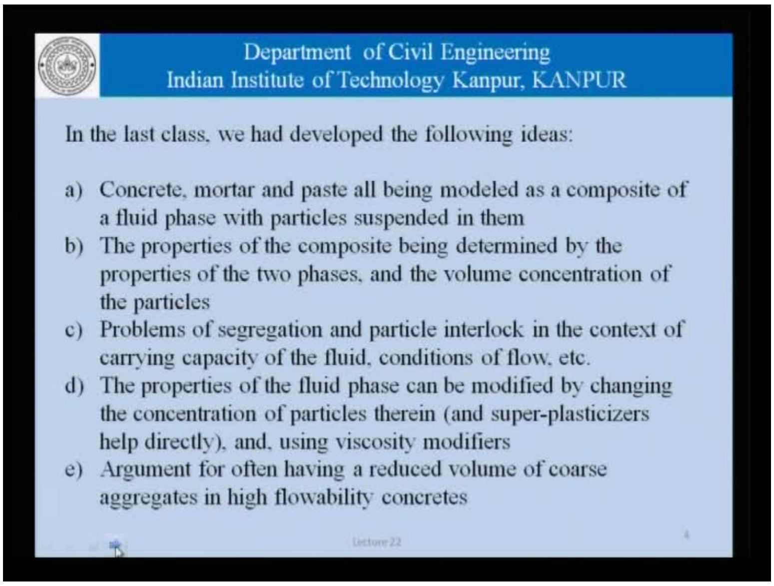

Concrete mortar and paste all can be modeled as a composite having a fluid phase with particles suspended in them, paste can be modeled as cement particles suspended in water, mortar can be modeled as sand particles suspended in paste, and concrete can be modeled as coarse aggregate suspended in mortar.

The properties of the composite whether it is paste or it is mortar, or it is concrete can be determined by the properties of these two phases. That is in the case of concrete for example, it will be the properties of the aggregate and the mortar, and also the volume concentration of the particles, that is if you are talking of concrete how much coarse aggregate is there in the composite by volume.

We are also talked about the problems of segregation, and particle interlock in the context of the carrying capacity of the fluid, the conditions of flow and so on. We had talked about the properties of the fluid phase, which can be modified by changing the concentration of particles there in, and super-plasticizers help us directly in that context and also using viscosity modifiers.

We had also built an argument for having a reduced volume of coarse aggregates in high flowability concretes. In fact, there was a slide if you would remember where we had said that depending on the concentration of reinforcement, or the complexity of the shape in which the concrete has to be cast, the maximum volume of coarse aggregate in the concrete can be limited, or needs to be limited.

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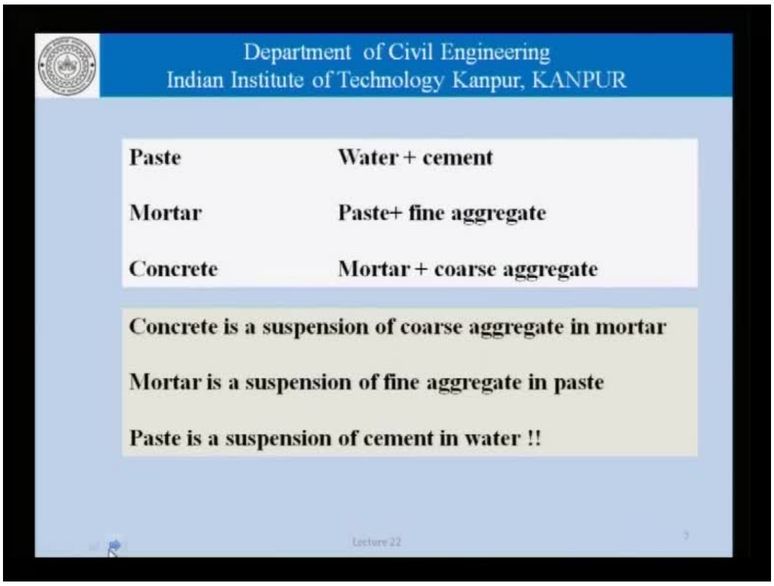

Continuing with that discussion and reiterating that paste is water and cement, mortar is paste and fine aggregate, concrete being mortar and coarse aggregate, and the suspensions as we have discussed.

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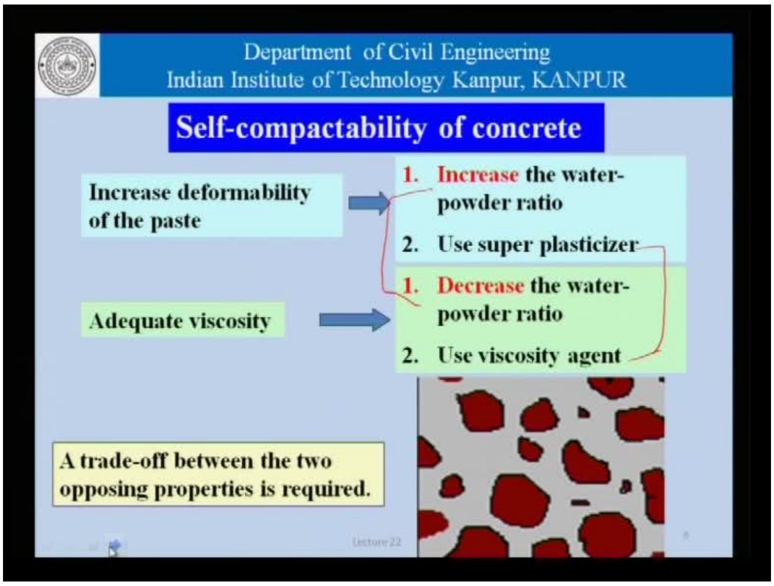

We now, talk about self-compactability of concrete where we said that on the one hand we need increased deformability of the paste, which calls for an increase in the water to powder ratio, and the use of super-plasticizers. And in the other hand we require adequate viscosity and for that we need to reduce the water powder ratio, and we use viscosity agents. So, these two are the chemical admixture root or this is the physical root where we are trying to change water powder concentration in the system.

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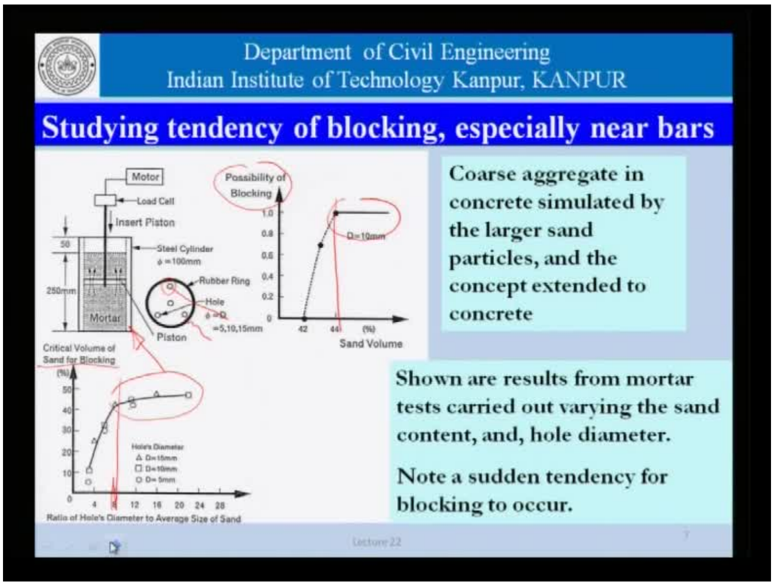

Now, as far as the self-compactability of concrete is concerned or a high flowability of concrete is concerned; we are really looking at a trade-off between these two opposing properties: One of them requires the paste phase or the liquid phase to be more deformable whereas, the other requires the same phase to be less deformable which basically a trade-off.

Building on that argument we had discussed this slide, which talks about the possibility of blocking, and the critical volume of sand required for blocking if we were doing an experiment as shown here; where in an small cylinder we are trying to push a piston which has a configuration like this having holes of different diameters, and these diameters are related to the particles size that we have, and we had talked about a sudden change that is occurring here under relatively sudden change which is occurring at round this value here.

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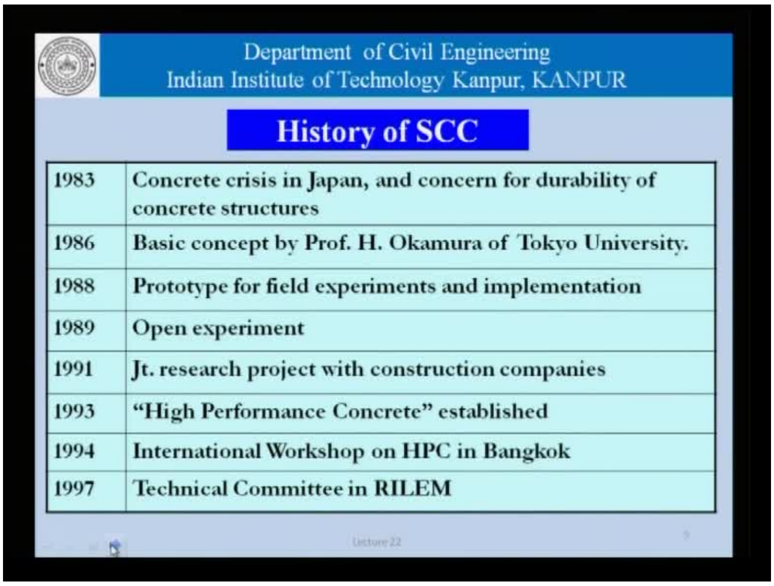

We had also talked about the history of the self-compacting concrete briefly, and starting from about 1983 84 to about 1997 was an extensive mortar work done in Japan, and in other countries. Notably, the Netherlands where the emphasis was on developing high deformability, high flowability and self-compacting concretes, on the other hand there was a discussion in groups in the world working on high performance concrete interpret it slightly differently, they were working more in terms of increasing the strength of concrete.

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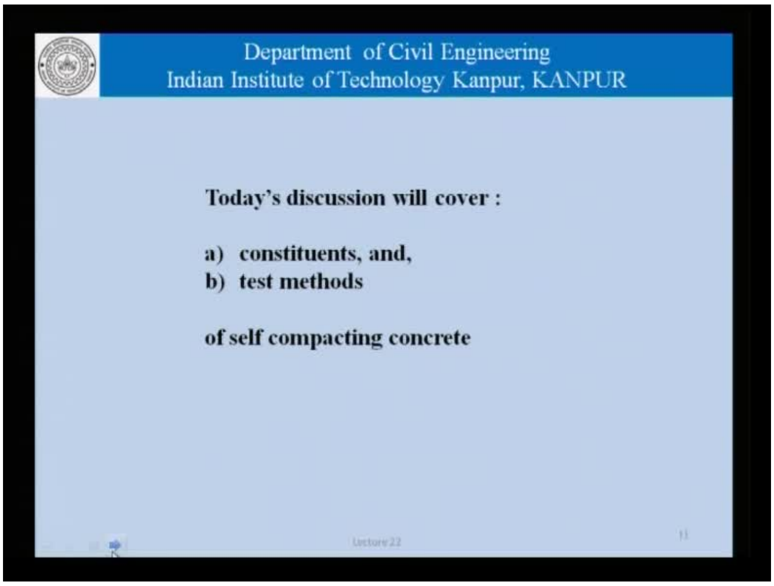

Now, coming to a discussion today we will focus on self-compacted concrete that is SCC, and that is one of the examples of high flowability concretes. So, in this case in addition to high flowability the concrete should have self compactability, that is it should not require external vibration in order to be compacted. So, we will cover basically the constituents and the test methods of this special concrete.

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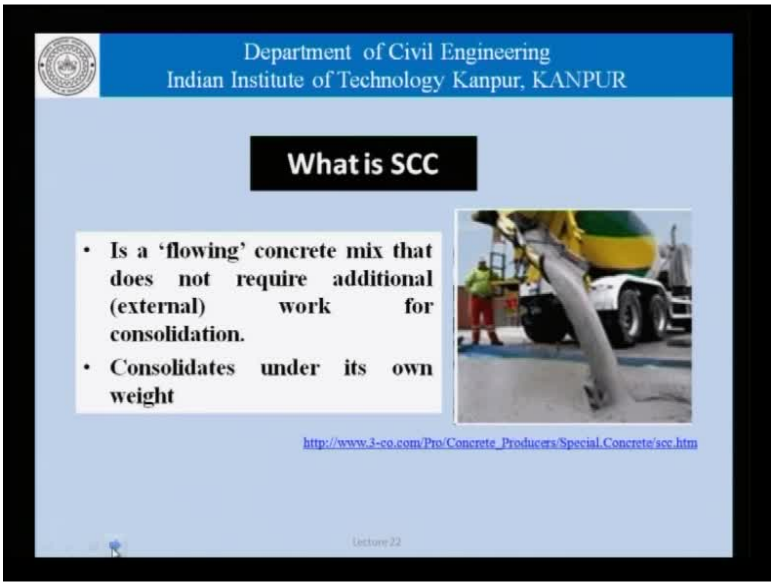

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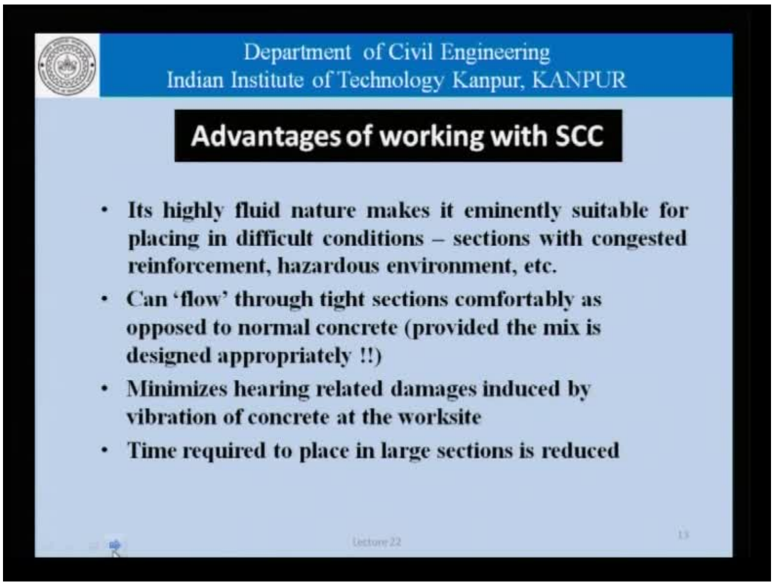

As far as what SCC is it really is a flowing concrete mix, that does not require additional or external work for consolidation, in terms of internal or form vibrators, and consolidates under its own weight. So, as we can see from the picture here on the right, the concrete more or less flows as it fit for a fluid. Now, the advantage is of working with this kind of concrete that self-compacting concrete is that, its highly fluid nature makes it eminently suitable for placing in difficult conditions which could be sections with congested reinforcement, hazardous environment, and so on.

So, at times reinforcement arrangement or the arrangement of reinforcement is such that, it makes it very very difficult of concrete to be placed, or a concrete to move through the reinforcing bars. And if and even if concrete can negotiate that gap it is almost impossible to actually have a vibrator reach that area similarly, there could be hazardous environments where we would like to limit, the amount of exposure to people to human beings; we would like to have as few people working in that area as possible, and in these cases the use of self-compacting concrete comes in very handy.

As we said that, it can flow through type sections comfortably as opposed to normal concrete of course, provided the mixes designed appropriately that has a right amount of segregation resistance; It minimizes hearing related damage induced by the vibration of concrete at the work site. The use of vibrators whether it is internal vibrators, or form vibrators is one of the major sources of sound pollution at a construction site, and if you are able to get rid of that we have a much more silent construction site. Indeed the time required to place concrete in large sections is also greatly reduced, because the concrete virtually flows rapidly into the form that is being casting.

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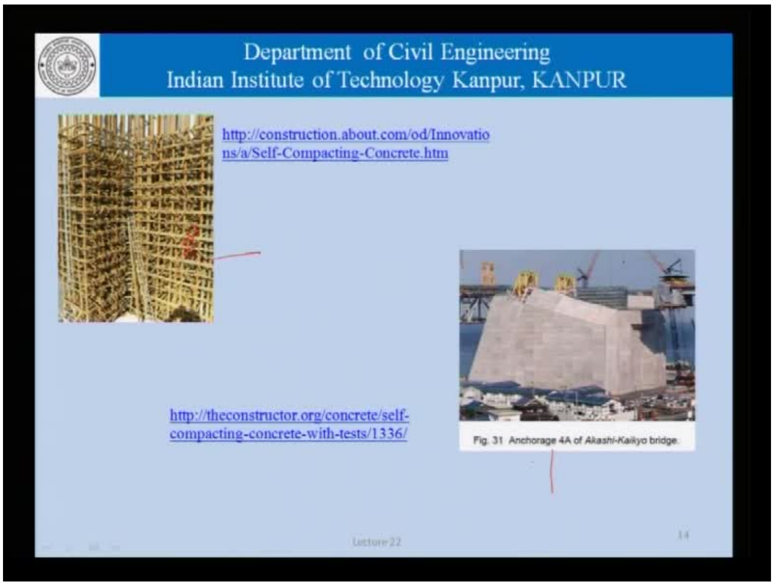

Here are examples, where self-compacting concrete would be eminently suitable. For example, if we look at this picture here, we can see that the reinforcement is so dense, that it would be impossible for concrete to penetrate these small patches between the reinforcing bars save the self-compacting, or a very very highly deformable concrete. Only that concrete which literally flows like water can be poured into the formwork, and it can be expected that it will flow through these openings or gaps, and set in a manner that reinforce concrete designer would like it to you. On the picture here is the anchorage of the 4 A of the Akashi-Kaikyo bridge, one of the major bridges in Japan, and I would like you to understand or study a little bit more on how the self-compacting concrete was used in this large anchorage.

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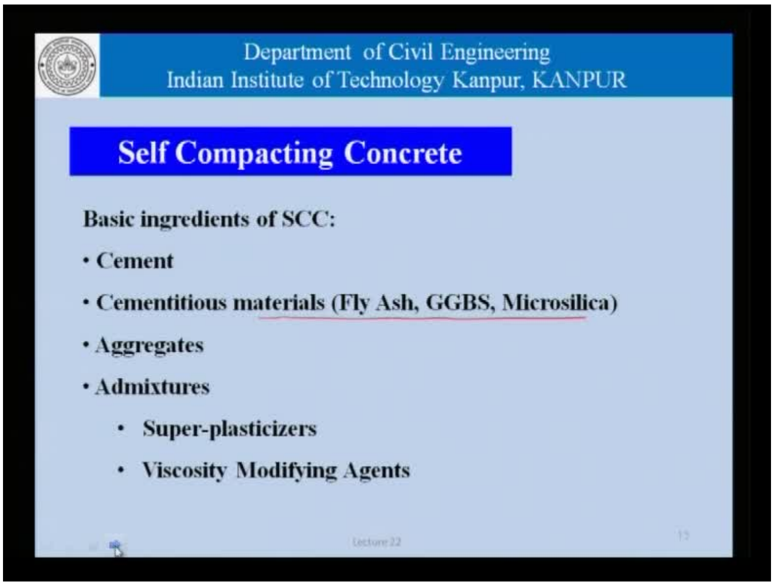

As far as the ingredients of self-compacting concrete are concerned, they are no different from the usual Cement, other Cementitious materials - Fly Ash, Glass furnace slag, Microsilica, stone dust, Aggregates which is fine and coarse, and Admixtures which could be Super-plasticizers or Viscosity Modifiers.

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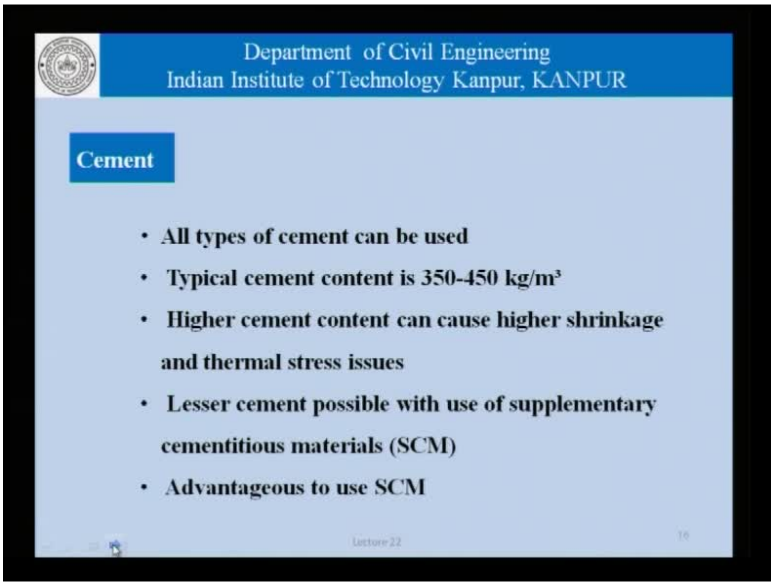

Now, we use a land up using a lot of these cementitious materials in self-compacting concretes for the simple reason, that we need to have higher volume of paste higher powder content in the mix, this is something which we talked about last time and we will look at it once again today.

As far as cement is concerned we can obviously use almost any type of cement, the typical cement content is no different from normal concrete; it is about 350 to 450 kg a cubic meter, and higher cement content obviously if we use we will land up with higher shrinkage and thermal stress issues and therefore, even though we require a higher paste volume or a higher powder volume in the paste, it is not always advisable to use cement, we would rather use materials of similar fineness, but not having the hydration related issues in terms of heat and so on. And as we have stated lesser cement content is possible by the use of the supplementary cementitious materials.

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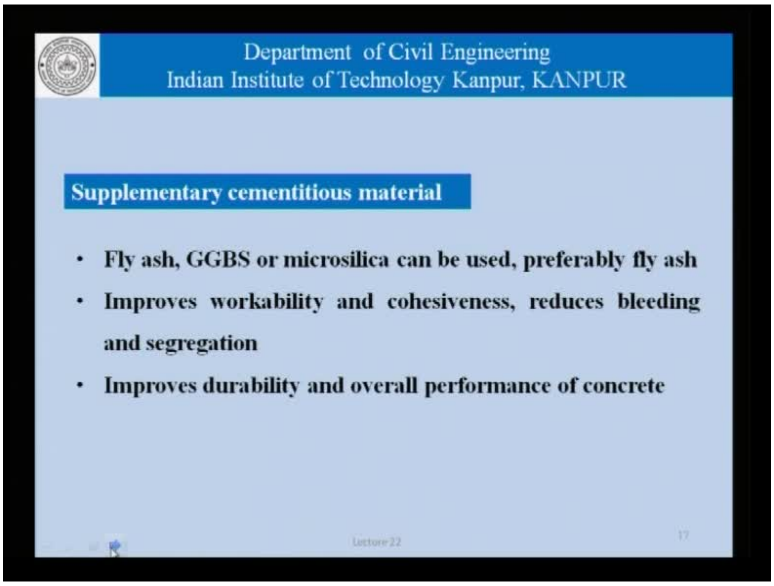

As far as these materials are concerned we could use fly ash, the blast furnace slag or microsilica, preferably fly ash because of its spherical nature they use improves a workability and cohesiveness, reduces bleeding and segregation, improves durability and overall performance of the concrete.

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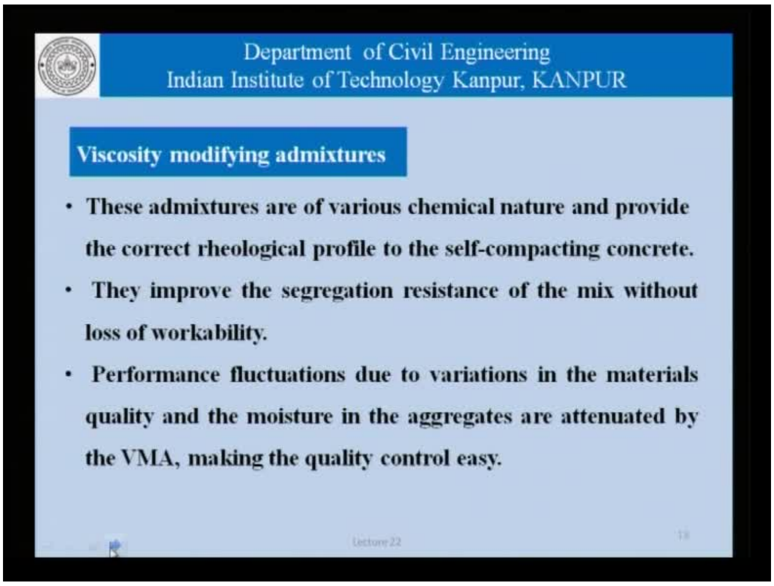

As far as the viscosity modifying admixtures are concerned these are of various chemical nature, and provide or correct desired rheological profile to the self-compacting concrete, they improved the segregation resistance of the mix without loss of workability, they also help to reduce performance fluctuations due to variations the material quality. And the moisture in the aggregates this helps us maintain a consistent quality as far as self-compacting concretes are concerned.

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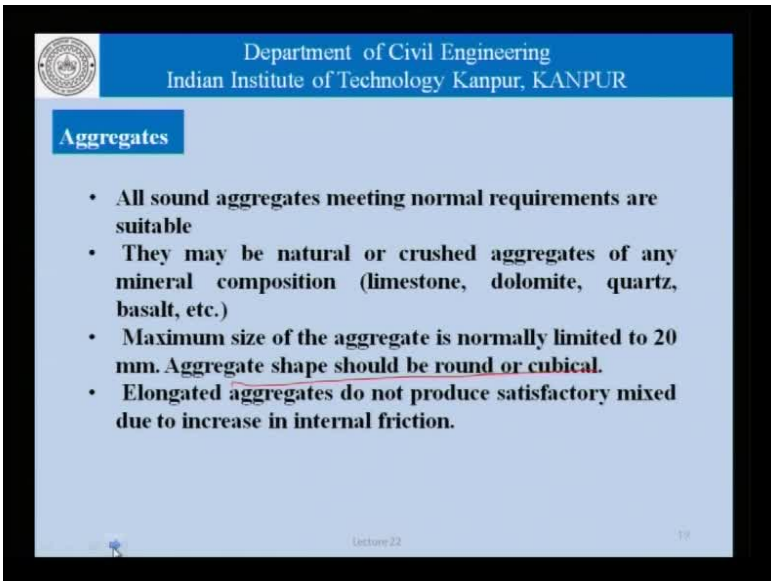

Coming to aggregates; all sound aggregates meeting normal requirements are suitable. We must remember that with the material like, concrete it is very difficult to specify very special kinds of aggregates, whether it is fines aggregates or coarse aggregates, because concrete as a construction material is economical only, if we use locally available material to the extent possible. The only factory made product used is cement and that is where we have some specification, that this cement and not that cement, this particular chemical composition and not that particular chemical composition and so on.

But if we become very choosy with respect to aggregates, that will push the cost of concrete beyond a certain point, and that will make concrete and uneconomical proposition. So, as far as possible, no matter how special the concrete becomes, the engineer always tries to use local material. And to that extent all sound aggregates meet in normal requirements are suitable for use in self-compacting concretes, as well. These aggregates could be natural or crushed aggregates of any mineral composition - limestone, dolomite, quartz, basalt, whatever. Except that the usual rules as far as alkali aggregate reaction will apply, we do not want to use reactive aggregates.

As far as maximum size of the aggregate is concerned that is normally limited to about 20 m m. And aggregate shape should be round or cubical. Now, this is something which we need to be little careful, as far as which is used in self-compacting concrete is concerned, because elongated aggregates do not produce satisfactory mixes due to an increased internal friction, and their tendency for aggregate interlock. And that is something which we would like to really watch out against, when we are talking in terms of self-compacting concerned concretes.

In normal concretes, because we use vibrators we have the possibility, or a chance to break aggregate interlocks with the vibrators, but in self-compacting concrete we cannot afford that similarly, we cannot afford aggregate interlock in equipment, or in piping and so on. So, we must ensure that as far as aggregates are concerned they are at least rounded or cubical in nature.

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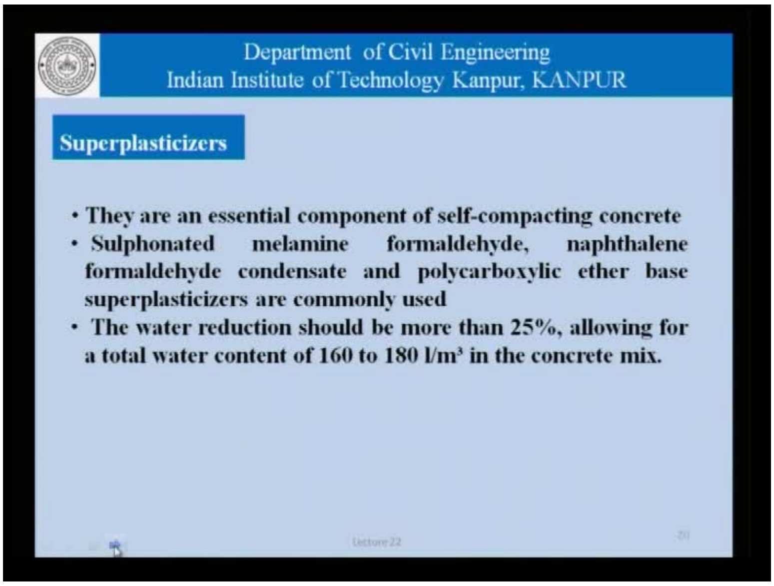

Coming to super-plasticizers they are an essential component of self-compacting concrete, because they help us reduce the water content and as far as these admixtures are concerned, normal sulphonated melamine formaldehyde, naphthalene formaldehyde condensate and polycarboxylic ether base super-plasticizers are commonly used. Depending on the chemical composition of the cement, there may be issues related to compactability of a particular admixture with the cement, and so on. And that is something which needs to be established from time to time as far as a construction site is concerned. As far as these admixtures are concerned water reduction achieved should be about 25 percent or more so, that total content of water is restricted to about 160 to 180 liters per cubic meter, anything more than that would make the demand on the powder content simply to hide.

Now, the mechanism of self-compaction is in self-consolidating concrete is based on the large quantity of fines of the order of about 500 to 650 kgs a cubic meter, the use of high range water reducing super-plasticizers, and the range of more than 25 percent of water reduction and viscosity modifying admixtures.

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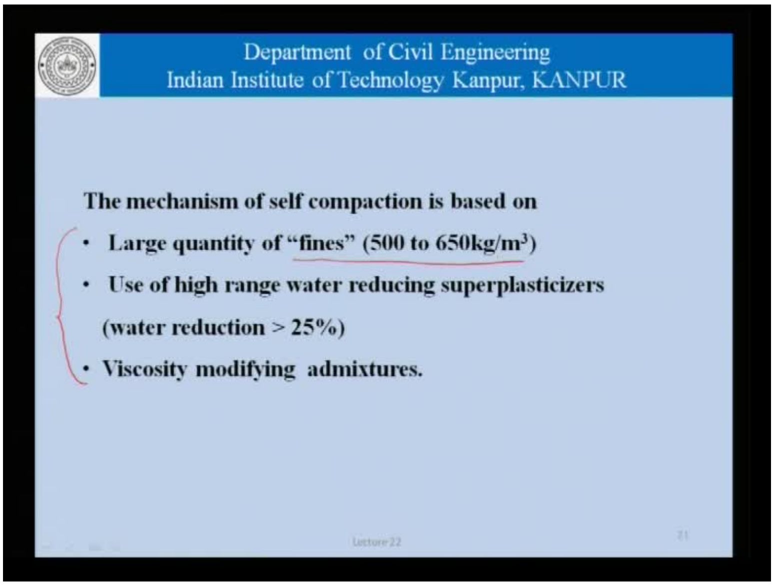

So, it is these three principle factors or a combination of these factors which helps us obtain self-compactability in concrete. So, when we are talking of a large amount of fines we can imagine that if you are looking at 500 to 650 kgs per cubic meter fines, this is not including the fine aggregate, this is really the fines in the sense of cement and particles which are of similar size.

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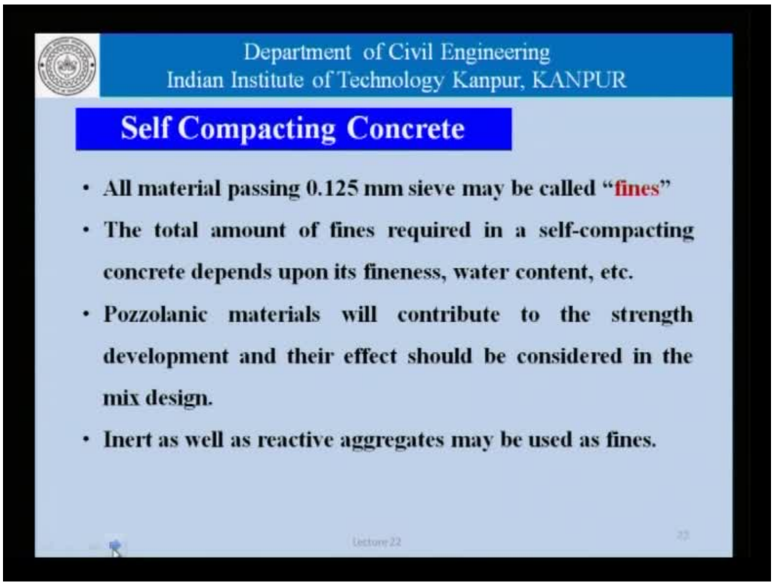

So, we cannot obviously have this amount of cement sitting in a concrete matrix so, the cement content has to be restricted to about 350 to say 450 and therefore, perforce or by a requirement of self-compactability we need to have at least 200 and 250 kgs per cubic meter, of either a supplement cementitious material which will participate in secondary pozzolanic reaction, or secondary hydrations or a material which even if it does not participate in that secondary hydration contributes to increase the viscosity of the paste phase.

Now, coming to self-compacting concrete all material passing through 0.125 m m sieve may be called fines, and that is how you are trying to define the fines material in the previous slide, the total amount of fines required in a self-compacting concrete depends upon its fineness the water content and so on. Pozzolanic materials will contribute to the strength and their effect should also be considered on the mix design of course, we could use inert as well as reactive aggregate sometimes in fines but, with caution.

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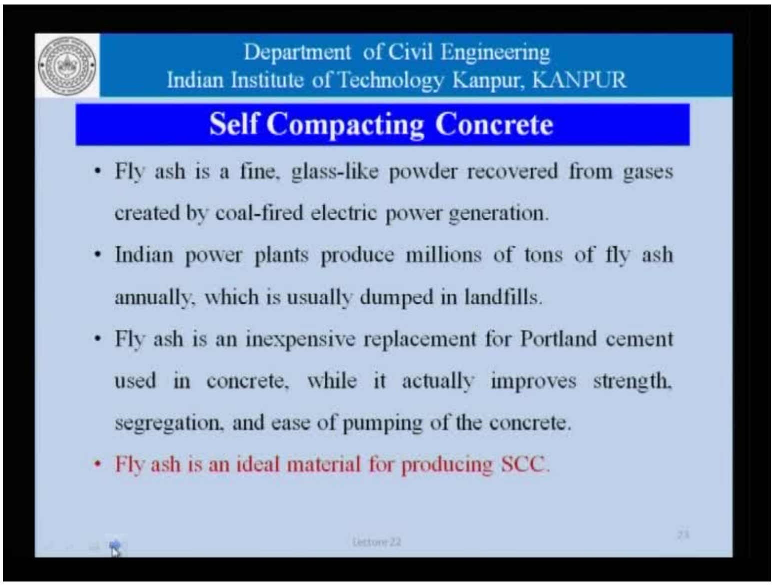

Now, fly ash is one of the most commonly used supplementary cementitious materials, and is a fine glass like powder recovered from flue gasses created in a coal-fired electric power generation or a thermal power plant. As far as India is concerned we produce millions of tons of fly ash but, it is usually dumped in landfills. Fly ash as such is an inexpensive replacement for Portland cement to be used in concrete, while it actually improves the strength, segregation, and also the ease of pumping the concrete. Of course, it should be noted that not all fly ash can be used it is not only the size, and the reactivity, and so on. But, also the fact that the properties would depend on the coal which is used the fineness the burning temperature and so on.

So, if there is a lot of variation in the quality of coal being used in a thermal power plant, the quality of fly ash is also likely to vary. And this variation is one of the reason why fly ash has not really become an absolute replacement for cement; sometimes we get very good fly ash and sometimes we do not get such good quality fly ash, and that is why as far as specifications are concerned , as far as engineers are concerned, we cannot make a blanket statement that we can use large volumes of fly ash in a given concrete.

Of course, if an engineer is conscious of that does periodic quality control there is absolutely no reason why fly ash cannot be used, it is an ideal material for self-compacting concretes.

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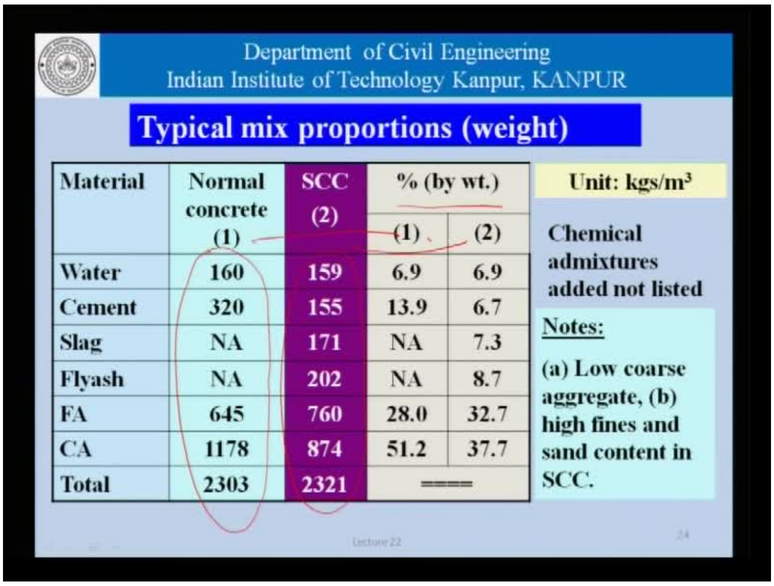

Now, if we look at the typical mix proportions by weight of normal concrete and of self-compacting concrete, this numbers here are those for a normal and these numbers are for a self-compacting concrete. Now, if you look at these numbers these are the proportions in mix one that is the normal concrete, and the self-compacting concrete, and we are able to see the proportions by weight.

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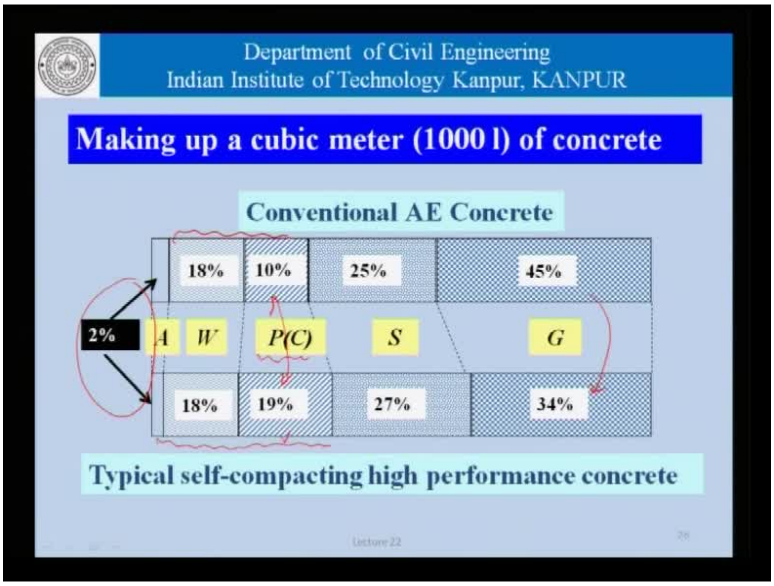

Now, if this data was converted to a volumetric chart which says that air, water, powder or cement, sand and gravel. This here is the distribution as far as normal conventional air entrained concrete is concerned, and picture below is that of a typical self-compacting high performance concrete.

Now, if we look at the numbers in both cases we can assume that the air content is not really different, it is the same 2 percent water is about the same as far as powder or cement or fines is concerned, there is a mark difference that is 10 percent in about that is about 10 percent in conventional concrete whereas, in self-compacting concrete it could be as high is about 18 to 12 percent.

The sand is not really so much different, and this increase here is compensated by a concerned decrease in the coarse aggregate percentage. So, in the end result self-compacting concretes have a larger paste volume compare to conventional volumes, and this is compensated or made up by the reduced volume of coarse aggregates, and that is something which we are talked about last time.

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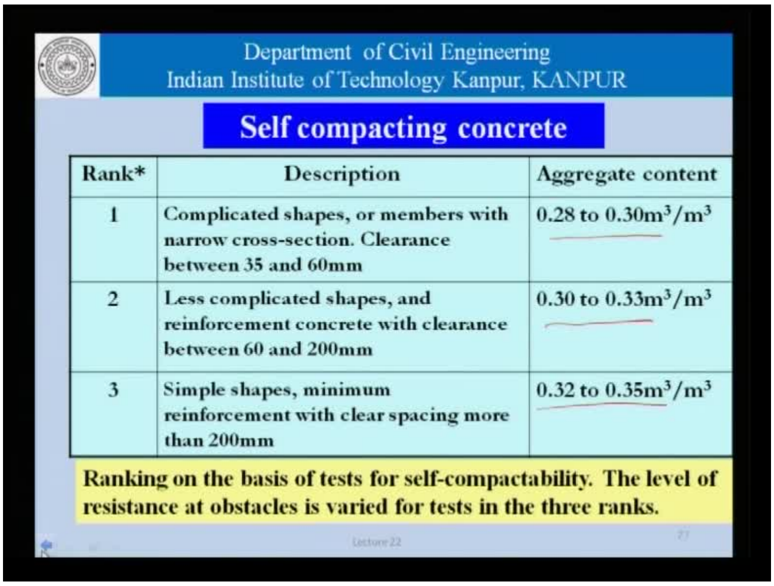

And we had also seen this slide here which talks in terms of limiting, the coarse aggregate content between 28 to 35 percent depending on the complexity of the formwork, or complexity of the member in which self-compacting concrete is to be cast. This ranking that is given here, rank one, two and three for the aggregate content is based on tests for self-compactability , and the level of resistance at obstacles is varied for the test in the three ranks. Now, comes to testing of self-compacting concrete, that is really the second part of our discussion today; and now let us talk about how we actually test self-compacting concretes, which is different in a manner compare to conventional concretes.

Now conventional concretes we know, we test in terms of workability, and air content may be sometimes carry out bleeding test, or setting time, and so on. and as far as workability is concerned, we need to slump compaction factor and so on but, when it comes to self-compacting concretes or high flowability concretes, the material is beyond the classification range of a slump test, we need to have more specialized tests and that is something we are going to talk about.

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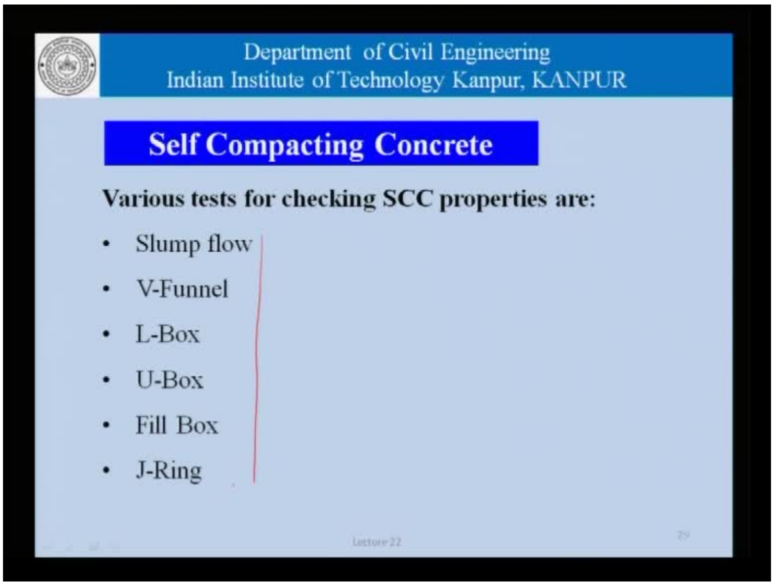

Some of the test that we will talk about today are the Slump flow, the V-Funnel, the L-Box, the U-Box, Fill Box and the J-Ring. Now, these tests give us an entirely different framework in which a self-compacting concrete can be evaluated; we must remember that self-compacting concrete has been developed only about 25 30 years ago and therefore, a lot of these tests are still in some form of development or the other.

Some of them have been standardized, and we can look up ASTM or European standards on that, but some of these tests are still evolving, and would sooner or later become part of a standard quality control regime, as far as quality assurance programs of self-compacting concretes in concerned; it is not only self-compacting concretes, but these tests can also be used to evaluate the workability of any other high flowability concrete. Of course, air content and so on. can be tested in a manner which is similar to conventional concrete. Now, let us take a look at these test one by one.

Coming to the slump flow; the test aims at investigating flowing ability of the self-compacting concrete, and measures the spread the diameter of the slump being a measure of that flowability, and indicates the free unrestricted deformability of the concrete, recommended values of slump flow are in the range of 650 to 800 millimeters.

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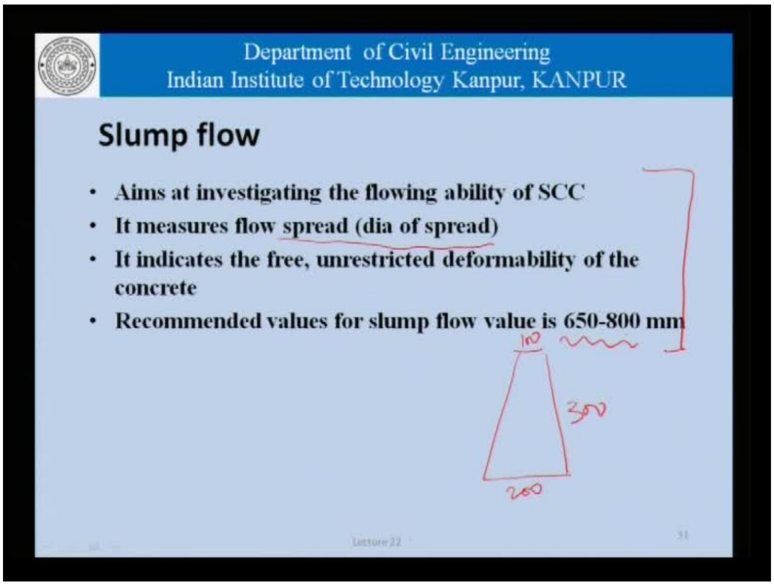

What we must remember is that the standard slump cone, measures a 100 millimeters on the top, 200 millimeters here, and has a height of 300 millimeters. So when we are talking of a slump flow of 650 to 800 millimeters;

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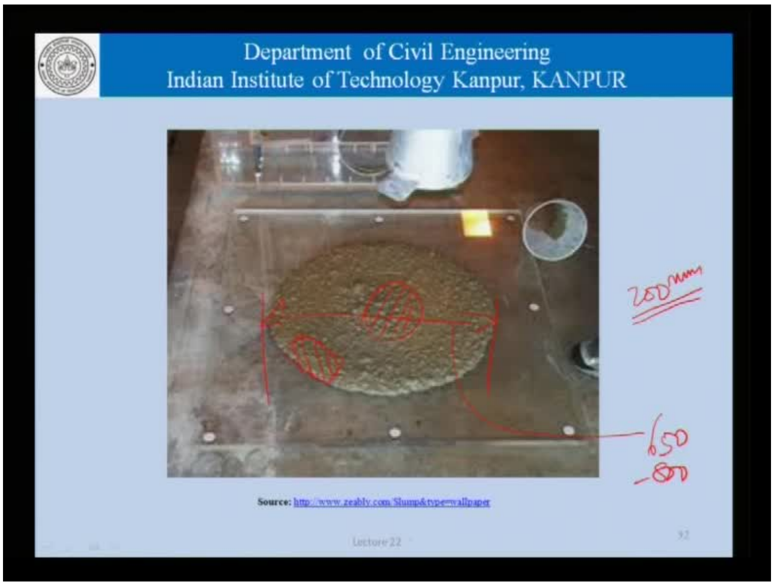

What we are really talking about is that this diameter here, which is what the concretes spreads into once the slump cone has been removed, this should be of the order of 650 to 800 millimeters or 600 to 850 millimeters. The original diameter here as when it was contained in the slump cone is about 200 millimeters, so we are talking of a large spread of the concrete, as the slump cone has been removed.

When we are evaluating the concrete using the slump flow, we should also watch for aggregates having reached the edges, so it should not happen that the concentration of aggregates in the periphery of the slump flow is spread is differential equation from the aggregate concentration in the center, and that is what slightly to happen if the concrete is segregation prone; if the concrete is segregation prone, the aggregate would not move with the mortar towards the periphery.

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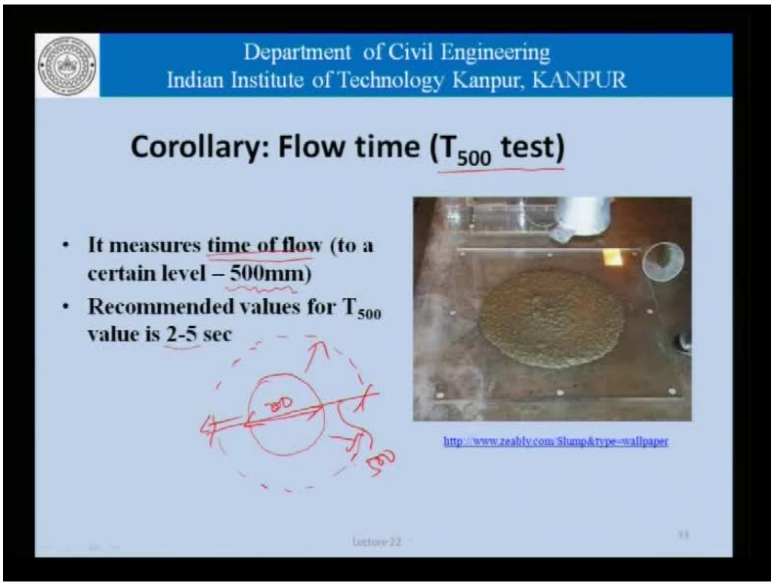

As a corollary to the slump flow test, we also sometimes use a flow time which is sometimes called the T 500 test; and now this T 500 refers to the time, it takes for a concrete to achieve or reach a diameter of 500 millimeters, and the typical time could be in the range of 2 to 5 seconds.

So as the slump cone measuring 200 millimeters and diameter is lifted, the concrete spreads in all directions, and we look at the time that it takes for the concrete to reach a diameter of 500 millimeters; and this time is called the T 500. Depending on the kind of viscosity that we have, as far as the mortar is concerned, it is possible that for the same slump flow which is the final diameter that the concrete really achieves the T 500 times could be different. And obviously, the T 500 would be higher for a concrete which is more viscous, and concrete being more viscous really means that the mortar phase has a higher viscosity.

So, even though we are not measuring viscosity directly, parameters such as the T 500 help us to determine, and compare the viscosity of two concretes which have the same or different slump flows or that final spreads. Now, if we look at the slump flow test once again we would realize, what the import of the free unrestricted deformability is; the concrete in the slump cone as it flows out is unencumbered; it flows out freely without any encumbrance, without any obstacle, or obstruction to its flow. And that is not something which we have as far as most reinforce concrete structures is concerned. In most cases the concrete is expected to negotiate reinforcing bars, and that is something which the slump flow itself does not measures. So most of our test beyond this point have this parameter added into the testing regime.

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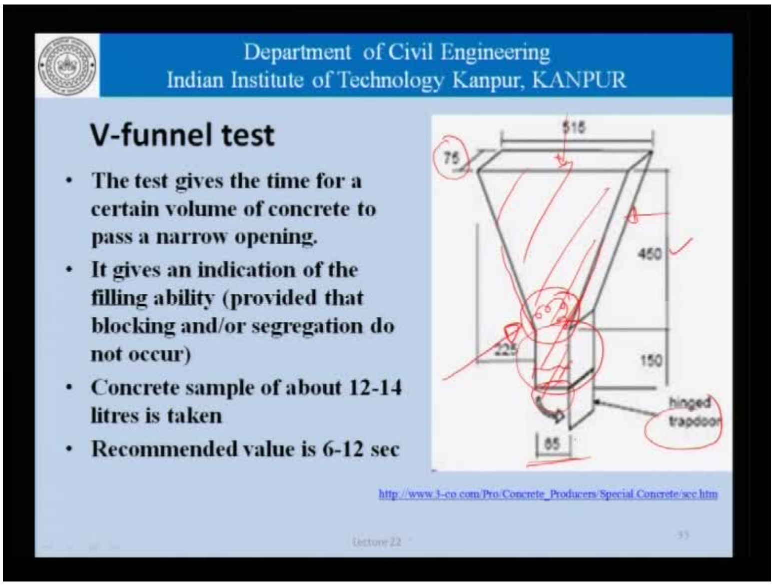

Now, if we come to the V-funnel test. The test give us the time for a certain volume of concrete to pass through a narrow opening; it gives an indication of the filling ability provided that no blocking, and or segregation occurred, concrete samples would depend upon the size of the V-funnel; it could be about 12 to 14 liters, and the time would vary between 6 and 12 seconds.

So, if we have concrete filled in this funnel, which measures about say 500 millimeters on the top has a width of about 75 millimeters here, and a height of 450 millimeters with a constricted region here of about 150 millimeters. What we expect is that the concrete filled in this portion here, there is a lid which when opened allows the concrete to flow through this, and the time that it takes for the concrete to flow through is the V-funnel time.

Now, once the concrete is flowing from a larger cross sectional to a smaller cross sectional area here, the possibilities of aggregate interlock can be easily checked, and that is something which the slump flow simply cannot do. The slump flow therefore, is the measure of the unrestricted deformability whereas, test such as the V-funnel helps us evaluate the concrete from the point of view of aggregate interlock and so on.

As far as the time is concerned when do we say that, all the concrete has actually passed through the funnel; one of the methods that can be used as a basis or as a guide line can be once the concrete moves through this funnel, if we are watching from the top, we should be able to see the light at the end of the funnel. And this funnel has a diameter of about or a square is about 185 or 80 m m, and that is something which would help us.

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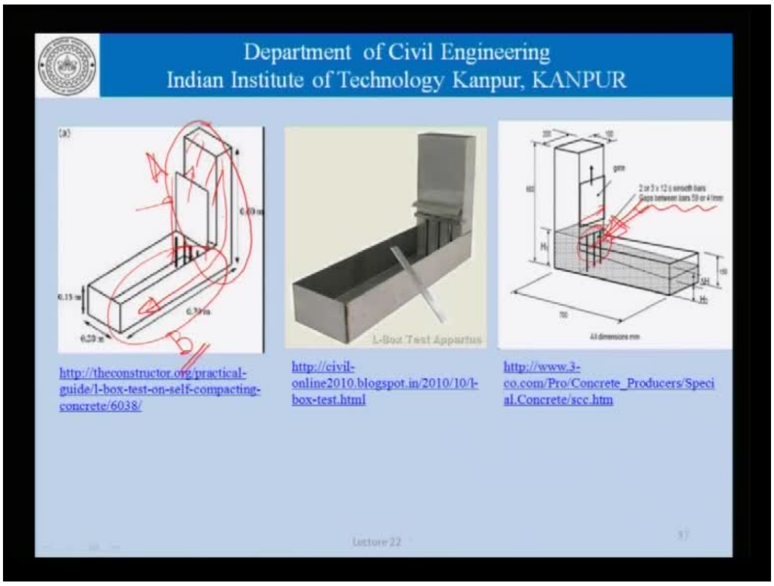

Now coming to the third test, that we need to talk about, and that is the L-box. Now this test here means or has an L-box that is there is a box here which is let us say A, and another portion here which is let us say B, and we fill the concrete in A, there is this gate which is closed, and once we lift this gate the concrete from the block A flows into block B.

Now this flow from block A to block B is restricted by the presence of these pipes, or reinforcing bars, or any such arrangement, that we may choose to use. Some of the standards have standardized, the kind of obstruction that can be used in the form of pipes of different diameters, or in the form of reinforcing bars of different diameters, in a manner that the space here is divided into different open spaces.

So the kind of obstruction, that we use here is somehow related or somewhat related to the kind of reinforcement in an actual structure, which the concrete is expected to negotiate. So of course, here also we have the possibility of an aggregate interlock occurring behind the reinforcing bars, which would prevent the concrete from block A flowing into block B. So the kind of measures that we need to take or the kind of measure that would be used, as far as testing the L block is concerned it is largely the difference in this height at these two places.

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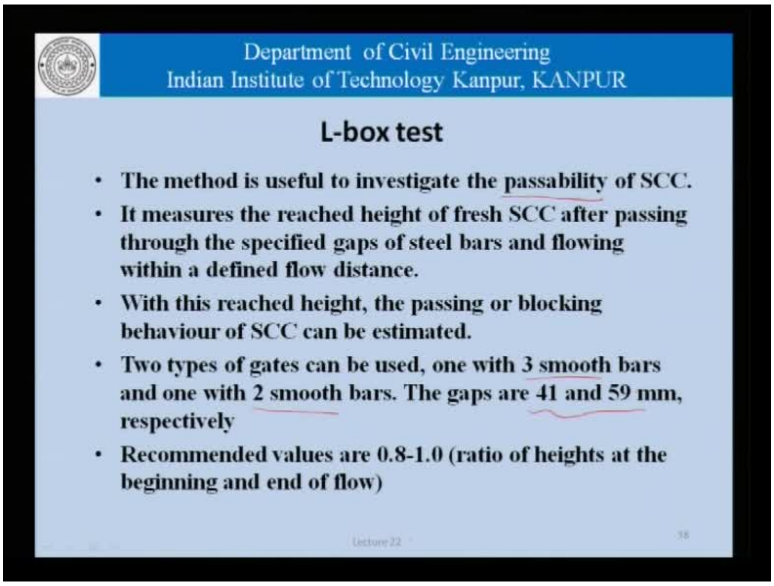

So, H 1 and H 2 and then there is this delta H, so if the concrete was to behave as a real fluid, then we would not expect any difference in the height. Over this length that the concrete is flowing, but since the concrete at the end of it is not really a fluid, there will be a certain amount of difference in the height s at these two places, and that is the difference that we want to monitor. And measure as the output from this test which is called the L-box test, as I explained before that is this is what is driven in the text here the method is useful to investigate the possibility of self-compacting concrete.

So, possibility being ability of the concrete to negotiate the simulated reinforcing bars, and it measures the least height of fresh SCC after passing through the specified gaps of steel bars, and flowing within a defined flow distance which were shown to be about 700 millimeters in the previous slide, and with this height reached the passing or blocking behavior of the self-compacting concrete can be estimated. And two types of gate can be used: one with three smooth bars, two smooth bars the gaps would be different depending on the kind of diameters with the bars, that we use and so on. and we can have standards which would help us evaluate a concrete from this point of view, that is from the point of view of an L-box test which is using the ratio of the heights at the beginning and end of flow.

So we have always stated in this discussion, in different lectures, as far as this module is concerned test methods are always such that, they would yield a value any test method, any test would yield a value, and a specification is something which the engineer has to say or state that if we carry out this test for this application, this is the value which is acceptable.

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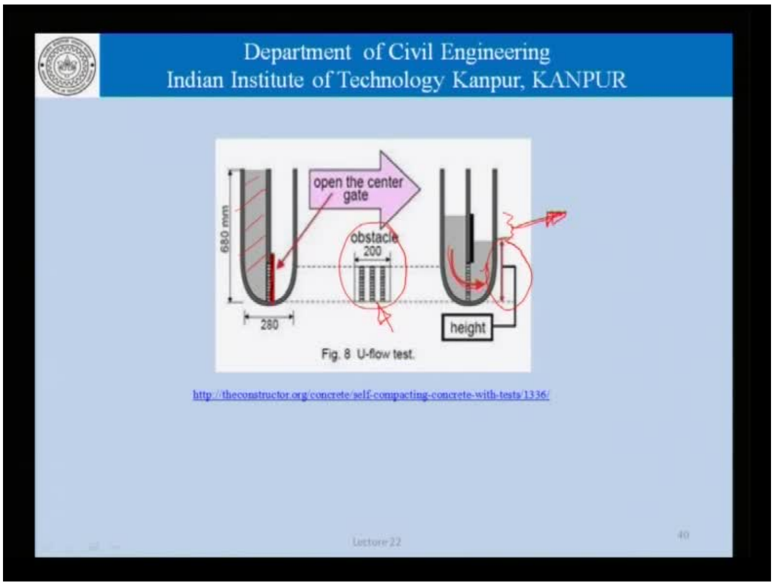

So, we can in this case for example have different tests, as far as self-compacting concretes are concerned, and the engineer can lay down different specifications, as far as L-box test is concerned, I want the concrete which has a ratio of the two heights to be let us say 0.9, as far as the funnel test is concerned, I want a concrete which should not have a time of flow greater than say 10 seconds; it should not have a slump flow less than 55 centimeters or 550 millimeters and so on. So this is the basic concept in terms of testing of self-compacting concretes.

Continuing with the tests, let us look at the U-box test, as the name suggest talks about the flow of concrete in a U shaped box. So concrete is filled on one end of a U box, closed initially with the gate, and this gate has an obstacle which again has simulated reinforcing bars, and once the gate is opened, the concrete flows from one end to the other; and we can always talk in terms of this height or the difference in these two heights, and again if the concrete was a fluid or a liquid in that sense, then we do not expect any difference in the heights in the two sides of the U.

Again, if because concrete is not a true liquid in that sense, we will expect certain amount of difference, and that difference would be the measure of the self - compactability of the concrete. The smaller this difference between the two sides, the more self-compactible the concrete can be stated to be, again this gate or this obstruction that we design or use as far as this test is concerned can be modified, or chosen to be in a manner that represents the kind of reinforcement that we use.

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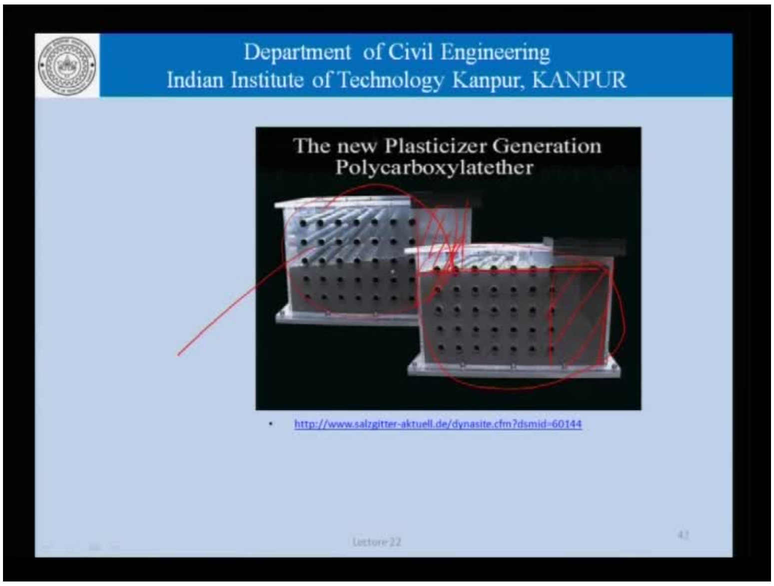

Coming to the Fill box test which is the, which is the slight variation of the test, that we use earlier. This test here deuce with the concretes ability to fill a box, once the concrete is placed in this end of the box, and these pipes here represent the actual reinforcing bars or the reinforcement in a reinforced concrete structure.

So depending on the complexity of the reinforcement, that we are emphasizing in a particular application, we can change the diameter, and the spacing of these bars, and have the concrete fill this box. Normal concretes, as we can imagine will not be able to more or less negotiate the gaps between the simulated reinforcement almost at all, it is only after certain amount of self-compactability, or high level of deformability, that is achieved will we get some semblance of a horizontal surface which is what we finally, want in a truly self-compacting concrete.

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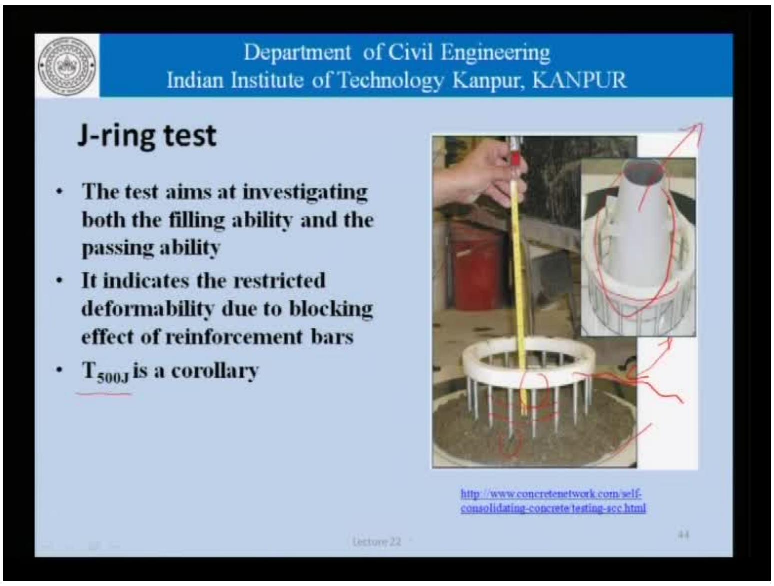

Last of all in the series of test, that we are talking about, let us talk a little bit about the J-ring. Now, the J-ring test aims at investigating both the filling ability, and the passing ability. At the same time and indicates the restricted deformability due to blocking effect of reinforcing bars, in a manner of speaking the J-Ring is a combination of the slump flow kind of test with the added complication, that the concrete is required to flow through this added cylindrical contraption, which has these reinforcing bars and gaps in the bars.

So the concrete is placed in a usual manner in a slump cone with this contraption on the outside, the cone is removed, and then concrete is allowed to flow through this contraption. And as it flows through, it is not the free unrestricted flow, as we would expect in the case of normal slump flow, but the concrete is flowing now through obstacles. And the measure could be in terms of again the flow, that we achieve or the difference in heights inside and outside this barrier and so on.

A variation of the T 500 time, that we talked about when we are talking about a corollary to the slump flow is the T 500 j. The T 500 j is the time, that it takes for the concrete to achieve a diameter of 500 millimeters when tested with the J-Ring. T 500 was the time that it took for the concrete to reach a diameter of 500 without any restriction, or without any obstacle to its deformation. So, this j here is the added suffix, and helps us find out the viscosity of the concrete with the modified slump flow, that is using a J-Ring.

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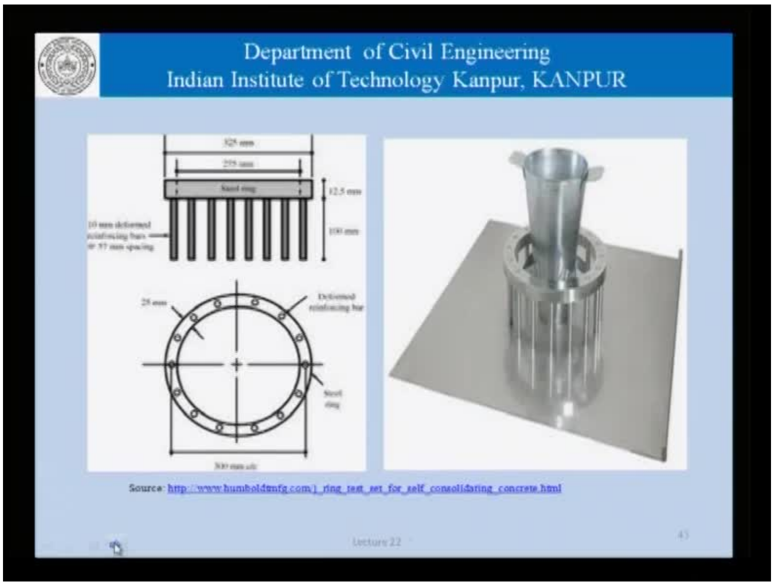

These pictures here show, another representation or view of the J-Ring test. There is another test which we have not talked about, or we have not listed in this discussion, and that is a test which involves having the concrete pass through a large U-Tube, where there is a substantial amount of distance involved here, and we place the concrete here, expect the concrete to flow all this distance, and rising this tube here.

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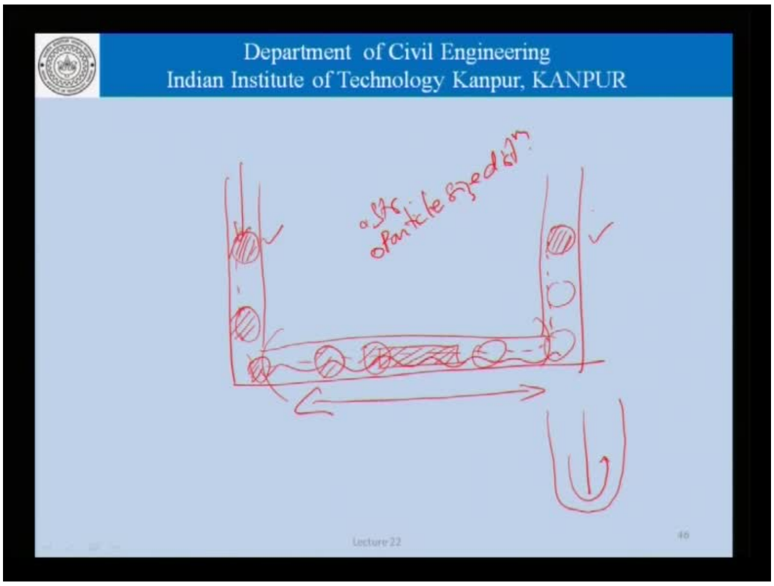

So it is a variation of the U-Tube test, that we talked about except that concrete is just not flowing from one leg of the U to the other, but it is passing through or reasonably long distance. Now, as this concrete goes through this distance, we can always have innovations which would create obstacles in the path of the flow, and still expect the concrete to negotiate the barriers that we put in place.

This kind of a test, because of its size can also help us evaluate properties of concrete, at this end of the flow that is the end where the concrete is being poured, and this and here where the concrete is reaching at the end of the flow. So we can take coarse specimens at the end of the whole thing, at the end of the hardening, and strength development, and so on. and we can try to find out properties such as strength, may be even particles size distribution of course aggregates, and so on. using this course, and to establish at the end of it. Conclusively that yes, the concrete at this end and this end is really the same, and it did not go through any segregation, and so on. while it was negotiating this whole path.

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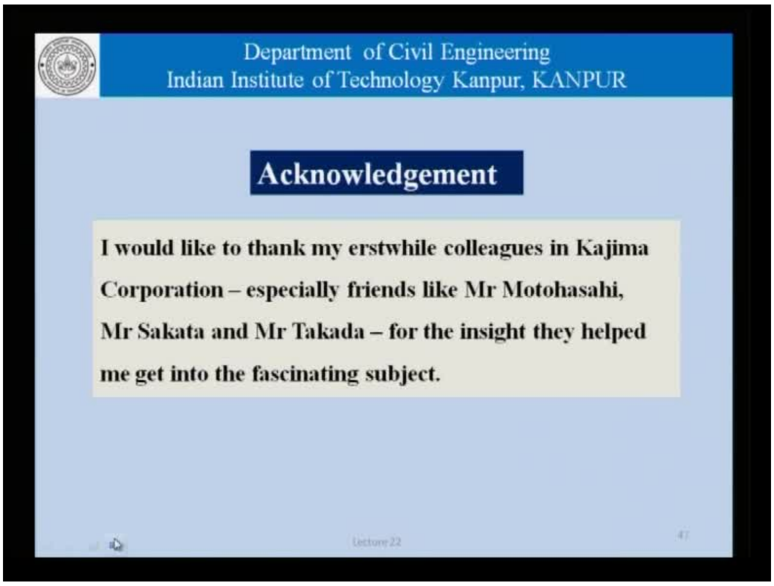

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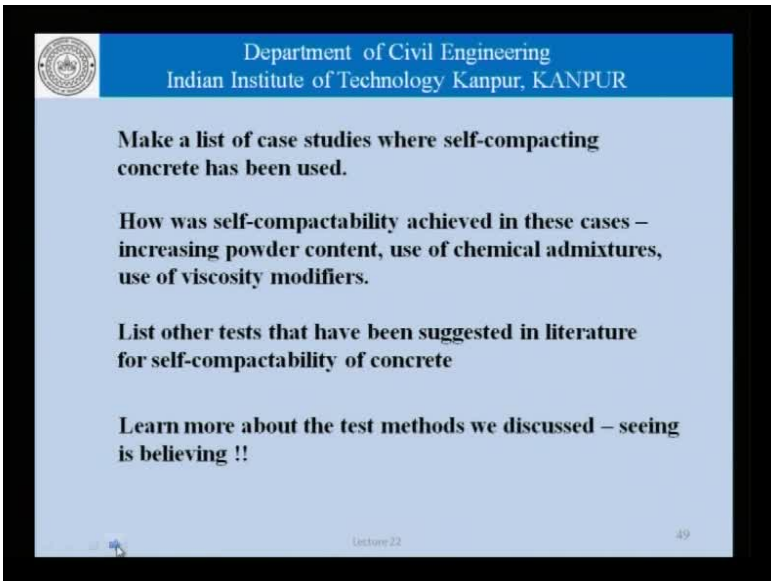

Now, before we close I would like to thank my erstwhile colleagues in kajima corporation - especially friends like Mister Motohasahi, Sakata and Takada - for the insight they helped me get into this fascination subject of high flowability self-compacting concretes. Now before we close of course, as usual we will have a series of items which we could look into a little bit more closely to get better understanding of self-compacting concretes, we could make a list of case studies where self-compacting concrete has been used.

We could study from that , from that list of project we could try to understand, how was the self-compactability achieved in these cases, we have talked about different roots, we have talked about increase in the powder content use of chemical admixtures, that is super-plasticizers or the use of viscosity modifiers. So these are some of the roots that we talked about in theory.

Now, once we look at the actual concrete mixes being used in different projects, where self-compacting concrete was used; it would be possible for you to understand which of the roots was taken to achieve self-compactability in these cases.

We have talked about some tests in our discussion today, to give you insight into the different variations that have been proposed, and are been used in different standards, to evaluate the self-compactability of concrete. There are several other test which we of course, had not had the time to cover, and we could try to make a list of other tests, that are been suggested in literature for the self-compactability of concrete.

Now, as a corollary to this question we could have a list of standards, which address the test that we use today; the slump flow, the J-Ring, the U-Tube, and so on. There are variations in even the slump flow test, and I would like you to examine some of the standards which describe the slump flow test.

Learn more about these test as we have discussed, seeing is believing there are several videos and movies available on the internet, which you could take a look, and see how these test are actually carried out. Once you see these test being actually carried out, that will give you much better understanding on what we are talking about the deformability, how the concrete flows as far as the slump flow is concerned, how that high flowing concretes are placed in more congested formworks, and so on. With this we come to an end of the discussion today on self-compacting concretes.

Thank you.